Tree species diversity and composition of the Pala Wetland Reserve Forest, Mizoram, Indo-Burma hotspot, India

Article *in* Biocatalysis and Agricultural Biotechnology · December 2019

DOI: 10.1016/j.bcab.2019.101474

CITATIONS
2

READS
293

2 authors:

Seikuti Nohro
Pondicherry University
2 PUBLICATIONS **2** CITATIONS

SEE PROFILE

S. Jayakumar
Pondicherry University
70 PUBLICATIONS **972** CITATIONS

SEE PROFILE

Biocatalysis and Agricultural Biotechnology 23 (2020) 101474

Contents lists available at ScienceDirect

Biocatalysis and Agricultural Biotechnology

journal homepage: http://www.elsevier.com/locate/bab

Tree species diversity and composition of the Pala Wetland Reserve Forest, Mizoram, Indo-Burma hotspot, India

Seikuti Nohro, Shanmuganathan Jayakumar *

Department of Ecology and Environmental Sciences, School of Life Sciences, Pondicherry University, Puducherry, 605014, India

1. Introduction

According to the FAO, 2015, tropical forest covers 44% of the Earth's land surface and sustained the greatest wealth of biological and genetic diversity with more than half of the World's species population (Hubbell and Foster, 1983; May and Stumpf, 2000; Keenan et al., 2015) thriving under these forest which is spread worldwide. An estimated 0.8–2% of these forests disappeared per year (Sagar et al., 2003), greatly affecting the biodiversity in this regions causing a serious environmental and economic problem all over the world (Hare et al., 1997). Floristic composition, species diversity, soil fertility and forest regeneration characteristics are the parameters often considered for assessment of forest structure (Hitimana et al., 2004; Khumbongmayum et al., 2006). These assessments are necessary for collecting information on the regional biogeographical patterns and structure (Gordon and Newton, 2006; Naidu et al., 2018) which is crucial for implementing a proper managerial system to protect endangered and threatened species, thus working towards conservation of biodiversity. In recent years, small sized permanent plots (1–2 ha) have been established to document their structure, composition and diversity (Philips and Gentry, 1994; Strasberg, 1996; Parthasarathy, 2001). These quantitative assessments mainly of floristic inventory and diversity are essential for understanding the present biodiversity status and they provide indispensible information for sustainable development strategies (Ayyappan and Parthasarathy, 1999; Jayakumar et al., 2011). In the Indian sub-continent, many researchers have done an extensive work over the years and their compiled data on the plant diversity inventories are available from the different tropical forest across the country (Jayakumar et al., 2009; Krishnamurthy et al., 2010; Pragasan and Parthasarathy, 2010; Reddy et al., 2011; Sahu et al., 2012; Sathish et al., 2013; Anbarashan and Parthasarathy, 2013; Premavani et al., 2014; Gopalakrishna et al., 2015; Sathya and Jayakumar, 2017).

The Northeastern part of the country falls under the Indo-Burma hotspot (Mittermeier et al., 2005) but only a few part of the States have been explored and studied. Data on the tree diversity and composition of forest from the Northeast region (India) are available for these states- Arunachal Pradesh (Behera et al., 2002; Bhuyan et al., 2003), Assam (Borah and Garkoti, 2011; Dutta and Devi, 2013; Sarkar and Devi, 2014), Manipur (Devi and Yadava, 2006; Vashum and Jayakumar, 2016); Meghalaya (Upadhaya et al., 2003; Mishra et al., 2004), Mizoram (Lalfakawma et al., 2009; Sahoo and Rocky, 2015; Devi et al., 2018), Sikkim (Sundriyal and Sharma, 1996) and Tripura (Majumdar et al., 2012). With the growing awareness and need for conservation, quantification of tree species distribution and abundance is vital and Northeast India when compared to the rest of the country is under-studied. One major factor and hurdle for enthusiast researchers could be the topography of the area itself, which are often not easily accessible, as most of the states in this part of the country have a hilly terrain resulting in a cost and time intensive study. This objective was formulated with the need for contributing to the growing floristic database and to understand the forest structure based on the tree diversity which can be an asset in conservation and management of the Pala Wetland Reserve Forest, Mizoram, India.

1.1. Study area

Mizoram is one of the eight States of the North-Eastern part of India and has two major rivers-the Tlawng River and the Chhimtuipui River. Due to its steep and hilly topography, there are many streamlets and small Lakes in the gorges of the hilly areas, the largest of which is the Pala Tipo ('Tipo' meaning Lake in the regional Mara language), also known as Palak dil ('dil' meaning Lake in Lushai) in the remote corner of Siaha District, a region inhabited by the Mara Tribe. Hereon, the Lake will be referred to as Pala Tipo.

The Pala Tipo lies between 22°10′ 44" - 22°13′05″ N and 92°52′50" - 92°55′30" E and it is located in a remote corner in the Southern part of the State in Siaha District. The size of the lake is roughly about 1.35 km^2 with an average depth of about 20 m. The lake and its surrounding forest are officially part of the Pala Wetland Reserve Forest, which covers an estimated 18.5 km^2. It is a natural lake and is believed to be a tectonic lake due to its unusual setting, al-

* Corresponding author.
E-mail address: jayakumar.eco@pondiuni.edu.in (S. Jayakumar).

https://doi.org/10.1016/j.bcab.2019.101474
Received 30 August 2019; Received in revised form 6 December 2019; Accepted 13 December 2019
Available online 19 December 2019
1878-8181/

though no study has validated this hypothesis. A semi-evergreen forest with patches of bamboo brakes covered the hilly gradients surrounding the Lake, prompting the Government of Mizoram to protect this area and eventually declared a Wetland Reserve in 1998 by the Government of India (Forest Department report, Siaha unpublished).

The study area is under the direct influence of the South-West monsoon causing heavy Curtis and McIntosh, 1950; Forest Report, rainfall from May to September and the average rainfall is estimated to be 2540 mm per annum. Winter in this region is dry with temperature varying from 24 °C to 4 °C. Summer is short with temperature between 19 °C to 34 °C and is accompanied or followed by monsoon which is harsh, often causing landslides. The soil is mostly of deep, dark brown to yellowish brown, strongly acidic, clay loam surface and clay sub-surface soils. The soil on the banks of the lake is greyish peat with high water content (Forest Department report, MADC, Siaha).

2. Materials and methods

2.1. Data collection

A quadrat technique was chosen for the floristic study of trees in the area, wherein we laid a 20 × 20 m quadrat randomly all over the reserve forest (Fig. 1). All trees within the quadrat, with ≥30 cm GBH (Girth at Breast Height) were measured at 1.3 m from the ground (Fig. 2). The local/botanical names of the trees measured and their assigned plot number along with their co-ordinates were recorded for each plot. The co-ordinates for each plot were recorded using a Trimble Juno 3B GPS (Global Positioning System). Voucher specimens mainly flowers, fruits, leaves and twigs were also collected during the said flowering season for a period of 1 year which includes 4 seasons.

2.2. Data analysis

Structural composition of the forest was determined by categorizing the tree species into different diameter classes starting from 30-60 cm to <501 cm. Data collected from the plot study was used to calculate the various quantitative indices-frequencies, density, basal area and their IVI index was determined by the sum of relative frequency, relative density and relative dominance (Curtis and McIntosh, 1950). Diversity indices were calculated using the Shannon-Wiener index (H') and Simpson dominant index (Magurran, 2004) as given below:

Shannon- Wiener's index (H')

$$H' = - \sum pi \ln pi$$

where, pi = proportion (n/N) of individuals of one particular species found (n) divided by total number of individuals found (N).

Simpson's index for dominance (1-D)

$$D = \sum (pi)^2$$

where, D = Simpson's index. The range of the D is from 0 to 1, where 0 represents infinite diversity and 1 means no diversity. Simply put, the greater the value of D, the lower the dominance/evenness as Simpson's index takes into account both richness and evenness of a species.

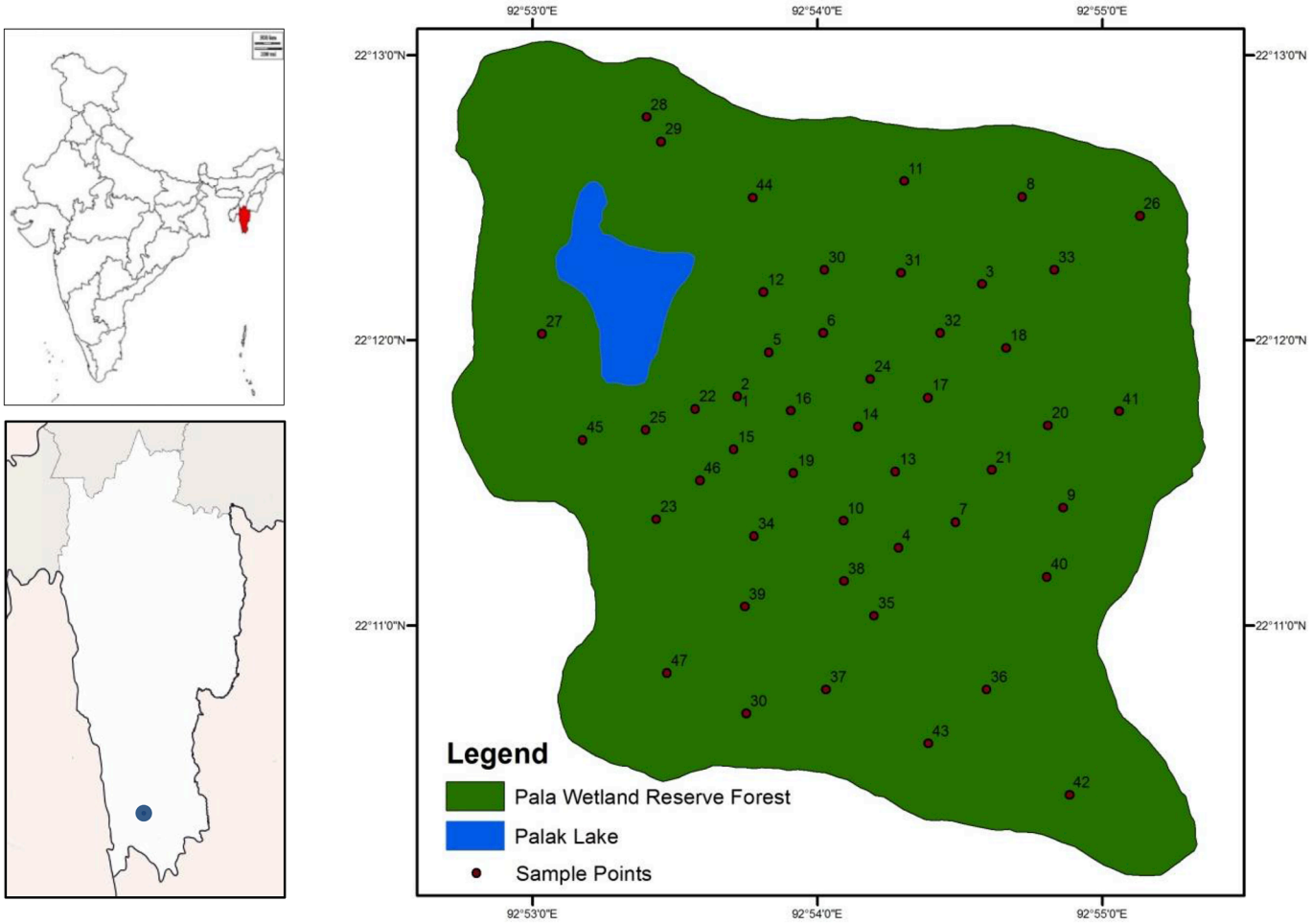

Fig. 1. Demarcation of the pala wetland reserve forest, Mizoram.

Fig. 2. Plot study carried out inside the Pala Wetland Reserve Forest, Mizoram
A,B- Quadrat study; C- Forest area; D- Voucher specimen of *Xerospermum noronhianum*.

3. Results and discussions

3.1. Tree diversity and stand structure

From the 47 random plots made, a total of 995 tree individuals belonging to 65 species of 57 genera and 31 families were recorded from the Pala Wetland Reserve Forest (Table 1).

The diversity of plant species is mostly influenced by anthopogenic and natural disturbances (Rasingam and Parthasarathy, 2009), and the diversity level of a forest site depends on the tree species richness and minimum diameter class of a defined study site (Wattenberg and Breckle, 1995). The number of tree species (65) recorded in our study site when compared with the floristic study done in other semi-evergreen forest in India (Table 2), is closely associated to the inner-line undisturbed forest reserve reported from Assam by Borah and Garkoti (2011) with 69 species. This record is higher than those reported from the forest of Manipur.

(Devi and Yadava, 2006; Vashum and Jayakumar, 2016), Mizoram (Lalfakawma et al., 2009) and South India (Kadavul and Parthasarathy, 1999), but it is contrastingly lower than those reported from the undisturbed Barak Reserve forest, Assam (Borah and Garkoti, 2011), Kholahat Reserve Forest (Borah et al., 2015) and Swer Sacred grooves, Meghalaya (Mishra et al., 2004). According to Putman (1994), diversity of species is highly inclined to the advantages and liability of the environment. The favorable climatic conditions and the sheltering of these forests from excessive anthropogenic intrusions over time could be one of the factors influencing the species richness of these reserve forests (Upadhaya et al., 2003).

Table 1
Summary of the vegetation composition of the Pala Wetland Reserve, Mizoram.

VARIABLES	WETLAND FOREST
No. of plots surveyed	47
Area surveyed (hectares)	1.8
Total number of individuals	995
Density (no. ha $^{-1}$)	552.8
Total number of Species	65
Total number of genus	57
Total number of family	31
Total Basal area (m^2)	107.17
Basal area (m^2/ha)	59.54
Shannon-Weiner index (H′)	3.73
Simpson's index	0.04

3.2. Tree density and basal area

From the 995 tree individuals recorded, the stand density was estimated at 552.8 ha^{-1} which is equivalent to the density reported from the semi-evergreen forest of Assam (Borah et al., 2015), the wet evergreen forest of Arunachal Pradesh (Nath et al., 2005) and the moist deciduous forest in Tripura (Majumdar et al., 2012), all within the range of 336.25–610 ha^{-1}. The basal area for our present study area was calculated at 59.54 m^2/ha which is closer to the 55.3 m^2/ha reported from Little Andaman Island (Rasingam and Parthasarathy, 2009) but lower than that reported from Gibbon Wildlife Sanctuary with 90.29 m^2/ha (Borah et al., 2015). This result is consistent with that reported from the Popa Mountain Park in Myanmar (Htun et al., 2011), where the basal area recorded are distinctly lower than the stand densities recorded, implying the immature state of vegetation owing to past disturbances.

The diameter distribution of trees is often used to represent a forest population structure and the types of curves elucidated will be used for interpreting the vegetation characteristics (Rao et al., 1990). The diameter classes are categorized based on the basal area recorded and the contribution of individuals in the different classes are shown in Fig. 3. The second girth class (61–90 cm) has the highest number of individuals, surpassing the lowest girth class (30–60 cm) which is mainly represented by smaller trees. The well representation of medium to larger tree individuals (61–90 cm) with buttresses could be attributed to the favorable growing condition provided by the adjacent Pala Tipo and possibly the result of an effective managerial conservation by the Forest Department. As for the low contribution of small trees, slow regeneration rates, anthropogenic activities and sampling duration which is post winter for this study must be considered, although further studies are needed to identify the causal factors.

Table 2
Vegetation parameters from the semi-evergreen forests in different parts of India.

REGION	PLOT SIZE (ha)	SPECIES RICHNESS	DENSITY (number/ha)	BASAL AREA (m^2/ha)	SHANNON-WIENER INDEX	SIMPSON DOMINANCE INDEX	REFERENCES
Pala wetland reserve forest, Mizoram	1.8	65	552.8	59.54	3.73	0.04	Present study
Innerline undisturbed reserve, Assam	1.0	69	846	36.88	1.69	0.027	Borah and Garkoti (2011)
Barak reserve forest, Assam	1.0	91	1110	42.12	1.77	0.024	Borah and Garkoti (2011)
Gibbon Wildlife Sanctuary, Assam	0.1	71	286.92	90.29	1.22	0.085	Borah et al. (2015)
Kholahat reserve forest, Assam	0.1	108	416.25	62.49	0.16	0.043	Borah et al. (2015)
Forest near Indo-Myanmar border, Manipur	–	17	685–820	18.9–19.58	0.1094	–	Devi and Yadava (2006)
Hollongapar Gibbon Wildlife Sanctuary, Assam	1.0	75	750	58	3.55	–	Sarkar and Devi (2014)
Swer Sacred grove, Meghalaya	0.15	168	27.6 ± 2.9	26.9 ± 6 1.7	2.2	0.1	Mishra et al. (2004)
Little Andaman Island, India	1.0	83	935	55.3	3.6	0.05	Rashingam and Parthsarathy (2009)
Zobawk Undisturbed forest, Mizoram	1.0	32	–	–	3.1461	–	Lalfakawma et al. (2009)
Kamjong Sub-division primary forest, Manipur	3.0	45–48	1084–3150	33.65–63.99	2.76–3.09	0.9–0.93	Vashum and Jayakumar (2016)
Sanyasimalai reserve forest of Shervarayan hills (SM4), South India	1.0	50	986	44.26	2.37	0.143	Kadavul and Parthasarathy (1999)
Sathyamangalam Tiger Reserve, Tamil Nadu	2,0	90	779	21.6	3.48	0.94	Sathya and Jayakumar (2017)

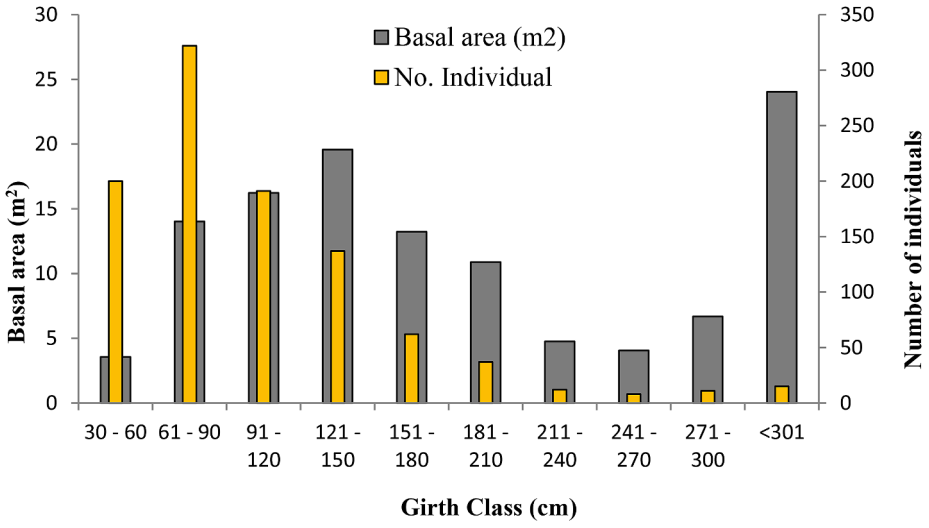

Fig. 3. Distribution of basal area and number of individuals in the different girth classes.

3.3. Diversity and dominance

Biodiversity indices are scales generated to compare the diversity and abundances of different species in different habitats and the higher the value, the greater the species richness (Naidu and Kumar, 2016). The Shannon-Weiner index from our study (3.73) is parallel to those reported from the Sacred Grooves (Upadhaya et al., 2003) and the evergreen forest of Meghalaya (Tynsong and Tiwari, 2011) both within the ranges of 3.42–3.87 indicating the high diversity of the forest (Table 3). These ranges are higher than those semi-evergreen forest recorded (1.16–3.6) in different parts of India.

The Simpson Dominance index for our study was 0.04 which falls under the reported 0.02–0.067 from the tropical forest of Northeast India.

3.4. Abundance, rarity and frequency

The species with maximum abundance was recorded for *Xerospermum noronhianum* with an estimated 5.4 individual per plot, followed by *Litsea laeta* (2.5), *Artocarpus lakoocha* (2.4), *Knima linifolia* (2.4), *Mesua ferrae* (2.1), *Dipterocarpus turbinatus* (2) and *Chisocheton cumingianus* (2). And the species recorded with the minimum abundance of 1 are *Beilschmiedia longifolia, Cantanopsis armata, Carya, Celtis tetranda, Derris robusta, Garcinia spicata, Gmelina arborea, Madhuca indica, Mallotus albus, Protium serratum, Sapindus mukorossi, Streblus asper, Toona ciliata* and *Walsura robusta.*

Sapindus mukorossi and *Garcinia spicata* are the two rare identified species with just 2 individuals each recorded from the 47 plots covering 1.8 ha of the Pala Wetland Reserve Forest.

Xerospermum noronhianum was recorded to be the most dominant species with 214 individuals, followed by *Mesua ferrae* and *Dysoxylym malabaricum* with 59 and 37 individual counts respectively. Family-wise, Meliaceae has the most number of species that includes *Dysoxylum excelsum, Dysoxylum binectariferum, Dysoxylum malabaricum, Chisocheton cumingianus, Chukrasia tabularis, Toona ciliata* and *Walsura robusta* culminating a total of 88 individuals. The dominance of few tree species may be the result of poor drainage or past vegetation damages (Parthasarathy and Karthikeyan, 1997). The disruption of

Table 3
Vegetation parameters from the tropical forest of the Northeastern parts of India.

FOREST TYPE	REGION	PLOT SIZE (ha)	SPECIES RICHNESS	DENSITY (number/ha	BASAL AREA (m^2/ha)	SHANNON-WIENER INDEX	SIMPSON DOMINANCE INDEX	REFERENCES
Wet evergreen forest	Namdapha National Park, Arunachal Pradesh	2.4	50	610	98.58	1.458	0.049	Nath et al., 2005
Sub-tropical broad leaved forest	Ialong and Raliang Sacred Grooves, Jaintia Hills, Meghalaya	1.0	123	938–1476	57.46–71.44	3.42–3.55	0.052–0.067	Upadhaya et al., 2003
Wet evergreen Forest	Deomali forest Division, Arunachal Pradesh	0.5	47	5452	104.60	2.02	0.06	Bhuyan et al., 2003
Moist deciduous forest and moist mixed deciduous forest	Primary Forest from Tripura	17	82–105	336.25–464.77	11.47–26.21	2.75–3.12	0.08–1.13	Majumdar et al. (2012)
Tropical evergreen forest	Pynursla and Siatbakon natural forest, Meghalaya	1	117	1972–2100	52.26–68.05	3.74–3.87	0.02–0.04	Tynsong and Tiwari, 2011Tynsong and Tiwari, 2011

forest succession processes by anthropogenic activities may also favor some species to thrive while selectively removing others (Htun et al., 2011). *Xerospermum* species are widespread in South-east Asia especially over the tropical rainforest regions of Malaysia (Davies et al., 2003), Thailand, Sumatra (Yoneda et al., 2009), Vietnam (Millet and Truong, 2011), Myanmar (Boonsuk and Chantaranothai, 2018) and Cambodia (Theilade et al., 2011). In India, the species of *X. noronhianum,* also recorded as *X. glabratum* in some studies was recorded from the states of Meghalaya (Jamir and Pandey, 2003; Mylliemngap et al., 2016), Assam (Deb and Sundriyal, 2007; Barbhuiya, 2014) and Mizoram (Nohro et al., 2019). Locally it is called Zima and based on the sizes of the fruit they are called Zima rahpa and Zima saihpa, although both are of the same species when cross-examined with the herbariums available on the Kew herbarium catalogue online. Based on pre-existing literatures on the plants of Mizoram, this particular species has only been reported from the Pala wetland reserve (Nohro et al., 2019) which is situated in the southern part of the State. The topography and vegetation of the study area which is dominated by *Xerospermum* and *Dipterocarpus* among others, is somewhat similar to those forest reported from parts of South-east Asia where these two species seemed to thrive well together (Okuda et al., 1997; Chua et al., 2000; Millet and Truong, 2011; Kar et al., 2018). The tiny fruits of *X. noronhianum* are traditionally used to cure severe stomach pains and its medicinal potentials are also being studied (Jean et al., 2009).

The top ten dominant species along with their enumerated basal area and IVI index is shown in Table 4.

4. Conclusions

The Pala wetland reserve forest is diverse in terms of species richness, diversity, and structure. We have recorded 65 species of 57 families and 31 genera based on the plot study, covering 1.8 ha of the study area. The total basal area (m^2/ha) of the 995 tree individuals was estimated at 59.54 (m^2/ha) and the Shannon and Simpson index were 3.73 and 0.04 respectively. This study entails the first record of *X. noronhianum* from the State of Mizoram and it is also the most dominant species with 214 individuals and the least dominant species are *Sapindus mukorossi* and *Garcinia spicata* with just 2 tree individuals each from the 47 plots laid out.

The study shows a normal forest growth structure except for the low contribution of smaller girth class trees which could be due to various factors such as anthropogenic activities and slow regeneration rate of tree species. A further study is needed to identify the causal factor in order to maintain and conserve the wetland forest.

Table 4
Top ten dominant species in the Pala Wetland Reserve, Mizoram, India.

SPECIES	NUMBER OF INDIVIDUAL	BA	IVI
Xerosperma noronhianum Blume	214	32.69	58.66
Mesua ferrae L	59	4.32	14.4
Dysoxylym malabaricum Blume	37	1.77	9.17
Knema linifolia (Roxb). Warb	33	1.7	7.12
Dipterocarpus turbinatus C. F. Gaertner	36	2.1	8.43
Neolamarckia cadamba (Roxb.) Bosser	20	0.67	4.69
Pterospermum lancifolium Roxb.	20	1.27	5.89
Bombax ceiba L.	19	1.63	5.65
Lagerstroemia parviflora Roxb.	19	1.64	5.02
Mimusops elengi L.	19	1.72	5.57

Declaration of competing interest

None.

Acknowledgements

We would like to thank the District Conservator of Forest (DCF) and all the Foresters working under the Forest and Environment Department, Mara Autonomous District Council (MADC), Siaha, Mizoram, for providing us with the necessary guide and accommodation during the field work. We also thank the University Grant Commission, Government of India, for awarding the National Fellowship for ST students (vide no: F117.1/201516/NFST201517STMIZ2847/(SAIII/Website) which greatly helped and provided the opportunity to explore new areas for this research. We also thank our field assistants Lameka and Beirachopaw for their help during field work.

References

Anbarashan, M., Parthasarathy, N., 2013. Tree diversity of tropical dry evergreen forests dominated by single or mixed species on the Coromandel coast of India. Trop. Ecol. 54 (2), 179–190.
Ayyappan, A., Parthasarathy, N., 1999. Biodiversity inventory of trees in a large scale permanent plot of tropical evergreen forest at Varagalaiar, Anamalais, Western Ghats, India. Biodivers. Conserv. 8, 1533–1554.
Barbhuiya, H.A., 2014. Forty new additions to the angiospermic flora of Assam, India. J. New Biol. Rep. 3 (3), 270–280.
Behera, M.D., Kushwaha, S.P.S., Roy, P.S., Srivastava, S., Singh, T.P., Dubey, R.C., 2002. Comparing structure and composition of coniferous forests in Subansiri district, Arunachal Pradesh. Curr. Sci. 82 (1), 70–76.
Bhuyan, P., Khan, M.L., Tripathi, R.S., 2003. Tree diversity and population structure in undisturbed and human-impacted stands of tropical wet evergreen forest in Arunachal Pradesh, Eastern Himalayas, India. Biodivers. Conserv. 12, 1753–1773.
Boonsuk, B., Chantaranothai, P., 2018. Lectotypifications in nephelium L. And Xerospermum blume (sapindaceae). Kew Bull. 73, 15.
Borah, M., Das, D., Kalita, J., Boruah, H.P.D., Phukan, B., Neog, B., 2015. Tree species composition, biomass and carbon stocks in two tropical forest of Assam. Biomass Bioenergy 78, 25–35.
Borah, N., Garkoti, S.C., 2011. Tree Species composition, diversity, and regeneration patterns in undisturbed and disturbed forests of Barak Valley, South Assam, India. Int. J. Ecol. Environ. Sci. 37, 131–141.
Chua, L.A.S.L., Kamarudin, S., Damahuri, S., 2000. A preliminary checklist of seed plants of the belum forest reserve, perak, peninsular Malaysia. Malay. Nat. J. 54 (3),

171–186.
Curtis, J.T., McIntosh, R.P., 1950. The interrelation of certain analytic and synthetic phytosociological characters. Ecology 31, 434–455.
Davies, S.J., Nur Supardi, M.N., LaFrankie, J.V., Ashton, P.S., 2003. The trees of Pasoh forest: stand structure and floristic composition of the 50-ha forest research plot. In: Okuda, T., Manokaran, N., Matsumoto, Y., Niiyama, K., Thomas, S.C., Ashton, P.S. (Eds.), Pasoh: Ecology of a Lowland Rain Forest in Southeast Asia. Springer, Tokyo, pp. 35–50.
Deb, P., Sundriyal, R.C., 2007. Tree species gap phase performance in the buffer zone area of Namdapha National Park, Eastern Himalaya, India. Trop. Ecol. 48 (2), 209–225.
Devi, L.S., Yadava, P.S., 2006. Floristic diversity assessment and vegetation analysis of tropical semi evergreen forest of Manipur, north east India. Trop. Ecol. 47 (1), 89–98.
Devi, N.L., Singha, D., Tripathi, S.K., 2018. Tree species composition and diversity in tropical moist forests of Mizoram, northeast India. Indian J. Ecol. 45 (3) 454-46.
Dutta, G., Devi, A., 2013. Plant diversity and community structure in tropical moist deciduous sal (Shorea robusta Gaertn.) forest of Assam, northeast India. J. Environ. Appl. Biores. 1 (3), 1–4.
FAO, 2015. Global Forest Resources Assessment 2015. UN Food and Agriculture Organization, Rome.
Forest Report. Forest and Environment Department, Mara Autonomous District Council (MADC), (Siaha District, Mizoram).
Gopalakrishna, S.P., Kaonga, M.L., Somashekar, R.K., Suresh, H.S., Suresh, R., 2015. Tree diversity in the tropical dry forest of bannerghatta national Park in eastern ghats, southern India. Eur. J. Ecol. 1 (2), 12–27.
Gordon, J.E., Newton, A.C., 2006. The potential misapplication of rapid plant diversity assessment in tropical conservation. J. Nat. Conserv. 14, 117–126.
Hare, M.A., Lantagne, D.O., Murphy, P.G., Chero, H., 1997. Structure and tree species composition in a subtropical dry forest in Dominican Republic: comparison with a dry forest in Puerto Rico. Trop. Ecol. 38, 1–17.
Hitimana, J., Kiyiapi, J.L., Njunge, J.T., 2004. Forest structure characteristics in disturbed and undisturbed sites of Mt. Elgon moist lower montane forest, western Kenya. For. Ecol. Manag. 194, 269–291.
Htun, N.Z., Mizoue, N., Yoshida, S., 2011. Tree species composition and diversity at different levels of disturbance in Popa mountain Park, Myanmar. Biotropica 43 (5), 597–603.
Hubbell, S.P., Foster, R.B., 1983. Diversity of canopy trees in a neotropical forest and implication for conservation. In: Sutton, S.L., Whitmore, T.C., Chadwick, A.C. (Eds.), The Tropical Rain Forest: Ecology and Management. Blackwell, Oxford, pp. 25–41.
Jamir, S.A., Pandey, H.N., 2003. Vascular plant diversity in the sacred groves of Jaintia Hills in northeast India. Biodivers. Conserv. 12, 1497–1510.
Jayakumar, S., Kim, S.S., Heo, J., 2011. Floristic inventory and diversity assessment – a critical review. In: Proceedings of the International Academy of Ecology and Environmental Sciences, 1. pp. 151–168.
Jayakumar, S., Ramachandran, A., Heo, J., 2009. Comparison of floristic diversity of evergreen forest inferred from different sampling approaches in the Eastern Ghats of Tamil Nadu, India. Curr. Sci. 96 (4), 575–581.
Jean, T.P., Shaari, K., Paet, C., Ismaila, I.S., Abasa, F., Lajis, N.H., Ahmad, V.U., 2009. Bidesmosidic oleanane saponins from Xerospermum noronhianum. Helv. Chim. Acta 92, 1973–1981.
Kadavul, K., Parthasarathy, N., 1999. Plant biodiversity and conservation of tropical semi-evergreen forest in the Shervarayan hills of Eastern Ghats, India. Biodivers. Conserv. 8, 421–439.
Kar, A., Boruah, D., Goswami, N.K., Saharia, D., 2018. Angiospermic flora of borail Wildlife sanctuary (BWS) in Assam, India : first report. Pleione 12 (2), 193–207.
Keenan, R.J., Reams, G.A., Achard, F., de Freitas, J.V., Grainger, A., Lindquist, E., 2015. Dynamics of global forest area: results from the FAO global ForestResources assessment 2015. For. Ecol. Manag. 252, 9–20.
Khumbongmayum, A.D., Khan, M.L., Tripathi, R.S., 2006. Biodiversity conservation in sacred groves of Manipur, northeast India: population structure and regeneration status of woody species. Biodivers. Conserv. 15, 2439–2456.
Krishnamurthy, Y.L., Prakasha, H.M., Nanda, A., Krishnappa, M., Dattaraja, H.S., Suresh, H.S., 2010. Vegetation structure and floristic composition of tropical dry deciduous forest in Bhadra Wildlife Sanctuary, Karnataka, India. Trop. Ecol. 1 (2), 235–246.
Lalfakawma, Sahoo, U.K., Roy, S., Vanlalhriatpuia, K., Vanlalhluna, P.C., 2009. Community composition and tree population structure in undisturbed and disturbed tropical semi-evergreen forest stands of North-east India. Appl. Ecol. Environ. Res. 7 (4), 303–318.
Magurran, A.E., 2004. Measuring Biological Diversity. Hoboken (NJ). Blackwell Publishing, USA.
Majumdar, K., Shankar, U., Datta, B.K., 2012. Tree species diversity and stand structure along major community types in lowland primary and secondary moist deciduous forests in Tripura, Northeast India. J. For. Res. 23 (4), 553–568.
May, R.M., Stumpf, M.P.H., 2000. Species–area relationships in tropical forests. Science 290, 2084–2086.
Millet, J., Truong, L.H., 2011. Assessment of the diversity and distribution of the threatened tree species in a logged forest in Vietnam. Trop. Conserv. Sci. 4 (1), 82–96.
Mishra, B.P., Tripathi, O.P., Tripathi, R.S., 2004. Effects of anthropogenic disturbance on plant diversity and community structure of a sacred grove in Meghalaya, northeast India. Biodivers. Conserv. 13, 421–436.
Mittermeier, R.A., Gil, P.R., Hoffmann, M., Pilgrim, J., Brooks, T., Mittermeier, C.G., Lamoreux, J., Fonseca, G.A.B., 2005. Hotspots Revisited: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions. CEMEX/Agrupacio´n Sierra Madre, p. 432.
Mylliemngap, W., Nath, D., Barik, S.K., 2016. Changes in vegetation and nitrogen mineralization during recovery of a montane subtropical broadleaved forest in North-eastern India following anthropogenic disturbance. Ecol. Restor. 31, 21–38.
Naidu, M.T., Kumar, O.A., 2016. Tree diversity, stand structure, and community composition of tropicalforests in Eastern Ghats of Andhra Pradesh, India. J. Asia Pac. Bus. 9, 328–334.
Naidu, M.T., Premavani, D., Suthari, S., Venkaiah, M., 2018. Assessment of tree diversity in tropical deciduous forests of Northcentral Eastern Ghats, India. Geol., Ecol. Landsc. 2, 216–227.
Nath, P.C., Arundachalam, A., Khan, M.L., Arunachalam, K., Barbhuiya, A.R., 2005. Vegetation analysis and tree population structure of tropical wet evergreen forests in and around Namdapha National Park, northeast India. Biodivers. Conserv. 14, 2109–2136.
Nohro, S., Bera, S.K., Jayakumar, S.. https://doi.org/10.1080/01916122.2018.1557273.
Okuda, T., Kachi, N., Yap, S.K., Manokaran, N., 1997. Tree distribution pattern and fate of juveniles in a lowland tropical rain forest – implications for regeneration and maintenance of species diversity. Plant Ecol. 131, 155–171.
Parthasarathy, N., Karthikeyan, R., 1997. Plant biodiversity inventory and conservation of two tropical dry evergreen forests on the Coromandel coast, south India. Biodivers. Conserv. 6, 1063–1083.
Parthasarathy, N., 2001. Changes in forest composition and structure in three sites of tropical evergreen forests around Sengaltheri, Western Ghats. Curr. Sci. 80, 389–393.
Philips, O.L., Gentry, A.H., 1994. Increasing turnover through time in tropical forests. Science 263, 954–958.
Pragasan, L.A., Parthasarathy, N., 2010. Landscape-level tree diversity assessment in tropical forests of southern Eastern Ghats, India. Flora (205), 728–737.
Premavani, D., Naidu, M.T., Venkaiah, M., 2014. Tree species diversity and population structure in the tropical forests of North central eastern ghats, India. Not. Sci. Biol. 6 (4), 448–453.
Putman, R.J., 1994. Community Ecology. Chapman and Hall, New York.
Rao, P., Barik, S.K., Pandey, H.N., Tripathi, R.S., 1990. Community composition and tree population structure in a sub-tropical broad-leaved forest a disturbance gradient. Vegetatio 88, 151–162.
Rasingam, L., Parthasarathy, N., 2009. Tree species diversity and population structure across major forest formations and disturbance categories in Little Andaman Island, India. Trop. Ecol. 50, 89–102.
Reddy, C.S., Babar, S., Amarnath, G., Pattanaik, C., 2011. Structure and floristic composition of tree stand in tropical forest in the Eastern Ghats of Andhra Pradesh, India. J. For. Res. 22 (4), 491–500.
Sagar, R., Raghubanshi, A.S., Singh, J.S., 2003. Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. For. Ecol. Manag. 186, 61–71.
Sahoo, U.K., Rocky, P., 2015. Species composition and plant diversity as influenced by altitude and size of homegardens in Mizoram, North-East India. J. Ecol. Environ. Sci. 41, 3–4.
Sahu, S.C., Dhal, N.K., Mohanty, R.C., 2012. Tree species diversity, distribution and population structure in a tropical dry deciduous forest of Malyagiri hill ranges, Eastern Ghats, India. Trop. Ecol. 53 (3), 163–168.
Sarkar, M., Devi, A., 2014. Assessment of diversity, population structure and regeneration status of tree species in Hollongapar Gibbon Wildlife Sanctuary, Assam, Northeast India. Trop. Plant Res. 1 (2), 26–36.
Sathish, B.N., Viswanath, S., Kushalappa, C.G., Jagadish, M.R., Ganeshaiah, K.N., 2013. Comparative assessment of floristic structure, diversity and regeneration status of tropical rain forests of Western Ghats of Karnataka, India. J. Appl. Nat. Sci. 5 (1), 157–164.
Sathya, M., Jayakumar, S., 2017. A contemporary assessment of tree species in Sathyamangalam Tiger Reserve, Southern India. Proc. Int. Acad. Ecol. Environ. Sci. 7 (2), 30–46.
Strasberg, D., 1996. Diversity, size composition and spatial aggregation among trees on a 1ha rain forest plot at La Reunion. Biodivers. Conserv. 5, 825–840.
Sundriyal, R.C., Sharma, E., 1996. Anthropogenic pressure on tree structure and biomass in the temperate forest of Mamlay watershed in Sikkim. For. Ecol. Manag. 81, 113–134.
Theilade, I., Schmidt, L., Chhang, P., McDonald, J.A., 2011. Evergreen swamp forest in Cambodia: floristic composition, ecological characteristics, and conservation status. Nord. J. Bot. 29, 7180.
Tynsong, H., Tiwari, B.K., 2011. Diversity and population characteristics of woody species in natural forests and arecanut agroforests of south Meghalaya, Northeast India. Tropical Ecology 52 (3), 243–252.
Upadhaya, K., Pandey, H.N., Law, P.S., Tripathi, R.S., 2003. Tree diversity in sacred groves of the Jaintia hills in Meghalaya, northeast India. Biodivers. Conserv. 12, 583–597.
Vashum, K.T., Jayakumar, S., 2016. Impact of Slash and Burn Cultivation on Floristic Diversity, Soil and Tribal Communities in Kamjong Sub-division, Manipur, India PhD Thesis. submitted to Pondicherry Central University, Puducherry.
Wattenberg, I., Breckle, S., 1995. Tree species diversity of a premontane rain forest in the Cordillera de Tilaren, Costa Rica. Biotropica 1, 21–30.
Yoneda, T., Nishimura, S., Fujii, S., Mukhtar, E., 2009. Tree guild composition of a hill dipterocarp forest in West Sumatra, Indonesia. Tropics 18, 143–153.