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Research article

Assessment of diversity, population structure and regeneration status of tree species in Hollongapar Gibbon Wildlife Sanctuary, Assam, Northeast India

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Abstract: The present study was carried out for quantitative analysis of diversity, population structure and regeneration status of tree species in tropical semi-evergreen forest of Hollongapar Gibbon Wildlife Sanctuary, Assam, northeast India. The study was conducted during 2010–2011, by laying 100 quadrats (10×10m) following random plot sampling method. A total of 75 tree species (≥30 cm gbh), belonging to 60 genera and 40 families were recorded from the study area. Individuals were categorized into three groups, seedling, sapling and adult based on girth classes and the status of natural regeneration of species was determined based on their population size. Highest density (7756 individuals ha^{-1}) and species richness (73) were recorded in 0–30 cm girth class, while highest basal area (9.62 m^2 ha^{-1}) was observed in 120–150 cm girth class. Majority of tree species (36%) exhibited 'fair regeneration' condition followed by 'good regeneration' status (24%). The overall population structure of tree species shows a reverse J-shaped population curve and 'good' regeneration status which reveals that the future communities may be sustained. The study gives an understanding of the diversity, pattern of population and regeneration of the tree species of the sanctuary which may help in forest management and conservation of the species.
Keywords: Conservation - Forest - Population structure - Protected areas - Quantitative characters

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INTRODUCTION

The structure and function of forest ecosystem is determined by the plant component more than any other living component of the system (Richards 1996). The plant diversity at any site is influenced by species distribution and abundance patterns (Palit & Chanda 2012) and the richness of plant species is controlled by a variety of biotic and abiotic parameters (Rannie 1986, Huston 1994). Topography, soil, climate and geographical location of a region influence the vegetation diversity of the forest ecosystem (Ram *et al*. 2004). It was found that, plant diversity inventories in tropical forests have mostly been concentrated on tree species than other life-forms (Mani & Parthasarathy 2006). The nature of forest communities largely depends on the ecological characteristics in sites, species diversity and regeneration status of species (Khumbongmayum *et al*. 2006). Species diversity is one of the most important indices used for evaluating the stability and sustainability of forest communities. Information on the species composition of a forest is essential for its wise management in terms of economic value, regeneration potential (Wyatt-Smith 1987) and ultimately may be leading to conservation of biological diversity (Verma *et al*.1999).

Population structure is expressed in terms of number of individuals present in each of the definite girth class distribution of tree species. Saxena & Singh (1984) reported regeneration behaviour of tree species in a forest can be revealed from the population structure. A successful regeneration is indicated by presence of sufficient number of seedlings, saplings and young trees in a given population (Pokhriyal *et al*. 2010) and the number of seedling of any species can be considered as the regeneration potential of that species (Negi & Nautiyal 2005). Natural regeneration is a central component for tropical forest ecosystem dynamics (Getachew *et al*. 2010) and is essential for preservation and maintenance of biodiversity (Rahman *et al*. 2011). It is important to understand the growth status of a species in the ecosystem and is one of the key parameter to determine ecosystem stability (Kadavul & Parthasarathy 2001, Deb & Sundriyal 2011). Several types of disturbances like logging, landslides, gap formation, litterfall, herbivory, etc. can affect the potential regenerative status of species composing the forest stand spatially and temporally (Guariguata 1990, Welden *et al*. 1991, Barik *et al*. 1996a, Boerner & Brinkman 1996, Liang & Seagle 2002, Ganesan & Davidar 2003, Khumbongmayum *et al*. 2005, Ceccon *et al*. 2006, Khumbongmayum *et al*. 2006, Ward *et al*. 2006, Guarino & Scariot 2012).

The northeast India is a storehouse of rich biodiversity which includes variety of plant and animal species and it is considered as one of the richest biodiversity centres of the Indian continent (Tynsong & Tiwari 2010) with rich species density and diversity (Nath *et al*. 2005). Assam, a state in northeast India, has total recorded forest area of 28,748 km^2. which covers 32% of the total geographical area of the state and harbours 3017 species of flowering plants (Patiri & Borah 2007). Most of the population and regeneration studies in Northeast India were reported from the states of Arunachal Pradesh, Meghalaya, Manipur, Mizoram and Tripura, but a few studies from Assam (Borah & Garkoti 2011, Nandy & Das 2013, Dutta & Devi 2013, Saikia & Khan 2013). Therefore, the present study was undertaken to analyse the tree species diversity, population dynamics and to assess the regeneration pattern of tree species of this tropical semi-evergreen forest of Assam, Northeast India. The findings of the study will definitely add records on quantitative data on tree species diversity of forest of Assam in particular and tropical forest in general.

MATERIAL AND METHODS

Study area

Hollongapar Gibbon Wildlife Sanctuary (26°40'–26°45' N and 94°20'–94°25' E) is situated in Mariani range of Jorhat district in upper Assam at an altitudinal range of 100–120 m above msl. It has got the status of Reserve forest in 1881 and then in 1997, the Hollangapar Reserve Forest was upgraded to Gibbon Wildlife Sanctuary (Fig. 1). Again in the year 2004, its name was changed to Hollongapar Gibbon Wildlife Sanctuary (abbreviated as HGWLS hereafter) but it is still popularly known as Gibbon Wildlife Sanctuary. The area is situated amidst tea gardens and villages, crisscrossed with numerous rain fed streams (*nallahs*). It covers an area of 19.49 km^2 and the sanctuary has been divided into five compartments. The area receives an average annual rainfall of 249 cm. The soil is sandy clay loam in texture, slightly acidic in nature having pH 5.1 and soil organic carbon content records 2.03%. The weather in the area may be classified as subtropical hot, wet monsoon periods (May-August) and cool dry winter (September to April). Winter rains are also not uncommon and the average temperature varies from 5°C (min) – 38°C (max).

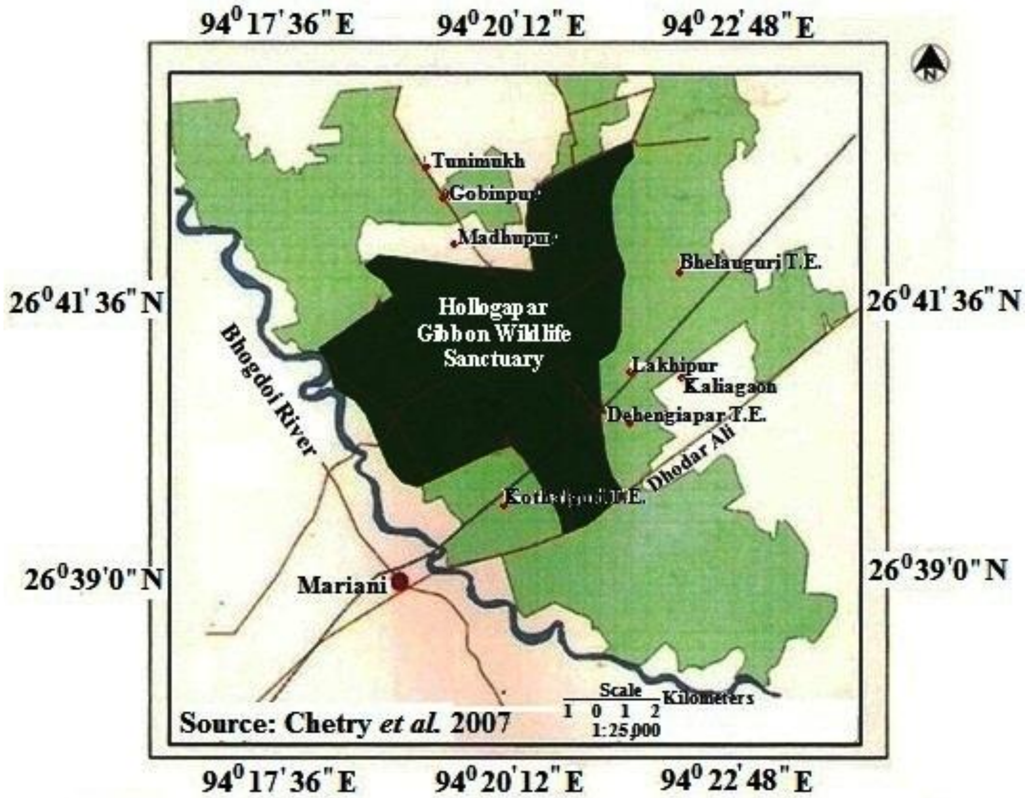

Figure 1. Map of the study site.

As per Champion & Seth (1968), classification scheme, the forest type of HGWLS is "Assam Plains Alluvial Semi Evergreen Forests (1/2/2B/C)". The sanctuary is a suitable habitat for large number of mammalian, birds and invertebrate species. It harbours seven species of primates viz. Western Hoolock gibbon, Slow loris, Capped langur, Rhesus, Pigtailed, Stump-tailed and Assamese macaque. This Sanctuary has the rare distinction of holding one of the highest densities of gibbon populations in Assam. Extensive studies on primates have been carried out in this sanctuary by several workers, but there is a lack of baseline information and detailed study on quantitative characteristics of diversity, population structure and natural regeneration status of tree species of HGWLS. Therefore, the study has been carried out and the recorded data on quantitative characters of tree species may be helpful to formulate conservation strategy for plant species in particular and for the proper conservation of animal species inhabiting in the sanctuary in general.

Methods

The study for the assessment of tree diversity, population structure and quantitative characteristic features was conducted during 2010–2011 using random sampling method. Extensive field survey in all the five compartments was carried out in the sanctuary during phytosociological study period. Quadrat method was followed to record the tree species diversity and other quantitative parameters. For the study, 100 quadrats of 10×10m were laid down randomly in the study site, covering an area of 1 ha. All the species and individuals encountered in each quadrat were counted and the girth was measured. Individuals having ≥30 cm girth (gbh) were considered as adult, saplings with ≥10 cm to < 30 cm girth and seedlings with < 10 cm girth. The number of individuals and girth of each individual species encountered in each quadrat were used for further quantitative analysis. Population structure of the species was analyzed across thirteen girth classes *i.e.* 0–30, 30–60, 60–90, 90–120, 120–150, 150–180, 180–210, 210–240, 240–270, 270–300, 300–330, 330–360 and >360 cm. The status of regeneration of species was determined based on population size of seedlings, saplings and adults as (modified from Khan *et al*. 1987, Shankar 2001, Khumbongmayum *et al*. 2006): (a) 'good', if seedlings > or < saplings > adults; (b) 'fair', if seedlings > or ≤ saplings ≤ adults; (c) 'poor', if a species survives only in sapling stage, but no seedlings (though saplings may be <, > or = adults); (d) 'none', if it is absent both in sapling and seedlings stages, but found only in adults and (e) 'new', if a species has no adults, but only saplings and/or seedlings. Community quantitative parameters such as frequency, density, abundance, basal area (BA), relative frequency, relative density, relative dominance and Importance Value Index (IVI) were calculated (Cottam & Curtis 1956). The Shannon-Wiener index (H′) (Shannon & Weaver 1963), Simpson's index (C_D) (Simpson 1949) and Pielou's evenness index (e) (Pielou 1966) were also evaluated. Identification of plants was made by referring taxonomic literature (Kanjilal & Bor 2005) and by consulting plant specimen at Botanical Survey of India, Itanagar, Arunachal Pradesh. Herbarium specimen are deposited and preserved in the Department of Environmental Science, Tezpur University.

RESULTS

Tree diversity

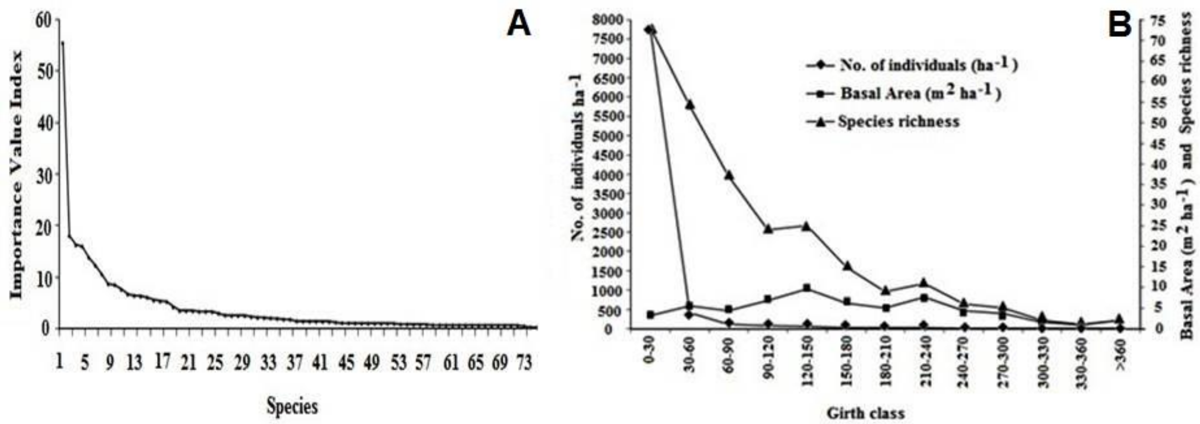

Figure 2. Tree species: **A**, Dominance diversity (D-D) curve; **B**, Density, basal area and species richness in different girth classes.

A total of 75 tree species, belonging to 60 genera under 40 families were recorded from the study area. Moraceae was the dominant family having 8 species followed by Magnoliaceae with 5 species, Anacardiaceae, Euphorbiaceae, Lauraceae and Meliaceae recorded 4 species each. Under Moraceae family, the genus *Ficus* contributed highest number of six species viz. *Ficus benghalensis, Ficus benjamina, Ficus fistulosa, Ficus lamponga, Ficus racemosa* and *Ficus religiosa*.The total basal area of the tree species was computed as 58.0 m² ha^{-1} with density of 750 individuals ha^{-1}. The dominant tree species was *Vatica lanceaefolia* Bl. (Dipterocarpaceae), a critically endangered species as given by International Union for Conservation of Nature red list of threatened species(IUCN 2014), which contributed 55.52 IVI value recording highest density (227 individualsha^{-1}) with basal area of 6.525 m² ha^{-1}. Detailed quantitative data of each tree species, density (ha^{-1}), basal area (m² ha^{-1}) and IVI values are given in table 1.The other important species based on IVI values were *Artocarpus chaplasha* (18.13), *Lagerstroemia speciosa* (16.30), *Magnolia hookeri* (16.07) and *Dipterocarpus retusus* (13.91) as shown in fig. 2A. The Shannon-Wiener index (H'), Simpson's index (C_D) and Evenness index (e) for the tree species were calculated as 3.55, 0.05 and 0.82, respectively.

Population structure and regeneration status

Overall population structure of tree species depending on size-class distribution yielded reverse J-shaped curve in HGWLS (Fig. 2B). The highest percentage (91.22%) of tree individuals were recorded in 0–30 cm girth class and it gradually decreased with increasing girth class. Highest density (7756 individuals ha^{-1}) and species richness (73) were recorded in 0–30 cm girth class, while *Tetrameles nudiflora* showed lowest density (1 individual ha^{-1}) and species richness (1) in 330–360 cm girth class. Highest basal area (9.62 m² ha^{-1}) was observed in 120–150 cm girth class and lowest (0.97 m² ha^{-1}) in 330–360 cm girth class. Population structure of a few dominant tree species in HGWLS such as *Magnolia hookeri*, *Dipterocarpus retusus*, *Artocarpus chaplasha* and *Vatica lanceaefolia* showed reverse J-shaped population curve, whereas *Lagerstroemia speciosa* showed an interrupted population curve (Fig. 3).

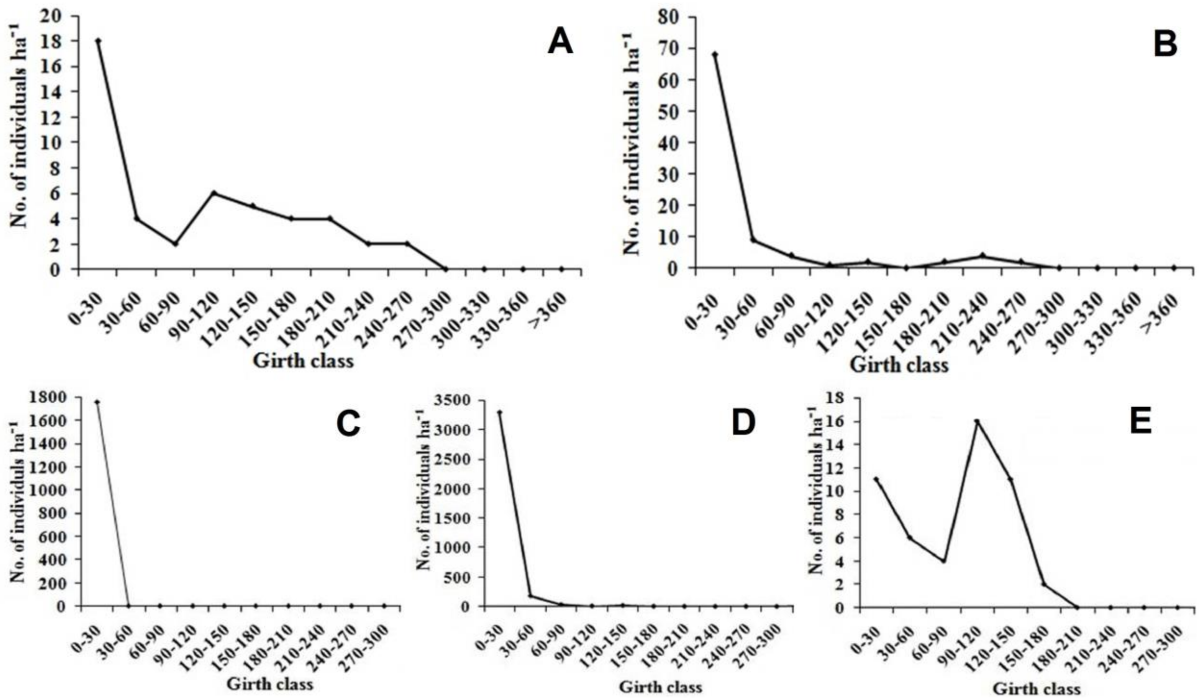

Figure 3. Population structure of few dominant tree species recorded in the study site: **A**, *Magnolia hookeri*; **B**, *Dipterocarpus retusus*; **C**, *Artocarpus chaplasha*; **D**, *Vatica lanceaefolia*; **E**, *Lagerstroemia speciosa*.

In the present study, 24% tree species exhibited 'good' regeneration status, 36% showed 'fair' regeneration condition and 8% showed 'poor' regeneration status. A total of 17% tree species were 'not regenerating' at all and 15% tree species, which were available only in sapling or seedling stage, were considered as 'new' in HGWLS (Table1). The 'poor' regenerating tree species were *Aglaia spectabilis*, *Cinnamomum glaucescens*, *Dillenia indica*, *Ficus racemosa*, *Hydnocarpus kurzii*, *Magnolia hodgsonii* and *Terminalia catappa*. Species which were found in 'none' or 'not regenerating' category were *Albizia lebbek*, *Alstonia scholaris*, *Cyathea gigantea*, *Duabanga grandiflora*, *Evodia meliaefolia*, *Macaranga denticulate*, *Morinda angustifolia*, *Neolamarckia cadamba*, *Palaquium obovatum*, *Pterospermum acerifolium*, *Quercus gemelliflora*, *Sterculia villosa*, *Terminalia myriocarpa*, *Vernonia arborea* and *Walsura robusta*. 'New' regeneration status included

Actinodaphne angustifolia, *Albizia lucidior*, *Bischofia javanica*, *Chrysophyllum roxburghii*, *Cinnamomum bejolghota*, *Gynocardia odorata*, *Horsfieldia kingii*, *Machilus gamblei*, *Meliosma pinnata*, *Phoebe goalparensis*, *Syzygium cumini*, *Terminalia bellirica* and *Toona ciliata*. The total density of seedlings (6754 individuals ha^{-1}) was recorded to be higher than the saplings (1002 individuals ha^{-1}) and adults (750 individuals ha^{-1}) in the study site, thus exhibiting overall 'good' regeneration condition. The dominant tree species, *Vatica lanceaefolia* had maximum seedling density (2876 individuals ha^{-1}) with highest sapling and adult density of 412 and 227 individuals ha^{-1}, respectively showing 'good' regeneration status. Among all tree species recorded in the study site, *Vatica lanceaefolia* is a critically endangered species which contributed 37% towards the overall regeneration status.

Table 1. Density (D=individuals ha^{-1}), basal area (BA=m^{2}ha^{-1}), Importance Value Index (IVI) and regeneration status (RS) of adult tree species of Hollongapar Gibbon Wildlife Sanctuary.

Scientific Name	Family	D	BA	IVI	RS
Actinodaphne obovata (Nees.) Bl.	Lauraceae	17	0.31322	6.15975	Fair
Aglaia spectabilis (Miq.) S.S.Jain & Bennet	Meliaceae	22	2.65147	10.6607	Poor
Ailanthus integrifolia Lam.	Simaroubaceae	3	0.72318	2.23857	Fair
Albizia lebbeck (L.) Benth.	Mimosaceae	1	0.03361	0.38852	None
Alseodaphne petiolaris Hook. f.	Lauraceae	3	0.04198	1.0641	Fair
Alstonia scholaris (L.) R. Br.	Apocynaceae	1	0.01833	0.36217	None
Altingia excelsa Noronha	Altingiaceae	16	0.52636	5.40771	Fair
Aquilaria malaccensis Lam.	Thymelaeaceae	2	0.01846	0.69297	Fair
Artocarpus chaplasha Roxb.	Moraceae	28	6.29636	18.1394	Good
Artocarpus lakoocha Roxb.	Moraceae	3	0.19543	1.32867	Fair
Baccaurea ramiflora Lour.	Phyllanthaceae	10	0.1217	3.51555	Good
Balakata baccata (Roxb.) Esser	Euphorbiaceae	2	1.17837	2.69281	Fair
Barringtonia acutangula (L.) Gaertn.	Lecythidaceae	2	0.24522	1.08393	Fair
Canarium bengalense Roxb.	Burseraceae	8	0.63933	3.35239	Good
Carallia brachiata (Lour.) Merr.	Rhizophoraceae	3	0.0572	1.09034	Good
Castanopsis indica (Roxb. ex Lindl.) A.DC.	Fagaceae	20	1.72433	8.59823	Fair
Castanopsis tribuloides (Sm.) A.DC.	Fagaceae	8	2.38789	6.76163	Fair
Chukrasia tabularis A.Juss.	Meliaceae	2	0.04891	0.74547	Fair
Cinnamomum glaucescens (Nees) Hand.-Mazz.	Lauraceae	14	1.54341	6.50011	Poor
Cyathea gigantea (Wall. ex Hook.) Holtt.	Cyatheaceae	1	0.00959	0.3471	None
Dillenia indica L.	Dilleniaceae	4	1.70451	4.2611	Poor
Diospyros variegate Kurz	Ebenaceae	2	0.02531	0.70478	Good
Dipterocarpus retusus Bl.	Dipterocarpaceae	24	3.69504	13.91	Fair
Drimycarpus racemosus (Roxb.) Hook.f. ex Marchand.	Anacardiaceae	2	0.08046	0.79987	Good
Duabanga grandiflora (DC.) Walp.	Lythraceae	2	0.0368	0.7246	None
Dysoxylum gotadhora (Buch.-Ham.) Mabb.	Meliaceae	23	0.86818	7.71934	Good
Elaeocarpus serratus L.	Elaeocarpaceae	4	0.07487	1.45138	Fair
Endospermum diadenum (Miq.) Airy Shaw	Euphorbiaceae	4	0.10866	1.50962	Good
Eurya acuminata DC.	Pentaphylacaceae	2	0.02101	0.69737	Fair
Evodia meliaefolia Benth.	Rutaceae	2	0.02522	0.70463	None
Ficus benghalensis L.	Moraceae	2	1.12092	2.59377	Fair
Ficus benjamina L.	Moraceae	2	0.31396	1.20246	Fair
Ficus fistulosa Reinw. ex Bl.	Moraceae	19	0.29231	5.60142	Good
Ficus lamponga Miq.	Moraceae	8	0.55708	3.40782	Fair
Ficus racemosa L.	Moraceae	3	0.04018	0.86374	Poor
Ficus religiosa L.	Moraceae	1	0.43934	1.08805	Fair
Garcinia morella (Gaertn.) Desr.	Clusiaceae	3	0.09923	1.1628	Good

Garcinia pedunculata Roxb. ex Buch.-Ham.	Clusiaceae	3	0.0434	1.06654	Good
Gmelina arborea Roxb.	Lamiaceae	4	0.05154	1.41115	Fair
Hydnocarpus kurzii (King) Warb.	Achariaceae	4	0.11162	1.51474	Poor
Ilex godajam Coleb. ex Hook.f.	Aquifoliaceae	6	0.09145	2.1411	Good
Khasiaclunea oligocephala (Havil.) Ridsdale	Rubiaceae	11	0.97748	5.3216	Good
Kydia calycina Roxb.	Malvaceae	6	0.11537	2.18235	Fair
Lagerstroemia speciosa (L.) Pers.	Lythraceae	39	3.69519	16.3047	Fair
Litsea monopetala (Roxb.) Pres.	Lauraceae	12	0.21	3.53998	Good
Macaranga denticulata (Blume) Müll.Arg.	Euphorbiaceae	2	0.09987	0.83334	None
Magnolia champaca (L.) Baill. ex Pierre	Magnoliaceae	3	0.29418	1.49892	Fair
Magnolia griffithii Hook.f. & Th.	Magnoliaceae	3	0.53187	1.90874	Fair
Magnolia hodgsonii (Hook.f. & Th.) H.Keng	Magnoliaceae	12	1.39598	6.37373	Poor
Magnolia hookeri (Cubitt & Smith) Raju & Nayar	Magnoliaceae	29	5.13547	16.074	Fair
Magnolia oblonga (Wall. ex Hook.f. & Thomson) Figlar	Magnoliaceae	2	0.06037	0.568	Fair
Mallotus nudiflorus (L.) Kulju & Welzen	Euphorbiaceae	2	0.07335	0.78761	Fair
Mangifera sylvatica Roxb.	Anacardiaceae	4	0.43083	1.86786	Good
Mesua ferrea L.	Calophyllaceae	21	3.26135	12.3678	Good
Morinda angustifolia Roxb.	Rubiaceae	2	0.04877	0.74522	None
Neolamarckia cadamba (Roxb.) Bosser	Rubiaceae	4	1.00231	3.0504	None
Olea dioica Roxb.	Oleaceae	6	0.2247	2.37084	Good
Palaquium obovatum (Griff.) Engl.	Sapotaceae	2	0.53042	1.57566	None
Premna bengalensis Cl.	Lamiaceae	2	0.03218	0.71663	Fair
Pterospermum acerifolium (L.) Willd.	Malvaceae	2	0.02715	0.70796	None
Quercus gemelliflora Bl.	Fagaceae	2	0.01739	0.69113	None
Saurauia roxburghii Wall.	Saurauiaceae	26	0.33236	8.77342	Fair
Spondias mombin L.	Anacardiaceae	4	1.21775	3.42185	Fair
Spondias pinnata (L.f.) Kurz.	Anacardiaceae	2	0.03171	0.71582	Fair
Sterculia villosa Roxb.	Malvaceae	2	0.03853	0.72758	None
Stereospermum chelonoides (L.f.) DC.	Bignoniaceae	3	0.03336	1.04924	Good
Symplocos ferruginea Roxb.	Symplocaceae	4	0.00975	1.14185	Fair
Syzygium kurzii (Duthie) Balakr.	Myrtaceae	10	0.13052	3.53075	Good
Terminalia catappa L.	Combretaceae	2	0.16568	0.9468	Poor
Terminalia chebula Retz.	Combretaceae	3	0.03446	0.8539	Good
Terminalia myriocarpa Van Heurck & Müll. Arg.	Combretaceae	4	0.74261	2.60265	None
Tetrameles nudiflora R. Br.	Tetramelaceae	2	1.12475	2.60037	Fair
Vatica lanceaefolia Bl.	Dipterocarpaceae	227	6.52549	55.5215	Good
Vernonia arborea Buch.-Ham.	Asteraceae	3	0.08561	0.94208	None
Walsura robusta Roxb.	Meliaceae	2	0.78779	2.0194	None

DISCUSSIONS

Tree diversity

The present semi-evergreen forest patch harbours rich tree diversity. The tree species richness (75 species) recorded in this study site is higher than tropical semi evergreen forest of Manipur (Devi & Yadava 2006) and Mizoram (Lalfakawma *et al*. 2009) which recorded 17 and 32 tree species, respectively. The value is comparable to semi-evergreen and evergreen forest of Little Andaman Island, India with 83 and 84 tree species, respectively (Rasingam & Parathasarathy 2009). According to Whitmore (1984), in tropical rain forests the tree species ranges from 20 to a maximum of 223 ha^{-1}. Tree density (750 ha^{-1}) and basal area (58.0 m^2 ha^{-1}) recorded in tropical semi-evergreen forest of HGWLS are found to be similar (685–820 tree ha^{-1} and 18.9 to 19.58 m^2 ha^{-1} respectively) with tropical semi evergreen forest of Manipur (Devi & Yadava 2006), tropical wet evergreen forest Namdapha National Park, northeast India (34 to 610 individuals ha^{-1} and 7.81 to 98.58 m^2 ha^{-1}, Nath *et al*.

2005) and evergreen forest of Kalakad National Park of Western Ghats (575 to 855 individuals ha^{-1} and 61.7 to 94.6 m^2 ha^{-1}, Parthasarathy 1999). Tree density in tropical forests varies from 245 to 859 for trees of ≥30 cm gbh (Richards 1952, Ashton 1964, Campbell *et al.*1992) and the recorded values of the present study lies within this range. Variation in density and basal area of different forest stand may be attributed by altitudinal variation, species composition, age structure, successional stage of the forest and degree of disturbance (Swamy *et al*. 2000). The Shannon-Weiner diversity index normally varies from 1.5 to 3.5 and rarely exceeds 4.5 (Kent & Coker 1992) and is generally higher in tropical forest. The Shannon-Wiener index (3.55) recorded in the present study site is higher than tropical semi evergreen forest of Mizoram (Lalfakawma *et al*. 2009). The diversity index (H') for Indian forests ranged from 0.83 to 4.1 (Singh *et al*. 1984, Parthasarathy *et al*. 1992, Visalakshi 1995) and the value of diversity index of the present study, therefore, lies within the range and it reflects high tree diversity in the study site. Simpson's index values of different Indian tropical forests ranged from 0.03 to 0.92 (Bhuyan *et al.* 2003, Nath *et al*. 2005, Devi & Yadava 2006, Deb & Sundriyal 2011, Kushwaha & Nandy 2012) and the average value is 0.06 as reported by Knight (1975). The concentration of dominance of the study site (0.05) corresponds well with the reported range for tropical forest. Evenness index (0.82) was comparable with a report from tropical wet evergreen forest of Arunachal Pradesh (Nath *et al*. 2005) and tropical evergreen region of Meghalaya (Tynsong & Tiwari 2010). The higher evenness index value reveals more consistency in species distribution. IVI value of any species indicates the dominance of species in a mixed population and it gives a total picture of the social structure of species in a community and can be used to form an association of dominant species (Parthasarathy & Karthikeyan 1997). In the present study, it was found that *Vatica lanceaefolia* Bl., a critically endangered species, records highest IVI value emerging as the dominant tree species which was followed by *Artocarpus chaplasha, Lagerstroemia speciosa, Magnolia hookeri* and *Dipterocarpus retusus*. The observation shows that HGWLS harbours rich tree diversity providing habitat and food resources to large number of fauna. High species richness means greater diversity and which leads to a higher community stability (MacArthur 1955). However, the anthropogenic activities prevailing in the sanctuary like grazing by cattle and firewood collection by the local people to meet their energy requirements imposed threat to the survival and population structure of the species. So, if the present trend of anthropogenic pressure extended, the growth, survival and reproductive potential of the tree species will jeopardise in near future. Therefore, a proper strategy for the conservation and management of the study site is required to formulate, considering a sustainable harvest and utilization of forest resources by the local dwellers, for countering the same.

Population structure and regeneration status

The size class distribution of tree has often been used to represent the population structure of forests (Saxena & Singh 1984, Khan *et al*. 1987). Girth class frequency showed reverse J-shaped population curve in our present study which is similar to those reported from forest of North east India (Upadhaya *et al*. 2004, Mishra *et al*. 2005, Tynsong & Tiwari 2011), Eastern Ghats (Kadavul & Parthasarathy 1999, Sahu *et al*. 2012), Andaman Island (Rajkumar & Parathasarathy 2008, Rasingam & Parathasarathy 2009). The reverse J-shaped population curve of trees suggests an evolving or expanding population, climax or stable type of population in forest ecosystem, indicating that the forest harbours a growing and healthy population (Parthasarathy & Karthikeyan 1997, Mishra *et al.* 2005, Sahu *et al*. 2012). Micro-environmental factors which vary with seasonal changes have an effect on different growth stages of trees i.e. seedling, sapling, coppice and young trees that also helps to maintain the population structure (Khumbongmayum *et al*. 2006). The presence of established seedlings of dominant species like *Vatica lanceaefolia*, *Artocarpus chaplasha*, *Mesua ferrea,* etc. is an indicative of excellent recruitment of these species which also reflect that the prevailing environmental conditions of the study site are favourable for their establishment stage. High stem density in lower girth class representing young stage also reveals high biotic potential of the species which may be supported by the existing environmental conditions.

Tree regeneration can be predicted by the structure of their populations (Khan *et al*. 1987). In general, regeneration of species is affected by various anthropogenic factors (Sukumar *et al*.1994, Khan & Tripathi 1989, Barik *et al*. 1996b, Iqbal *et al*. 2012) and natural phenomena (Welden *et al*. 1991, Iqbal *et al*. 2012). The overall regeneration status of the tree species of the study site is satisfactory at community level showing 'good' regeneration status, but 17% tree species, falls under 'not regenerating' condition may affect the population size in HGWLS in future. Species under 'not regenerating' condition might have been occurred due to existing disturbance in the study site like, grazing, firewood collection, and poor biotic potential of tree species which either affect the fruiting and seed germination or successful conversion of seedling to sapling stage. Moreover, individuals in young stages of any species are more vulnerable to any kind of environmental stress and anthropogenic disturbance. The successful regeneration of a tree species depends on its ability to produce large number of seedlings and the ability of seedlings and saplings to survive and grow (Good & Good 1972). The forest having good canopy cover might have affected the survival of seedlings under good canopy (Pokhriyal *et al*. 2010) probably by reducing the penetration of sunlight reaching down to the forest floor. The 'poor', 'none' and 'new' regenerating categories include many important and useful tree species namely *Cinnamomum glaucescens, Dillenia indica, Ficus racemosa*, *Duabanga grandiflora*, *Neolamarckia cadamba, Syzygium cumini*, *Terminalia bellirica, Toona ciliata,* etc. which have certain economic values (timber and non timber forest products) and act as a source of food for the seven primate species residing in the sanctuary. 13 species contributing 15% of tree species were 'new arrivals'/ newly colonize to the study site, representing only in sapling or seedling stage. These species may have reached or colonized to the study site by dispersal of seeds through drooping of birds and animals and getting favourable microsite to germinate and establish. Another possible reason may be that the adult individuals were very poor and have been felled by locals but seed remain as seed bank which germinate during favourable season. On the other hand, regeneration of a species is affected by various factors such as light, canopy density, soil moisture, nutrients and anthropogenic pressure (Iqbal *et al*. 2012). Small openings in the forest canopy allow higher light availability in the forest floor which favours the seedling recruitment process of certain light demanding species (Webb & Sah 2003).

CONCLUSIONS

Precise assessment and understanding of the dynamics of plant resources is important for their sustainable management, utilization and biodiversity conservation. Quantitative analysis of tree species diversity of HGWLS will be useful in forest management and conservation as the location of the sanctuary, amidst tea gardens and villages, has made the flora more vulnerable with respect to human interference. This study provides a critical analysis of tree species richness in the study site. A reverse J-shaped population curve indicates high tree species richness and density in lower girth class which gradually decrease with increase in girth class population size. The overall population structure of tree species in the study site reveals that contribution of seedlings to the total population was highest followed by saplings and adult trees. It shows regeneration of tree species in the forest is 'good' and the future communities may be sustained unless there is any major environmental stress or interference exerted by human activities. However, considering the increasing anthropogenic pressure, there may be spatial and temporal threat to the seedling establishment and growth of tree species in the study site. The growth, survival and reproductive potential of the tree species will be at risk in near future if the present trend of anthropogenic continues. Thus, a systematic management plan is required for the conservation of vegetation and sustainable use of available resource. Quantitative analysis of diversity, population structure and regeneration status of tree species recorded from the present study may provide baseline information for formulating conservation and management strategies of the present forest.

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