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Original Article

A quantitative analysis of the homestead timber and fruit species diversity in two different agro ecological zones of Bangladesh

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ABSTRACT

Two different administrative districts have been selected with the objective of investigating the homestead timber and fruit species diversity in different agroecological zones of Bangladesh. A total of 61 tree species representing 25 genera and 27 species of timber origin and 27 genera and 34 species of fruit origin belonging to 28 families are recorded from both study areas. Anacardiaceae and Myrtaceae are the most diverse families with five species. The quantitative analysis reveals that in the both study areas *Acacia auriculiformis* is the most dominant tree species, whereas, *Areca catechu* and *Musa* species are dominant fruit species for two study areas. The values of diversity indices and evenness indices of the homestead tree and fruit species of the both study areas are close and highly resemble to each other. The higher similarity index value indicate almost similar homestead forest resources in two different agroecological zones of Bangladesh.

KEYWORDS: Agroecological zone, homestead, tree species, fruit species, diversity, diversity indices, Bangladesh.

INTRODUCTION

Bangladesh situating in the north-eastern part of the South Asia between$20^0 34^/$ and $26^0 38^/$ North latitude and $88^0 01^/$ and $92^0 41^/$ East longitude (Hossain, 2001) with a sub-tropical monsoon climate and is a transitional zone of flora and fauna because of its geographical and climatic characteristics (Hossain, 2001; Nishat et al., 2002;). Bangladesh has a forest cover of 2.53 million ha, among which 0.27 million ha areas is homestead forest (Choudhury and Hossain, 2009) scattered throughout the country. Unfortunately the government forest resources of the country is not only inadequate and unevenly distributed throughout the country but also the yield is very low and subjected to loss both floral and faunal diversity. On the other hand, a wide range of plant resources are found in the homestead forests of the country and the rural economy depends on productivity of that natural resources which is intimately linked with the biodiversity in the ecosystem. Homestead forests are the multi-storied vegetation of shrubs, bamboos, palms, and trees that produce materials for a multitude of purposes including fuel, shelter, structural materials, fruits, fodder and medicines (Dauglas, 1981). In true sense, homesteads are the *in situ* conservation sites of wide range of plant biodiversity.

Bangladesh has 68000 villages each containing a few hundreds of homesteads and varies in species composition and tree density from one region to another region. Research on homestead forest resources of Bangladesh so far concentrated mostly on home garden agro forestry, floristic composition, home garden management and their economic importance (Alam et al., 1996; Bashar, 1999;Hasan and Majumdar, 1990; Khan and Alam, 1996; Leuschner and Khaleque, 1987; Millat-e-Mustafa, 1997; Motiur and Furukawa, 2005; Motiur et al., 2006; Siddiqi and Khan, 1999). The present study therefore designed to explore and compare the tree species diversity of the homesteads in two different agro ecological zones of Bangladesh. A detailed field survey and quantitative analysis of the homestead tree flora were carried out to assess the species composition and quantitative characteristics of the study areas. Diversity indices provide important information about rarity and commonness of species in a community. The ability to quantify diversity in this way is an important tool to understand community structure. Hence, two diversity indices (Simpson's Diversity Index and Shannon-Weiner Diversity Index), two evenness indices (Simpson's Evenness Index and Shannon-Weiner Evenness Index) and Sorensen similarity index are used in this study to gain important findings about the homestead tree species diversity of the study areas.

MATERIALS AND METHODS

STUDY AREA SELECTION

Study areas of this work were selected in two stages. Bangladesh consist of 30 agroecological zones (AEZs) (UNDP-FAO, 1988)overlapping with each other, in the first stage, we therefore, for the convenience of this study, combined two or three

AEZs for a region and thus a total of 12 mutually exclusive regions were considered for our study where each region aggregate a number of administrative districts. In the second stage, from the 12 AEZs considered, we selected two AEZs at a random, namely Lower Meghna River and Estuarine Floodplain (LMREF) and Greater Dhaka (GD) and then from each AEZ we selected one district randomly for our study. The selected districts are Lakshmipur under LMREF and Narsingdi under GD. The AEZs and other features of the selected study ares are shown in table 1. A multistage random sampling method was then applied to locate the villages and the homesteads of the study with district as the primary sampling unit and village as the ultimate sampling unit. From each district 3 villages were selected namely, Barakheri, Char gazi and Manikpur from Lakshmipur and Jinardi, Khanpur and Sekandardi from Narsingdi district. 30 homesteads from each village were selected randomly classifying the homesteads into Small (0.20-1.00 ha. of farm holdings), Medium (1.01-3.03 ha of farm holdings) and Large (3.04 ≤ ha of farm holdings) (BBS, 2011a,b). Taking 10 homesteads from each category of farm holdings therefore provide a sample size of 90 homesteads for each district.

Table 1. Selected Agroecological Zones (AEZs), selected study areas and their features.

AEZ name AEZ no.	District Villages	Latitudes Longitudes	Land type Soil type	Climate	Total area Govt. forest
Lower Meghna River and Estuarine Floodplain (**LMREF**)	Lakshmipur	$22^0 30^/$ N and $23^0 10^/$ N	HL<1%, MHL 45%, HS &Water 47%	MAR<2500mm to >3000mm	1548.38 (sq. km)
17, 18, 19	Chargazi, Barakheri, Manikpur	$90^0 38^/$ E and $90^0 1^/$ E	Calcareous alluvium	MAT 25.7^0c	2.12 (sq. km)
Greater Dhaka (**GD**)	Narsingdi	$23^0 29^/$ N and $23^0 45^/$ N	HL 28%, MHL 18%, MLL20%, HS &Water 10%	MAR 2000mm to 2300 mm	1140.76 (sq. km)
9, 16, 28	Jinardi, Khanpur, Sekandardi	$90^0 10^/$ E and $90^0 43^/$ E	Non-calcareous dark grey, Shallow grey terrace	MAT 26.5^0c	–

Source: UNDP-FAO, 1988; BBS 2011a,b.

PLANT SURVEY AND ANALYSIS

A complete study on 180 homesteads from both districts was carried out to assess the homestead plant diversity in the two different agro-ecological zones of Bangladesh. Although the homesteads possess a ground vegetation of shrubs, climbers and herbs, the present study was confined only to the timber species and fruit species of tree in nature. The species were identified by following Prain (1903) and Brandis (1906). All the species having diameter at breast height (dbh) ≥ 5cm were individually measured and recorded. The relative density (RD), relative frequency (RF), relative dominance (RD_o) and importance value index (IVI) were analysed following the methods of Shukla and Chandel (1980) and Mueller-Dombois and Ellengberg (1974).

The species richness is the total number of all the species (*S*), Simpson's diversity index (*D*) and evenness index (E_D), (Simpson, 1949) Shannon-Weiner diversity index (H') and evenness index ($E_{H'}$) (Shannon and Wiener, 1963; Mandaville,2002) and Sorensen similarity index (C_S) (Legendre and Legendre, 1998; Magurran, 1988) were calculated to analyze and compare the regional diversity of homestead forests tree species in the study areas using the formula:

$$D = 1 - \Sigma \left(n_i(n_i - 1) / N(N-1) \right)$$

Where, *D* is the Simpson's diversity index; n_i is number of individuals belonging to *i* species; *N* is the total number of individuals.

$$H' = - \Sigma p_i \ln p_i$$

Where, H' is Shannon-Weiner diversity index; p_i is the proportion of the ith species; ln is the natural logarithm.

$E_D = D / D_{max}$ with $D_{max} = LnS$
$E_{H'} = H' / C = LnS$
Where, E_D *is* Simpson's evenness index; $E_{H'}$ is the Shannon-Weiner evenness index; D_{max} and $E_{H'}$ are the maximum value of Simpson's index and Shannon-Weiner index respectively; S is the species richness.

$C_S = 2A / (2A+B+C)$
Where, C_S is the Sorensen similarity index; A is the number of species sharing in two populations; B is the number of species in population 1 and C is the number of species in population 2.

RESULTS AND DISCUSSION

SPECIES STRUCTURE AND COMPOSITION

A total of 61 plant species representing 25 genera and 27 timber species and 27 genera and 34 fruit species belonging to 28 families have been recorded from the both study areas. The results of vegetative analysis and distribution pattern of all trees are shown in table 2 and table 3. Similar results were found in the other regions of Bangladsh, Uddin et al., (2002) identified 62 useful tree species from the homesteads of saline areas, Islam (1998) found 77 tree species at Rangpur homesteads of Bangladesh, whereas study of Anam, 1999 shows only 28 tree speciesfrom the Barind Tract areas. Annacardiaceae and Myrtaceae are the most dominant families with 5 species, followed by Leguminoceae, Palmae, Moraceae and Rutaceae with 4 species. Figure 1 shows the family level distribution of all the species found in both districts. *Artocarpus chaplasha* (Moraceae), *Cassia siamea* (Caesalpiniaceae), *Lagerstroemea speciosa* (Lythraceae), *Michelia champaca* (Magnoliaceae), *Mimusops elengi* (Sapotaceae), and *Tectona grandis* (Verbenaceae) among timber species, and *Diospyros embryopteris* (Ebenaceae), *Fefonia limona* (Rutaceae), *Gercinia cowa* (Guttiferae), and *Syzygium wallichi* (Myrtaceae) among fruit species are found only in Lakshmipur district (Fig. 1; Table 2; Table 3).

Table 2. Quantitative analysis of the timber species of the study homesteads of the Lakshmipur and Narsingdi district.

Sl. no.	Species name	Stra-tum	Lakshmipur				Narsingdi			
			RF (%)	RD (%)	RD_O (%)	IVI (%)	RF	RD (%)	RD_O (%)	IVI (%)
1.	*Acacia auriculiformis*	B	5.75	21.53	15.06	42.34	9.79	26.84	18.11	54.74
2.	*Albizia lebbeck*	B	6.78	11.54	12.77	31.09	6.01	7.53	8.33	21.87
3.	*Albizia proera*	B	7.82	13.31	13.46	34.59	9.10	8.32	11.33	28.75
4.	*Anthocephalus chinensis*	A	4.48	1.88	3.44	9.80	2.40	0.94	0.16	3.50
5.	*Aphanamixis polystachya*	B	1.49	0.51	1.00	3.00	3.26	1.10	2.89	7.25
6.	*Artocarpus chaplasha*	A	1.38	0.74	2.41	4.53	—	—	—	—
7.	*Azadiracta indica*	B	5.51	2.07	3.52	11.10	6.18	2.14	2.80	11.21
8.	*Bombax ceiba*	A	3.52	1.33	0.75	5.60	3.56	1.15	0.59	5.30
9.	*Butea monosperma*	B	2.07	0.70	1.03	3.80	0.86	0.26	0.04	1.16
10.	*Cassia fistula*	B	3.45	1.25	1.47	6.17	2.58	0.89	0.73	4.20
11.	*Cassia siamea*	B	0.80	0.31	0.59	1.70	—	—	—	—
12.	*Dalbergia sissoo*	B	1.38	0.90	0.71	2.99	1.03	0.42	0.48	1.93
13.	*Delonix regia*	A	3.44	1.25	2.66	7.35	0.69	0.26	0.15	1.10
14.	*Erythrina variegata*	C	5.29	1.96	3.30	10.55	3.44	1.67	1.88	6.99
15.	*Eucalyptus camaldulensis*	A	1.84	0.66	0.37	2.87	4.12	1.31	1.77	7.20
16.	*Ficus racemosa*	C	6.09	2.27	3.55	11.91	2.92	0.94	1.87	5.73
17.	*Gmelina arborea*	B	2.41	0.86	4.52	7.79	1.72	0.63	2.27	4.62
18.	*Lagerstroemea speciosa*	B	2.87	1.41	1.37	5.65	—	—	—	—
19.	*Lannea coromandelica*	B	3.79	1.49	4.20	9.48	9.45	3.14	6.32	18.91
20.	*Leucaena leucocephala*	B	3.10	11.35	0.32	14.77	5.84	10.46	8.70	25.00
21.	*Michelia champaca*	A	1.15	0.51	0.63	2.29	—	—	—	—
22.	*Mimusops elengi*	C	1.03	0.35	0.10	1.48	—	—	—	—
23.	*Samanea saman*	B	10.11	7.16	10.33	27.60	12.20	14.44	15.36	42.00
24.	*Swietenia mahagoni*	B	5.75	11.94	9.73	27.42	7.22	14.65	12.44	34.31
25.	*Techtona grandis*	A	3.22	1.17	2.56	6.95	—	—	—	—
26.	*Terminalia arjuna*	B	2.99	1.17	0.02	4.18	1.72	0.68	0.91	3.31
27.	*Trewia polycarpa*	B	2.41	1.06	0.13	3.60	6.01	2.20	2.71	10.92
Total			100	100	100	300	100	100	100	300

Table 3. Quantitative analysis of the fruit species of the study homesteads of Lakshmipur and Narsingdi district.

Sl	Species name	Stra-tum	Lakshmipur				Narsingdi			
			RF (%)	RD (%)	RD_O (%)	IVI (%)	RF	RD (%)	RD_O (%)	IVI (%)
1.	*Aegle mermelos*	B	1.96	0.43	0.92	3.31	2.20	0.41	0.50	3.11
2.	*Annona reticulata*	C	3.02	0.50	0.41	3.93	2.93	0.58	0.27	3.78
3.	*Annona squamosa*	C	1.28	0.25	0.21	1.74	1.36	0.37	0.17	1.90
4.	*Artocarpus heterophyllus*	B	5.89	4.01	7.90	17.8	6.81	1.89	6.11	14.81
5.	*Artocarpus lakoocha*	B	0.75	0.15	0.29	1.19	0.31	0.10	0.11	0.52
6.	*Areca catechu*	A	6.80	40.45	16.41	63.66	5.86	7.62	4.94	18.82
7.	*Averhoa bilimbi*	C	2.27	0.41	0.30	2.98	1.26	0.41	0.17	1.84
8.	*Averrhoa carambola*	B	3.93	0.64	0.32	4.89	4.71	0.88	0.25	5.84
9.	*Baccaurea ramiflora*	B	2.04	0.37	0.20	2.61	6.28	8.17	7.52	1.97
10.	*Borassus flabellifer*	A	3.02	0.49	1.81	5.32	6.91	2.16	14.41	23.48
11.	*Carica papaya*	B	3.63	0.69	0.25	4.57	3.66	1.07	0.22	4.95
12.	*Citrus grandis*	B	3.17	0.53	0.09	3.79	2.93	0.66	0.06	3.65
13.	*Citrus spp.*	C	3.78	0.80	0.02	4.60	3.14	0.74	0.01	3.89
14.	*Cocos nucifera*	A	6.65	9.48	15.08	41.21	3.99	3.70	5.70	13.39
15.	*Diospyros embryopteris*	B	1.66	0.27	0.48	2.41	—	—		—
16.	*Diospyros phillipensis*	B	5.74	1.05	6.39	13.18	1.36	0.74	3.90	6.00
17.	*Elaeocarpus floribundus*	A	1.13	0.20	1.44	2.77	0.73	0.23	0.96	1.92
18.	*Emblica officinalis*	A	2.87	0.50	1.80	5.17	2.41	0.54	1.12	4.07
19.	*Feronia limonia*	B	0.30	0.10	0.09	0.49	—	—		—
20.	*Gercinia cowa*	B	1.06	0.15	0.56	1.77	—	—		—
21.	*Litchi chinensis*	B	1.44	0.25	1.61	3.30	2.41	0.66	2.38	5.45
22.	*Mangifera indica*	A	6.57	5.78	11.44	23.79	7.64	4.26	6.49	18.39
23.	*Manilkara sapota*	C	0.76	0.29	0.23	1.28	0.31	0.10	0.04	0.45
24.	*Moringa olifera*	B	2.27	0.52	1.47	4.26	2.72	0.58	1.30	4.60
25.	*Musa spp.*	C	4.00	17.62	13.18	34.80	9.12	59.22	29.36	97.30
26.	*Phoenix sylvestris*	B	3.10	0.61	2.38	6.09	0.73	0.41	1.15	2.29
27.	*Psidium guajava*	C	6.19	0.98	1.94	9.11	6.28	1.32	1.06	8.66
28.	*Spondias pinnata*	B	2.64	0.45	1.90	4.99	2.52	0.66	1.02	4.20
29.	*Syzygium cumini*	B	1.51	0.45	2.52	4.34	1.15	0.31	1.94	3.40
30.	*Syzygium samarangense*	B	1.66	0.32	2.03	4.01	1.99	0.47	1.88	4.34
31.	*Syzygium wallichi*	B	1.36	0.22	0.72	2.30	—	—		—
32.	*Tamarindus indica*	B	1.89	0.30	0.81	3.0	1.88	0.43	0.68	2.99
33.	*Terminalia catappa*	A	0.68	0.11	2.00	2.79	1.99	0.43	4.48	6.90
34.	*Zizyphus mauritiana*	C	4.98	0.77	2.80	8.55	4.41	0.88	1.80	7.09
Total			100	100	100	300	100	100	100	300

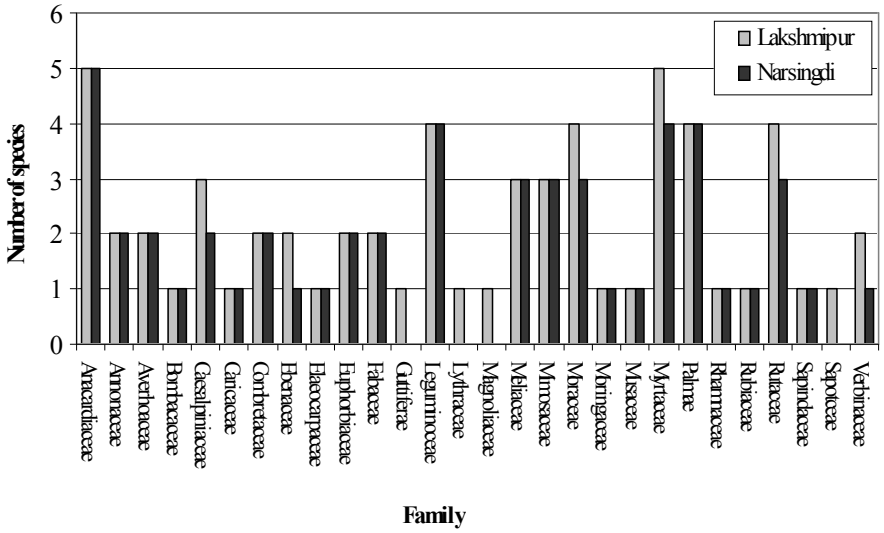


Fig. 1. Family level distribution of the homestead tree species in the study areas

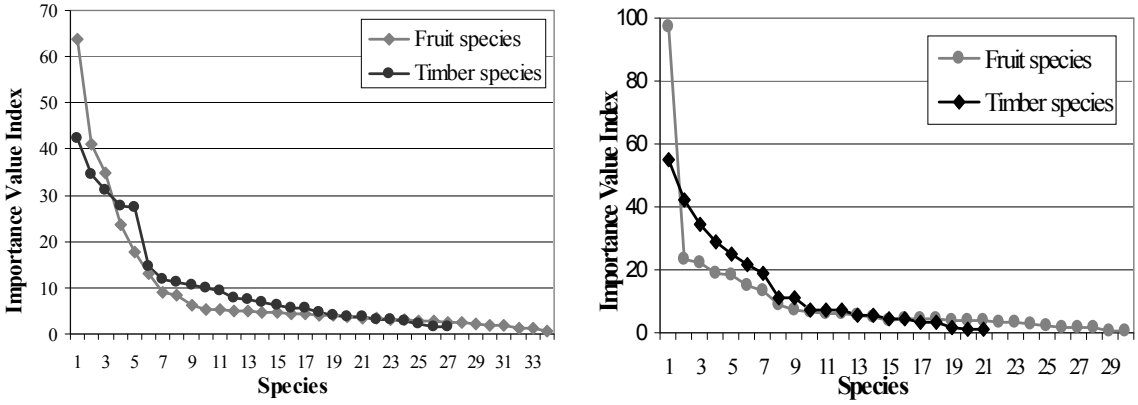
The studied homestead tree species show three distinct strata as shown in table2 and 3 in both districts. Tall tree stratum (A) is composed of large trees of >12m height, medium sized tree stratum (B)of 7-12m height and small tree stratum (C) of < 7m height. *Anthocephalus chinensis*, *Artocarpus*

chaplasha, *Bombax ceiba*, *Eucalyptus camaldulensis*, *Michelia champaca*, *Samanea saman and Tectona grandis are* common trees in the stratum A, among the timber species and *Areca catechu*, *Cocos nucifera, Borassus flabellifer* among the fruit species. Stratum B is found to form a quite dense sub-canopy with *Acacia auriculiformis*, *Albizia spp.*, *Azadiracta indica*, *Bombax ceiba Butea monosperma*, *Cassia spp.*, *Leucaena leucocephala*, *Delonix regia, Samanea saman*, *Swietenia mahagoni* etc. among the timber species and *Aegle mermelos, Artocarpus heterophyllus, Citrus grandis*, *Diospyros phillipensis*, *Emblica officinalis*, *Mangifera indica*, *Moringa olifera*, *Phoenix sylvestris*, *Spondius pinnata*, *Syzygium spp.*, *Tamarindus indica*, *Terminalia catappa* among the fruit species predominantly. *Erythrina variegata*, *Ficus racemosa*, *Mimusops elengi* among timber species and *Annona spp.*, *Averhoa carambola*, *Carica papaya*, *Citrus spp.*, *Musa spp.*, *Psidium guajava*, *Zizypus mauritiana* among the fruit species are common in stratum C in both study areas.

The highest IVI value is that of *Acacia auriculiformis* in both areas with a value of 42.34 in the homesteads of Lakshmipur and 54.74 in the homesteads of Narsingdi villages (Table 2). As the dominance of species in a heterogenous community is determined by the IVI value (Shukla and Chandel, 1980), the results of table 2 imply that *Acacia auriculiformis* is the most dominant timber species irrespective of agro ecological zones. Uddin et al. (2002) and Anam (1999) reported *Albizia procera* as the most domnat species in the saline areas and barind tract areas of Bangladesh.The other leading dominant timber species are *Albizia procera* (34.59), *Albizia lebbeck* (31.09) and *Samanea saman* (27.60) in Lakshmipur homesteads and *Samanea saman* (42.00), *Swietenia mahagoni* (34.31) and *Albizia procera* (28.75) in Narsingdi homeasteds.

In case of fruit trees, most dominant species in Lakshmipur villages is *Areca catechu* with an IVI value of 63.66 along with highest RF, RD and RD_o values (Table 4), whereas, *Musa* species is found most dominant fruit species in Narsingdi villages with an IVI value of 97.30 and 9.12% RF, 59.22% RD and 29.36% RD_o values. However, some other co-dominant fruit species in Lakshmipur are *Cocos nucifera* (IVI= 41.21), *Musa species* (IVI= 34.80) and *Mangifera indica* (IVI= 23.79) and *Borassus flabellifer* (IVI= 23.48), *Baccaurea ramiflora* (IVI= 21.97) and *Areca cate*chu (IVI= 18.82) in Narsingdi villages (Table 3).

The relationship governing the relative importance of different species can be analyzed by using the dominance-diversity curve (D-D curve) (Odum, 1983, Pianka, 1983). Figure 2 and 3 show the D-D curves plotted between the Importance Value Index and the timber species and fruit species sequences respectively depicting the relationship between different timber and fruit species of the study areas showing importance value. In Lakshmipur district, the curve for fruit trees is initially possess quite steep slope due to the quite higher IVI value of few fruit species like *Areca catechu* and *Cocos nucifera*, and then turns to gentle slope. In Narsingdi district homestead the curve has a very high value at initial point, because *Musa* species has a very high IVI value (97.30) as the fruit is being cultivated commercially in the study homesteads, then have a quick fall and remains consistent for the rest of the species. The shape of the tree species in both study areas found consistent with the normal distribution model of Preston (1948).



a) **b)**

Fig. 2. Dominance diversity curve for the a) Timber and fruit species of Lakshmipur district homesteads; b) Timber and fruit species of Narsingdi district homesteads.

SPECIES DIVERSITY INDICES

To understand the community structure the diversity indices shown in table 4 provide important information about rarity and commonness of species in both communities. Table 4 depicts timber and fruit species richness (*S*), Simpson's diversity index and evenness index, Shannon-Weiner diversity index, evenness index and Sorensen

similarity index. Maximum species richness (34) is observed for the fruit species in Lakshmipur district and minimum (21) is for timber species in Narsingdi district. The values of Simpson's diversity index values range between 0.63 - 0.89. The lowest diversity value is for the fruit species of Narsingdi district and highest diversity value is for timber species of Lakshmipur district. However, the values ranges between 0 -1 and the higher index values for timber species of both district (table 4) represent the probability that two individuals randomly selected from the timber community will belong to different species. This results are in agreements with the finding Simson's index value of Alam et al., 2002, and Bashar 1999 whereas quite higher than the findings of from Meghalaya homesteads and Kerala homesteads (Tynsong and Tiwari, 2010; Kumar et al., 1994).The results of Shannon-Weiner diversity index found to exist in the proper range (1.5 – 3.5) and show similar trend with Simpson's index values for timber and fruit species. The timber species of Lakshmipur district shows highest diversity (H' = 2.58) and fruit species of Narsingdi district shows lowest diversity (H' = 1.59), indicating a higher rate of species abundance for the timber species of Lakshmipur district and a lower rate of species abundance for the fruit species of Narsingdi district respectively. The Shannon-Weiner index values are are considerably higher than the homesteads of Cuba, Indonesia and India (Wezel and Bender, 2003; Kehlenbeck and Maass, 2004; Tynsong and Tiwari, 2010). The Sorensen similarity index (C_S) values in table 4 depict the extent to which species composition overlap between the two study districts. Both the C_S values are quite higher (near to 1) indicating a higher degree of similarity between the two agro ecological zones. Since the study areas irrespective of agroecological zones are diverse in tree population of timber and fruit species, further studies are essential to establish conservation measures to enhance the local biodiversity of the traditional homestead forests.

Table 4. Diversity indices of the Lakshmipur and Narsingdi district homestead forests.

Site	Species	S	N	D	H'	E_D	$E_{H'}$	C_S	
Lakshmipur	Timber	27	2555	0.89	2.58	0.36	0.78		0.87
Narsingdi	Timber	21	1911	0.86	2.30	0.35	0.74		
Lakshmipur	Fruit	34	9036	0.77	1.95	0.44	0.55		0.93
Narsingdi	Fruit	30	5141	0.63	1.59	0.10	0.47		

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