Comparative Study of Understory Between Exotic Monoculture Plantation (*Acacia* Sp.) and Adjacent Natural Sal (*Shorea Robusta*) Forest

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Abstract — To achieve forest management goal it is important to maintain biodiversity. This paper compares understory plant species diversity between exotic monoculture plantation (*Acacia auriculiformis*) and adjacent natural sal (*Shorea robusta*) forest. A total of 35 sample plots were taken by random sampling from six patches of adjacent natural sal forest and exotic monoculture plantation. Shannon-Wiener diversity index, species richness and evenness were calculated and compared. Result revealed that, a total of 2,218 plants of 42 species were recorded in natural sal (*Shorea robusta*) forest. Dominant families were Apocynaceae and Verbanaceae, having three species in each family. Shannon-Wiener diversity index was 2.1 and mean species richness was 14.4. On the contrary, 2,827 plants were found from 15 species in exotic monoculture (*Acacia auriculiformis*) plantation study area. Dominant family was Leguminosae family. Three species were found under Leguminosae family. Shannon-Wiener diversity index was 0.86 and mean species richness was 4.47. Therefore, Shannon diversity index and richness were significantly higher in natural sal forest as compared to exotic monoculture plantation. Species evenness of natural sal forest was 0.8 and 0.6 for monoculture plantation which indicates less equitable distribution of understory vegetation in monoculture than adjacent natural sal forest. With regard to herb species, evenness was significantly lower in monoculture plantation (0.03) as compared to natural sal forest (0.52). There was no equitable distribution for the herb species under monoculture plantation. Jaccard's similarity index showed that 36% shrub species and 30% of herb species were same in exotic monoculture plantation area and adjacent natural sal forest.

Index Terms — Herb, shrub, species diversity, species evenness, species richness.

I. INTRODUCTION

Monoculture plantation is defined as the plantation using single species of same age, first growing and short rotation [1]. The equivalent row detachment and clear felling system is practiced in order to simplify better harvesting in this plantation [2]. According to Harley [3], currently 3% of the world's forests are plantation forest containing 60 million hectares in developed and 55 million hectares in developing countries. It is scattering across the world to convey raw materials and replacing native forest. In Bangladesh, monoculture plantation program is increasing annually, and the exotic species are gaining preferences over the native one [4]. Bangladesh government is trying to reforest the area with some fast-growing exotic species [5] and about 70% of the plantation area is planted with exotic. Most extensively planted exotic in natural sal forest area are *Acacia*

auriculiformis, *Acacia mangium* and *Eucalyptus camaldulensis* which are 26.1%, 18.7% and 24.6% respectively [6]. In spite of prospect to manage natural sal forest, coppices were clear felled in many places to make way for commercial monoculture plantations with exotic species even the root was uprooted.

Sal forest is the only major natural forest resource of the central and northern part of Bangladesh [7, 8]. The majority sal forests are distributed in Gazipur, Tangail and Mymensing district [9]. Bangladesh has only 17.5% (2.52 million hectares) forest cover and the sal forest covers about 4.7% translating to 0.12 million hectares [7], [10]-[13]. It was reported that more than 60% of the sal forests were densely wooded in the late 1970s whereas about 38% of the sal forest cover existed in 1985 and 10% in 1990 [14]. Sal forest is the most vulnerable ecosystem of Bangladesh [13]. The rapid expansion of agriculture and monoculture plantation is a significant threat to the understory plant species diversity, and it has been rapidly exhausted in recent times due to rubber monoculture plantation and expanding commercial woodlot plantation [5]. Over the last forty years, the sal forests have shrunk drastically due to new plantation with exotic [6]. About 16,000 hectares of natural sal forest have been exchanged with woodlots monoculture plantation under Dhaka forest division [15], [16]. In Modhupur sal forest (under Tangail forest division), out of 18,623.48 hectares forest land 3157.89 hectares were assigned for rubber plantation. Another 40,000 hectares of sal forest were planned for monoculture plantation and agro forestry plantation in Tangail forest division under forestry sector project [17]. Plantation forestry is one of the biggest threats to the understory species diversity of natural sal forest [11].

The yield of plantation forest is a part of the economic growth and such economic growth should not be hampered by a lack of ecological information. It is important to quantify the connotation of exotic monoculture plantation with understory species diversity in order to ensure sustainable forest management. This document will flag and illustrate on the understory vegetation effect of exotic monoculture plantation, with a special emphasis in context of Gazipur, Bangladesh. This research will focus on the comprehensive ecological study encompassing understory species diversity, which has not been done till date in the study area. Although the replacement of sal forest by exotic monoculture plantations still increasing [13] which leads to disappearing of understory plant species diversity [18, 19]. Therefore, a comparative study to assess the understory plant

species diversity in exotic monoculture plantation and natural sal forest was felt necessary as stressed by Rahman *et al.* [5]. The aim of this study is to quantify understory species diversity and to assess the vegetation layer in exotic monoculture plantation and adjacent natural sal forest.

II. MATERIALS AND METHODS

A. Study Site

The study site is located at Kaliakair Upazilla under Gazipur district in Bangladesh. Exotic monoculture plantation (EMP) and the adjacent natural sal forest (NSF) were determined at Bualy beat office area under Kaliakair range. Latitude is 24°09'20", longitude is 90°15'34" and altitude lies between 6 m to 34 m above the sea level. Study areas fall into mid-south region [9]. The average annual temperature of the study area is 19.9 °C [20]. The average relative humidity lies from 70.5% to 78.51%. Rainy season (June through October) accounts for 70-85% of the annual rainfall and an average of 181 mm [20] precipitation.

Fig. 1. Forest map of Bangladesh (sal forest lies in central part)
(Source: Banglapedia).

B. Survey Method and Sampling Design

1. Sampling design

In order to generate representative data, six adjacent patches of natural sal forest and *Acacia auriculiformis* monoculture plantation were sampled. Data were collected applying random sampling. Reference point in each patch of forest was selected randomly and plot to plot distance of 100 m was maintained on the longest transect of each patch. Quadrats of 10×10 m were designed to enumerate understory plant species. Out of 35 sample plots surveyed, 17 were in exotic monoculture plantation and 18 in adjacent natural sal forest.

2. Methods

One of the most commonly used measures of species diversity is the Shannon-Wiener diversity index. The higher

number indicates higher species diversity. Species diversity index (H') was calculated by using Shannon-Wiener diversity Index [21].

$$H' = -\sum_{i=1}^s Pi(\ln Pi)$$

$$Pi = \frac{ni}{N}$$

where,

ni = Number of individuals of species".

N = Total number of individuals of all species.

Pi = Relative abundance of species "".

S = Total number of species.

H' = The Shannon-Wiener diversity index.

Species evenness was calculated to assess the equitability or evenly distribution pattern of different understory species. Evenness index ranges from 0 to 1, where 0 signifying no evenness and 1 signifying complete evenness.

$$\text{Evenness index } e = H' / \ln(S)$$

where,

H' = Shannon's diversity index.

S = No. of species (species richness).

The Jaccard's [22] index is a valuable tool because it allows one to determine whether two communities are composed of similar species.

$$\text{Jaccard index} = A / (A + B + C)$$

where,

A = Total number of species present in both communities.

B = the number of species present in community 1 but not 2.

C = the number of species present in community 2 but not in 1.

If the Jaccards' index is equal to 1 ($B = 0$ & $C = 0$), all species are shared between the two communities and near to 0, no species are shared between two communities.

C. Data Analysis

The preliminary data have been processed using Microsoft Excel spread sheet office 2010. Data compilation and graph were created through Microsoft Excel spread sheet. Analysis was carried out by using SPSS version 16. Nonparametric Mann-Whitney U test was carried out to determine the mean differences between exotic monoculture plantation and adjacent natural sal forest.

III. RESULT AND DISCUSSION

A. Composition of Species in Natural Sal Forest (NSF)

A total of 2,218 plants were recorded which belong to 42 species in NSF. Among the species, 37 species belong to 26 families. Three species were identified by local name and another two species were unidentified. Dominant families were Apocynaceae and Verbenaceae, having three species in each family. The species composition for Apocynaceae family includes *Holarrhena pubescens*, *Rauvolfia serpentina*, *Tabernaemontana coronaria* species and for Verbenaceae family: *Callicarpa arborea*, *Clerodendrum viscosum* and *Gmelina arborea*. Combretaceae, Euphorbiaceae, Fabaceae, Leguminosae, Myrtaceae,

Rubiaceae and Rutaceae families had two species each. The remaining 17 families were represented by single species each. Highest number of species richness (22) and diversity (2.62) had been found in plot S3 where lowest numbers of species richness (7) and diversity (1.24) found in plot S16. Mean species richness and mean diversity index were 14.4

and 2.1 respectively. Species evenness was highest in S2 and lowest in S16 which was 0.9 and 0.64 respectively. The mean evenness found for natural sal forest was 0.8. This indicates that NSF had equitable distribution of the species. Stem density was highest in S1 (265) and lowest in S16 (31) (Table 1).

TABLE 1: PLOT AREA, DIVERSITY, RICHNESS, EVENNESS AND DENSITY OF NATURAL SAL FOREST (NSF)

Plot ID	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18
Plot area (m ²)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Diversity (H')	2.3	2.43	2.62	2.1	1.77	2.59	2.49	2.29	1.68	2.24	1.92	2.3	1.81	1.99	1.67	1.2	2.11	2.1
Richness (Nos.)	19	15	22	14	9	22	17	17	11	20	12	17	11	10	10	7	13	14
Evenness (J')	0.78	0.9	0.85	0.8	0.81	0.84	0.88	0.81	0.7	0.75	0.77	0.8	0.75	0.86	0.73	0.6	0.82	0.8
Density (Nos.)	265	156	240	105	71	199	73	205	65	135	160	175	66	51	78	31	50	93

Note: S= Sal Sample Plot.

B. Composition of Shrub and Herb Species in Natural Sal Forest (NSF)

Shrub species were common in study area. A total of 27 shrub species were found. Out of that, 23 shrubs species were found from 18 families and four species family could not be identified. Apocynaceae family had higher number of species (*Holarrhena pubescens*, *Rauvolfia serpentina*, *Tabernaemontana coronaria*). Two species each had been found in Verbenaceae and Rubiaceae family. Another family had single species each. A total of eight herb species were found from six families. Single species were noted each from six families and two species were unidentified.

C. Species Coverage in Natural Sal Forest (NSF)

TABLE 2: SPECIES COVERAGE IN NATURAL SAL FOREST

Species	Family	Density (Count)	Coverage (%)
<i>Randia dumentorum</i>	Rubiaceae	403	18.2
<i>Curcuma zeodaria</i>	Zingiberaceae	239	10.8
<i>Clerodendrum viscosum</i>	Verbenaceae	192	8.7
<i>Antidesma</i> sp.	Euphorbiaceae	184	8.3
<i>Microcos paniculata</i>	Tiliaceae	143	6.4
<i>Chromolaena odorata</i>	Asteraceae	135	6.1
<i>Melastoma malabathricum</i>	Melastomataceae	86	3.9
<i>Flacourtia indica</i>	Flacourtiaceae	86	3.9
<i>Litsea monopetala</i>	Lauraceae	80	3.6
<i>Indigofera Tasmania</i>	Leguminosae	74	3.3
<i>Indigofera tinctoria</i>	Fabaceae	71	3.2
<i>Urena lobata</i>	Malvaceae	65	2.9
<i>Tabernaemontana coronaria</i>	Apocynaceae	59	2.7
<i>Ixora spectabilis</i>	Rubiaceae	56	2.5
<i>Calyopteris floribunda</i>	Combretaceae	50	2.3
<i>Callicarpa arborea</i>	Verbenaceae	35	1.6
<i>Rauvolfia Serpentina</i>	Apocynaceae	27	1.2
<i>Thysanolaena maxima</i>	Poaceae	27	1.2
<i>Syzygium fruticosum</i>	Myrtaceae	25	1.1
<i>Terminalia bellirica</i>	Combretaceae	20	0.9
<i>Cordia grandis</i>	Boraginaceae	14	0.6
<i>Phyllanthus embelica</i>	Euphorbiaceae	13	0.6
<i>Holarrhena pubescens</i>	Apocynaceae	13	0.6
<i>Zanthoxylum rhetsa</i>	Rutaceae	12	0.5
<i>Calamas</i> sp.	Palmae	9	0.4
<i>Flemingia bracteata</i>	Fabaceae	8	0.4
<i>Miliusa velutina</i>	Annonaceae	5	0.2
<i>Glycosmis pentaphylla</i>	Rutaceae	5	0.2
<i>Cassia fistula</i>	Caesalpinaceae	4	0.2
<i>Erioglossum edulis</i>	Sapindaceae	4	0.2
<i>Hyptis suaveolens</i>	Labiatae	3	0.1
<i>Barringtonia acutangula</i>	Lecythidaceae	3	0.1
<i>Mimosa pudica</i>	Leguminosae	2	0.1
<i>Gmelina arborea</i>	Verbenaceae	2	0.1
<i>Phyllanthus reticulatus</i>	Euphorbiaceae	1	0.05
<i>Glycyrrhiza glabra</i>	Fabaceae	1	0.05
<i>Swietenia mahagoni</i>	Meliaceae	1	0.05
Unknown species		61	2.8
Total		2218	100

Randia dumentorum species from Rubiaceae family covered 18.2% of the total vegetation and the density was

403 per 1800 m² which was highest dominating understory species. *Curcuma zeodaria* species form Zingiberaceae family represented 10.8% of the total vegetation and density was 239 per 1800 m². *Clerodendrum viscosum* from Verbenaceae family was 8.7% and density was 192 per 1800 m². *Phyllanthus reticulatus*, *Glycyrrhiza glabra* and *Swietenia mahagoni* had lowest portion of vegetation cover of the total species which was 0.05% and density was 1 per 1800 m² (Table 2).

D. Life Forms of Natural Sal Forest (NSF)

Tree, shrub, annual herb, and grass have been found in NSF study area. Study site was dominated by shrub species. Shrub species were representing 73% of the total species. Annual herb and tree were representing 18% and 7% respectively of the total species. Grass was representing 2% of the total species (Fig. 2).

Fig. 2. Life form of Natural Sal Forest.

E. Composition of Species in Exotic Monoculture Plantation (EMP)

A total of 2,827 plants were recorded which belong to 15 species and 13 families in EMP study area. Highest number of species was recorded from Leguminosae family. *Butea monosperma*, *Dalbergia sissoo*, *Mimosa pudica* species were found under Leguminosae family and eight numbers of individual plants have been found from this family in study area. Apocynaceae family includes 363 numbers of individual plants from *Holarrhena pubescens* species. *Chromolaena odorata* had 833 individuals from Asteraceae family in monoculture plantation study site. Dipterocarpaceae, Euphorbiaceae, Flacourtiaceae, Lauraceae, Malvaceae, Rubiaceae, Rutaceae, Sapindaceae, Tiliaceae and Verbenaceae families had single species each. Species richness was highest in M13 (9) and lowest was in

M5 (2). Mean richness for the EMP was 4.47. Highest numbers of species diversity have been found in M11 (1.46) where lowest was noted in M5 (0.37). Mean species diversity index was 0.86 in EMP. Highest species evenness was in M11 (0.91) and lowest in M7 (0.32). The mean evenness has

been found for EMP with 0.6. This indicates EMP have less equitable distribution of the species than adjacent NSF. Stem density was highest in M4 (519) and lowest in M11 (16). Mean stem density for EMP was 166.29 (Table 3).

TABLE 3: PLOT AREA, DIVERSITY, RICHNESS, EVENNESS AND DENSITY OF EXOTIC MONOCULTURE PLANTATION

Plot ID	M 1	M 2	M 3	M 4	M 5	M 6	M 7	M 8	M 9	M 10	M 11	M 12	M 13	M 14	M 15	M 16	M 17
Plot Area (m ²)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Diversity (H')	0.7	0.63	0.99	0.62	0.37	0.62	0.51	0.49	1.18	0.49	1.46	0.96	1.34	1.29	1	0.81	1.11
Richness (Nos.)	3	3	7	5	2	3	5	4	5	2	5	5	9	5	5	4	4
Evenness (J')	0.64	0.57	0.51	0.39	0.53	0.56	0.32	0.35	0.73	0.71	0.91	0.6	0.61	0.8	0.62	0.58	0.8
Density (Nos.)	88	137	382	519	81	40	390	418	144	31	16	180	153	48	105	42	53

Note: M=Monoculture Sample Plot.

F. Composition of Shrub and Herb Species in Exotic Monoculture Plantation (EMP)

Shrub species was dominant among EMP study area. A total of eleven shrub species have been found from eleven families. Euphorbiaceae, Leguminosae, Verbenaceae, Sapindaceae, Flacourtiaceae, Apocynaceae, Lauraceae, Tiliaceae, Rubiaceae, Malvaceae and Rutaceae families had single species each in shrub group. In case of herbs, *Chromolaena odorata* and *Mimosa pudica* were found from Asteraceae and Leguminosae family respectively.

G. Species Coverage in Exotic Monoculture Plantation (EMP)

Most dominating understory plant species was *Clerodendrum viscosum* from Verbenaceae family which covered 49% of total vegetation in EMP study site. The stem density was 1,373 per 1700 m² for *Clerodendrum viscosum* (Verbenaceae family) which was highest. *Chromolaena odorata* species from Asteraceae family had 29% of the total vegetation and density was 833 per 1700 m² which was second dominant species in the study site. *Holarrhena pubescens* from Apocynaceae family was 13% and the density was 363 per 1700 m². *Antidesma* sp. from Euphorbiaceae family, *Butea monosperma* and *Dalbergia sissoo* from Leguminosae family had the lowest percentage of vegetation cover with 0.04 % of the total vegetation (Table 4).

TABLE 4: SPECIES COVERAGE IN EXOTIC MONOCULTURE PLANTATION IN AN AREA OF 1700 m²

Species	Family	Density (Count)	Coverage (%)
<i>Clerodendrum viscosum</i>	Verbenaceae	1373	49
<i>Chromolaena odorata</i>	Asteraceae	833	29
<i>Holarrhena pubescens</i>	Apocynaceae	363	13
<i>Randia dumentorum</i>	Rubiaceae	162	6
<i>Microcos paniculata</i>	Tiliaceae	40	1
<i>Shorea robusta</i>	Dipterocarpaceae	23	1
<i>Flacourtia indica</i>	Flacourtiaceae	14	0.5
<i>Mimosa pudica</i>	Leguminosae	6	0.2
<i>Litsea monopetala</i>	Lauraceae	3	0.1
<i>Zanthoxylum rhetsa</i>	Rutaceae	3	0.1
<i>Erioglossum edulis</i>	Sapindaceae	2	0.1
<i>Urena lobata</i>	Malvaceae	2	0.1
<i>Antidesma</i> sp.	Euphorbiaceae	1	0.04
<i>Butea monosperma</i>	Leguminosae	1	0.04
<i>Dalbergia sissoo</i>	Fabaceae	1	0.04
Total		2827	100

H. Life Forms of Exotic Monoculture Plantation (EMP)

Tree, shrub, and annual herb were found in monoculture plantation study area. Study site was dominated by shrub and a total of 1,964 plants were recorded which represented 68% of the total understory vegetation cover. Annual herb (893) represented 31% of the total vegetation cover. Twenty four individual trees were counted in the study site which was 1% of total vegetation cover (Fig. 3).

Fig. 3. Life form of Exotic Monoculture Plantation

I. Species Composition in Natural Sal Forest (NSF) and Exotic Monoculture Plantation (EMP)

A total of 44 species were recorded from the natural sal forest and exotic monoculture plantation. Out of that, 14 species were found in both forest types while 28 species found only in natural sal forest and two species in monoculture plantation site only (Table 5).

J. Species Distribution in Exotic Monoculture Plantation (EMP) and Adjacent Natural Sal Forest (NSF)

It was found that *Randia dumentorum* had highest position and 4th in NSF and EMP area respectively. *Clerodendrum viscosum* was in second position which was dominant in EMP by existence as ranking first. *Microcos paniculata* and *Melastoma malabathricum* had the third and fourth position among the species and have been found in NSF study area. *Swietenia mahagoni* was in last position (Fig. 4). In the EMP site, *Chromolaena odorata* and *Holarrhena pubescens*, came into existence as ranking second and third respectively. *Dalbergia sissoo* had the last position among the species ranking (Fig. 5).

Fig. 4. Species distribution in Natural Sal Forest.

Fig. 5. Species distribution in Exotic Monoculture Plantation.

TABLE 5: SPECIES COMPOSITION IN NATURAL SAL FOREST AND EXOTIC MONOCULTURE PLANTATION

Local Name	Scientific Name	Life-form	Family	NSF	EMP
Agra	<i>Urena lobata</i>	Shrub	Malvaceae	Y	Y
Amloki	<i>Phyllanthus embelica</i>	Shrub	Euphorbiaceae	Y	X
Anoy	Un known	Shrub	Unknown	Y	X
Bahari Nil	<i>Indigofera tinctoria</i>	Shrub	Fabaceae	Y	X
Bajna	<i>Zanthoxylum rhetsa</i>	Shrub	Rutaceae	Y	Y
Bat	<i>Clerodendrum viscosum</i>	Shrub	Verbenaceae	Y	Y
Kutishor	<i>Holarrhena pubescens</i>	Shrub	Apocynaceae	Y	Y
Bon Jam	<i>Syzygium fruticosum</i>	Shrub	Myrtaceae	Y	X
Bon Khejor	Un known	Shrub	Un known	Y	X
Bon Rongon	<i>Ixora spectabilis</i>	Shrub	Rubiaceae	Y	X
Bon Tejpatha	<i>Melastoma malabathricum</i>	Shrub	Melastomataceae	Y	X
Bonkori	<i>Flacourtia indica</i>	Shrub	Flacourtiaceae	Y	Y
Boro Nil	<i>Indigofera Tasmania</i>	Shrub	Leguminosae	Y	X
Datoi	<i>Microcos paniculata</i>	Shrub/ Small tree	Tiliaceae	Y	Y
Gadila pata	<i>Callicarpa arborea</i>	Shrub/ Small tree	Verbenaceae	Y	X
Goache Lota	<i>Calyopteris floribunda</i>	Shrub	Combretaceae	Y	X
Machi Pata	<i>Flemingia bracteata</i>	Shrub	Fabaceae	Y	X
Soto Kardia	<i>Cordia grandis</i>	Shrub	Boraginaceae	Y	X
Moilta	<i>Glycosmis pentaphylla</i>	Shrub	Rutaceae	Y	X
Moish ful	<i>Tabernaemontana coronaria</i>	Shrub	Apocynaceae	Y	X
Mon Kata	<i>Randia dumentorum</i>	Shrub	Rubiaceae	Y	Y
Nal moni	Un known	Shrub	Un known	Y	X
Nonta Gota	<i>Antidesma sp.</i>	Shrub	Euphorbiaceae	Y	Y
Sagol Nadi	<i>Erioglossum edulis</i>	Shrub	Sapindaceae	Y	Y
Shorpogondha	<i>Rauvolfia serpentina</i>	Shrub	Apocynaceae	Y	X
Un9	Un known	Shrub	Un known	Y	X
Hokin Jheu	<i>Chromolaena odorata</i>	Annual Herb	Asteraceae	Y	Y
Ful Jharu	<i>Thysanolaena maxima</i>	Annual Herb	Poaceae	Y	X
Shoti	<i>Curcuma zedaria</i>	Annual Herb	Zingiberaceae	Y	Y
Sitki	<i>Phyllanthus reticulatus</i>	Annual Herb	Euphorbiaceae	Y	X
Son	Un known	Annual Herb	Un known	Y	X
Jastimodhu	<i>Glycyrrhiza glabra</i>	Annual Herb	Fabaceae	Y	X
Lojjaboti	<i>Mimosa pudica</i>	Annual Herb	Leguminosae	Y	Y
Tokma	<i>Hyptis suaveolens</i>	Annual Herb	Labiatae	Y	X
Un6	Un known	Annual Herb	Un known	Y	X
Un8	Un known	Annual Herb	Un known	Y	X
Polash	<i>Butea monosperma</i>	Tree	Leguminosae	X	Y
Kharajura	<i>Litsea monopetala</i>	Tree	Lauraceae	Y	Y
Bohera	<i>Terminalia bellirica</i>	Tree	Combretaceae	Y	X
Hijol	<i>Barringtonia acutangula</i>	Tree	Lecythidaceae	Y	X
Gamar	<i>Gmelina arborea</i>	Tree	Verbenaceae	Y	X
Gandhi gojar	<i>Miliusa velutina</i>	Tree	Annonaceae	Y	X
Shonalo	<i>Cassia fistula</i>	Tree	Caesalpinaceae	Y	X
Shall	<i>Shorea robusta</i>	Tree	Dipterocarpaceae	Y	Y
Shishu	<i>Dalbergia sissoo</i>	Tree	Fabaceae	X	Y

Note: NFS-Natural Sal Forest; EMP-Exotic monoculture plantation; Y-present, X-absence.

K. Species Diversity between Natural Sal Forest and Exotic Monoculture Plantation

Fig. 6 illustrated that there was remarkable difference of Shannon-Wiener diversity index and Mann-Whitney test ($U = 3$, $Z = 4.95$, $P < .05$) between EMP and adjacent NSF.

Species diversity was higher in NSF site compare to EMP site in at the entire sample plots. In NSF, mean Shannon-Wiener diversity was 2.09 while 0.86 for EMP.

Fig. 6. Comparative species diversity between NSF and EMP.

Different study revealed that NSF had significant higher tree species diversity index as compared to monoculture plantation in uttar pradesh, India [23]; Zimbabwe [24], Ethiopia and Kotiluo (n.d) [25]. Natural forest showed higher value of biodiversity index in all vegetation layers as compared to monoculture plantation [26]-[29].

In contrast, some study revealed that the overall plant biodiversity was higher at monoculture plantation site than in natural forest [30], [31]. Lower anthropogenic disturbance than the natural forest could be the reason to get higher diversity in plantation site. But in my study area silvicultural operation like clear felling and cleaning have been carried out. Even the roots were uprooted. It could be another reason to get significant difference of diversity in my study area.

L. Species Evenness between Natural Sal Forest (NSF) and Exotic Monoculture Plantation (EMP)

The species evenness was higher in NSF as compared to EMP in all sample plot (Fig. 7), but it was not significant. Mean evenness was 0.79 for NSF while 0.60 for EMP. In contrast, with regards to herb group, evenness was significantly higher in NSF (0.52) as compared to EMP (0.03). Mann-Whitney test revealed ($U = 37$, $Z = 3.83$, $P < .05$) that there was significant difference of evenness in herb group. Similarly, Pourbabaei *et al.* [26] stated that species evenness was significantly higher in natural forest as compared to coniferous plantation which was conducted in Iran. Baktash [32] and Yirdaw [27] also stated that evenness was higher in natural forest as compared to monoculture plantation where Chauhan *et al.* [31] found opposite result. More number of individuals from two particular species (*Chromolaena odorata* and *Clerodendrum viscosum*) could reduce evenness in monoculture plantation site.

Fig. 7. Comparative species evenness between NSF and EMP.

M. Species Richness Comparison between Natural Sal Forest (NSF) and Exotic Monoculture Plantation (EMP)

There was notable difference of species richness between EMP and adjacent NSF. In NSF, mean species richness was 14.47 while 4.47 for EMP (Fig. 8). Mann-Whitney test revealed that ($U = 2$, $Z = 5.01$, $P < .05$) there was significant difference of species richness between two forest types. Single species plantation has often been criticized for being associated with a low level of biodiversity in the ecosystem [32]. Similarly, the species richness was significantly high in natural forest as compared to monoculture plantation [23], [24], [26], [31], [33]-[35]. Study conducted by Huttel & Loumeto [36], stated that undergrowth species was relatively low under exotic monoculture plantation as compared to secondary forest. Study conducted in Iran by Taleshi [28] stated that species richness was higher in all vegetation layers in natural forest.

Fig. 8. Comparative species richness between NSF and EMP.

N. Stem Density (Nos.) between Natural Sal Forest and Monoculture Plantation

There was a little variation of stem density in different plot. Minimum (31) and Maximum (265) number of stem for NSF was recorded in plot number 16 and 17 respectively. Therefore, stem density for NSF lies within 31 to 265 where 16 to 519 for EMP (Fig. 9). The maximum (519) and minimum (16) number of stem density was noted in plot 4 and 11 respectively for EMP. EMP had higher stem density variation than NSF. The reason to get higher stem density variation is that two particular species had a greater number of individuals, but the total number of species was few. Moreover, in some plot the number of individuals was much higher than another plot. In fourth plot, total 519 numbers of individual were recorded from five species while 432 numbers of individuals were noted from *Chromolaena odorata* species. Similarly, in plot number seven, a total of 390 individuals were recorded from five species while 332 individuals were recorded from *Clerodendrum viscosum* species. In contrast, 16 individuals stem were recorded from five species in plot number eleven. It could be the reason to get much higher variation of stem density among two forest type. This also indicated that the species in not evenly distributed in EMP which support species evenness finding.

Fig. 9. Comparative species density between NSF and EMP.

O. Species Diversity Index according to Life Form in NSF and EMP with Jaccards' Similarity Index

Shannon-Wiener diversity index for the shrubs and herbs were 1.78 and 0.63; and 0.48 and 0.02 in NSF and EMP area correspondingly. NSF of the study area was more diverse than EMP area. Jaccards' similarity index allows us to quantify the degree of overlap between the species in two communities. Jaccards' similarity index was 0.36 for shrub and 0.30 for herb species in the study area. Result demonstrated that 36% of shrub and 30% of herb species were common and significantly varied between NSF and EMP. Around 70% of the species were common in both NSF and EMP with *Eucalyptus camaldulensis*. According to Yirdaw [27], 78% of the species were similarly found in natural forest as well as in monoculture plantation in Ethiopia.

TABLE 6: DIVERSITY INDEX OF PLANT SPECIES OF NSF AND EMP WITH JACCARDS' SIMILARITIES INDEX

Diversity Index	Shrub		Herb	
	NSF	EMP	NSF	EMP
Shannon diversity (H')	1.78	0.63	0.48	0.02
Jaccard's similarity Index	0.36		0.30	

P. Mean Value of Species in Different Vegetation Layers in Study Sites

For shrub vegetation layer, species diversity was found 1.78 and 0.63 for NSF and EMP. With respect to herb vegetation layer, species diversity of NSF (0.48) was much higher than EMP (0.03). Natural forest had the higher value of diversity in all vegetation layers than monoculture plantation (Table 7). Pourbabaei *et al.* [26] stated that, there were significant differences among diversity, evenness, and richness in all vegetation layers in different plantation area in Iran.

Species richness for shrub and herb were 10.56 and 3.26; and 2.00 and 0.78 for NSF and EMP vegetation layer separately. NSF had the higher value of richness in all vegetation layers (Table-7). Baktash [33], Taleshi [28] and Pourbabaei *et al.* [26] found the similar result. Although both types of forests were under same anthropogenic disturbance and similar microclimate environment but EMP had lower value of richness in all vegetation layers. It could be due to clear felling carried out in monoculture plantation and cleaning activities carried out for first two years. Moreover, it could be due to introduced species and single species plantation. They might have direct or indirect

effect on native understory vegetation, which has been supported by Brockerhoff *et al.* [37].

Evenness of herb and shrub were 0.77 and 0.51; and 0.52 and 0.03 for NSF and EMP study area separately (Table 7). There was little difference of equitable species distribution between two types of forest.

TABLE 7: MEAN VALUE OF SPECIES DIVERSITY, RICHNESS AND EVENNESS IN DIFFERENT VEGETATION LAYERS

Type	Vegetation type	Vegetation layer	
		Shrub	Herb
Mean species diversity	NSF	1.78 ± 0.39	0.48 ± 0.39
	EMP	0.63 ± 0.45	0.03 ± 0.07
Mean value of richness	NSF	10.56 ± 3.33	2 ± 1.19
	EMP	3.26 ± 1.66	0.78 ± 0.65
Mean value of evenness	NSF	0.77 ± 0.08	0.52 ± 0.4
	EMP	0.51 ± 0.31	0.03 ± 0.11

IV. CONCLUSION

The study demonstrated in this research that, understory plant species diversity index in natural sal forest was higher than exotic monoculture plantation in all vegetation layer. One of the most universal features of natural systems is species richness. The number of different species co-occurring in a given area varies enormously from place to place. Species richness may differ substantially between areas in comparable environments. In the study sites, differences were observed in the number of trees, shrub and herb species, families, and vegetation composition between exotic monoculture plantation site and natural sal forest site which was much lower in exotic monoculture plantation area. Natural sal forest contributes higher richness of shrubs and herbs. Several herbs and shrubs were restricted only to natural forest of the study site. Therefore, it is not easy to avoid plantation activities. Before plantation activities with fast growing species people used to fell sal pole to get wood, fuel wood and another domestic use. In such a way exotic fast growing monoculture plantation is indirectly helping to decrease natural sal forest degradation by providing wood and fuel wood. In many places of natural sal forest area, forest land is degraded and illegally taken by the local community. Plantation activities can be done in those degraded land rather than replace with natural sal forest. Management may be implemented through plantation program with mixed species rather than a single species and indigenous species need to be considered. Clear felling system may be stopped to make way for plantation. It requires to do further research on compare understory plant species diversity between exotic monoculture plantation, mixed species plantation and plantation with native species in order to understand which type of forest providing more understory diversity.

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