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Stand Structure, Regeneration Potential and Biomass Carbon Stock of Subtropical Forest of Mizoram, Northeast India

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Abstract: The present study deals with tree community attributes such as species diversity, composition, population structure and biomass carbon stock (above- and below ground) of subtropical forest of Lalsavunga Park, Mizoram, Northeast India. A total of 41 tree species (37 genera and 29 families) were recorded from the study area. Moraceae was the most dominant family contributing 10% of the total family recorded in the area. The dominant species were *Engelhardia spicata, Litsea cubeba*, *Macaranga peltata*, *Nyssa javanica* and *Schima wallichi.* These dominant species together contributed 60% of the total species in the forest area. The total tree density (individuals ha^{-1}) and basal area (m^2 ha^{-1}) in the forest was 784 and 53.36 respectively. The diversity indices such as Shannon diversity index and Simpson dominance index were 3.48 and 0.04 respectively. The present study showed that 37% of the species exhibited good regeneration whereas 17% of species exhibited poor regeneration. About 80% of the plant species followed clumped distribution pattern in the study area. The total tree biomass and carbon stock recorded in the present study were 314 Mg ha^{-1} and 147.53 Mg C ha^{-1}, respectively. Young trees (belonging to 10 – 60 cm girth class) contributed 41% of the total tree biomass. The findings of the present study will serve as baseline information that can be used by forest managers and policy makers to develop strategies for conservation, climate mitigation by enhancing vegetation carbon stock and sustainable use of forest resources of Mizoram, Northeast India.

Keywords: Tree diversity, Species composition, Regeneration, Biomass, Carbon stock

Climate change has become a major concern for global leaders, scientists and citizens due to increasing of greenhouse gases and rapid rise in temperature. For instance, the atmospheric CO_2 concentration has increased to over 50% from the pre-industrial era (i.e. 280 ppm) to current level of 420 ppm (Alli et al 2023). Thus, the rapid increase of CO_2 in the atmosphere can be mitigated by reducing carbon emission and increasing carbon sink in the biosphere through carbon sequestration in plant biomass and the soil (Mahajan et al 2023). Tropical forests are one of the important components of terrestrial biosphere as it represents ~40% of the total terrestrial biomass carbon stock and 30-50% terrestrial productivity (Pan et al 2011). These forests are the living biomass of both trees and understory vegetation and contain high carbon storage in dead mass of woody litters, debris and soil organic matter (Pillay et al 2021, Zuleta et al 2023). However, despite high carbon storage potential and rich biodiversity, tropical forests are facing high anthropogenic activities, which lead to alter forest structure, create mosaic landscape and set the initial condition for succession dynamics and structural development of these forests (Chen et al 2018). According to FAO and UNEP (2020), estimated global deforestation rate of 10.3 M ha yr^{-1} is responsible for the release of carbon stored in trees biomass to the atmosphere. Nevertheless, tropical forest has a high carbon storage potential than any other land covers and thus this land use has been the primary focus for scientific research and also gaining importance on carbon stock studies.

The Northeast region of India is consisting of eight states with a total geographic area of 26.2 million hectares, which can be physio graphically categorized as Eastern Himalaya and the plains of Barak valley. The region is identified as one of the biodiversity hotspots based on the high number of endemic species and the degree of threat to the biodiversity of the area (Ao et al 2023). Out of 68 million hectares of India's forest cover, the Northeastern region signifies approximately 17 million hectares which is one-fourth of the total forest cover of India (Joshi 2020). The tropical and subtropical forest of Mizoram is one of the largest biodiversity in India with a total record of 2358 plant species of which 2141 species belongs to angiosperm class distributed over 176 families and 905 genera where about two-third of plant species are dicots and one-third monocots (Singh 1997). Furthermore, it has also been reported that about 500 species recorded from the state forest has ethno medicinal properties (Devi et al 2018). However, the tropical forest of Mizoram has undergone an abrupt land transformation due to existing agricultural practices like shifting cultivation, tree felling for timber, fuel wood and cutting of hills for road constructions resulting to degradation of natural forest. The present study was carried out in the tropical forest of Lalsavunga park in Aizawl district of Mizoram with an aim to characterize the tree species composition, diversity and regeneration potential along with biomass carbon stock within tree community and its role in climate change mitigation.

MATERIAL AND METHODS

Study area: The Lalsavunga Park is located in the South Hlimen regions, in Aizawl district of Mizoram, Northeast India. It is located between 23°39'59.01" N latitude and 92°43'13.05" E longitude. The park is distributed in about 51 ha of land in the vicinity of the Aizawl. The area is a hilly landscape which is situated at an elevation between 1000 and 1200 meters above mean sea level. The study area has a diverse landscape with rich floristic diversity and provides habitat to large number of mammalians, birds and invertebrates. The park also provides various ecological services to the society such as improving air and water quality, protecting groundwater and providing a place to connect with nature. The area is largely constituted by Tertiary rocks of Bhuban sub group and the rocks are covered by an uneven layer of soil which is composed mainly of alternate thinly bedding shale (Beingachhi and Vanlalhmangaihsangi 2017). The park is composed of thick natural vegetation of subtropical evergreen forest with an average annual rainfall of 2500 mm. The mean minimum and maximum temperature varies from 17°C in winter and 27°C in summer season.

Sampling design: The present study was conducted during February-March 2020 following random sampling method. Tree species composition and population structure were assessed by establishing forty randomly located plots (10 x 10 m) within the park. Species regeneration status was determined based on population size of seedling, sapling and adult trees. All the individuals ≥10 cm (GBH) were considered as woody species, whereas individuals with girth ≥3 and ≤10 cm girth with >10 cm height were considered as saplings and individuals with <3 cm girth and upto 10 cm height were considered as seedlings. The girth of trees at breast height (1.37 m) was measured using a measuring tape. The specimens were collected and identified with the help of regional floras (Hooker 1872-1897, Kanjilal et al 1934-1940) and Botanical Survey of India, Eastern Regional Circle, Shillong, Meghalaya. The herbarium was prepared following Jain and Rao (1977) and deposited in the in the Mizoram University.

Data analysis: The vegetation parameters such as frequency, density, basal area, dominance and the Important Value Index (IVI) of species were quantatively analyzed by following the formula given by Misra (1968). The Importance Value Index of tree species was determined by summing up the values of relative frequency, relative density and relative dominance (Curtis and McIntosh 1950). To understand the population dynamics of species in the study area, the recorded individuals were categorized into eight girth classes (10-30 cm, 30-60 cm, 60-90 cm, 90-120 cm, 120-150 cm, 150-180 cm, 180-210 cm). Regeneration status of each individual species was studied based on the size of population of seedling, sapling, and adult trees (Khumbongmayum et al 2006). The regeneration is considered as good, if seedlings > or < saplings > adults; fair, if seedlings > or ≤ saplings ≤ adults; poor, if the species survives only in sapling stage, but no seedlings (saplings may be <, > or = adults); none if a species survives only in adult stage and new regeneration if a species is present only in seedling and sapling stage but no adults. The distribution pattern of species in the forest was determined by following Whitford's index (Whitford, 1948).

Tree species diversity: The diversity of tree species was measured by Shannon-Weiner diversity index (H') proposed by Shannon and Weaver (1963). It basically assumes that all species are represented in a sample and they are randomly sampled.

$$H' = -\sum pi \; ln \; pi \quad (1)$$

where, pi = the proportion of density of the i-th species ($pi = ni/N$), ni is the density of i-th species and N is the density of all the species.

Concentration of dominance (CD) of trees was estimated using the formula given by Simpson's index (1949). It reflects the probability of any two individuals drawn at random from an infinitely large community belonging to the same species.

$$CD = \sum (pi)^2 \quad (2)$$

The evenness refers to the degree of the relative dominance of each species in the forest. It was calculated according to Pielou (1966).

$$\text{Evenness (e)} = H'/ \; ln \; S \quad (3)$$

Where, H'= Shannon index of diversity, S= Number of species in the community

The species richness was calculated using Margalef species richness index (Dmg) (Margalef 1958)

$$Dmg = S\text{-}1/ \; ln \; N \quad (4)$$

Where, S = the number of species, N = Number of individuals

Total biomass (aboveground) of trees was estimated using the allometric equation developed for different forest types in Northeast India by Nath et al (2019)

$$AGB_{est} = 0.32 \, (D^2 H\delta)^{0.75} \times 1.34 \quad (5)$$

Where, D is the DBH, H denotes the height of the tree and δ as specific wood gravity

Belowground biomass was estimated by using the equation developed by Cairns et al (1997)

$$BGB = \exp[-1.085 + 0.9256 \times \ln(AGB)] \quad (6)$$

The total C stock of trees was calculated by the sum of AGB and BGB by assuming that the carbon content 47% of the total biomass (Martin and Thomas 2011)

RESULT AND DISCUSSION

Floristic diversity and composition: A total of 41 species belonging to 37 genera and 29 families were recorded from the subtropical forest of Lalsavunga park, Mizoram, Northeast India (Table 1). Most of the tree species (over 90%) recorded in the present study was indigenous. The Moraceae family was the most dominant family contributed 10% of the total number of species followed by Anacardiaceae, Euphorbiaceae, Lamiaceae, Lauraceae, Leguminosae, Magnoliaceae, Rutaceae and Styracaceae, each contributed 5% of the total number species and the other families were represented by a single species. The number of tree species recorded in the present study can be compared to tree species recorded from the tropical forest of Northeast India such as Bhuban hills of Southern Assam (Borah et al 2013, 49 species), subtropical forest of Manipur (Meetei et al 2017, 43 species) and Rowa Wildlife Sanctuary, Tripura (Debnath et al 2021, 44 species). However the tree species richness of the present study was found to be lower as compared to tree species recorded by various researchers in other tropical forest in India (Selvan 2014, 62 species, Joshi 2020, 71 species, Ao et al 2020, 60 species, Dash et al 2021, 60 species). Existing anthropogenic pressures such as agriculture expansion, tree feeling for timber, stone quarry and forest fire has taken a toll in the species richness of the park and may likely result to reduction of species in the community and change in forest structure, if no proper management of the park in ecological perspective is adopted (Tripathi et al 2016, Wapongnunsang et al 2020). The presence of high diversity of woody species in the present study suggests the result of successional process in the forest (Naidu et al 2021). Based on Important Value Index (IVI), the dominant species were *Schima wallichii* (44.30), *Engelhardia spicata* (23.01), *Macaranga peltata* (18.14), *Nyssa javanica* (11.76) and *Litsea cubeba* (10.71). These species together contributed over one-third of the total IVI of the tree community (Table 2).

Table 1. Phytosociological attributes, biomass and carbon stock of Lalsavunga Park, Mizoram

Parameters	Value
Number of species	41 ± 0.32
Number of genera	37 ± 0.29
Number of family	29 ± 0.28
Density (individuals ha^{-1})	784 ± 2.67
Basal area ($m^2 ha^{-1}$)	53.36 ± 3.45
Shannon wiener index (H')	3.48 ± 0.04
Simpson index (CD)	0.04 ± 0.02
Margalef species richness index (Dmg)	7.58 ± 0.09
Evenness index (e)	0.94 ± 0.03
AGB (Mg ha^{-1})	256.64 ± 2.94
BGB (Mg ha^{-1})	57.26 ± 0.71
TBC (Mg ha^{-1})	147.53 ± 1.35
Elevation	1179 m
Latitude	23°39'59.01" N
Longitude	92°43'13.05" E

The total tree density and basal area in the present study were 784 individuals ha^{-1} and 53.4 $m^2 ha^{-1}$, respectively. The tree density recorded in the present study was found to be similar with the tree density value (245-1620 individuals ha^{-1}) recorded from the tropical and subtropical forest of Northeast India as reported by various workers (Nohro and Jayakumar 2020, Joshi 2020, Suchiang et al 2020). Similarly the basal area recorded at the present study was comparable with the basal area value reported for various natural forests in tropical and subtropical regions in the country (Meena et al 2019, Bhat et al 2020, Sajad et al 2021). According to Vospernik (2021), forest trees in a natural habitat exhibits a large variations in basal area increment, which majorly depends on three key factors (a) tree specific factor (b) inter-tree relations (c) the environment. Wright et al (2018) also stated that basal area value could also be influenced by the level of stand disturbance in the forest.

An estimation of plant diversity indices in a forest community reveals the diversity patterns and abundance of species in the region (Shen et al 2016). The Shannon-Wiener diversity index (H') and Simpson dominance index (CD) recorded in the present study were 3.48 and 0.04, respectively (Table 1). According to Spies (2004) high diversity value and low dominance is the characteristic feature of any natural forest which is also supported by our findings. The Shannon-Wiener diversity index for tropical forest of Indian subcontinent ranges from 0.80-4.15 (Lynser and Tiwari 2015, Shaheen et al 2015, Suchiang et al 2021) where the present value recorded (3.48) is well within the range reflecting high tree species diversity in the community. Similarly, the Simpson index (0.04) recorded from the present study is also well within the range (0.03-0.09) for different Indian forest reported by various workers (Kushwaha and Nandy 2012, Akash et al 2018, Naidu et al 2018, Ao et al 2021).

Table 2. Tree species density (individual ha^{-1}), basal area (m^2ha^{-1}), important value index (IVI) and regeneration status of Lalsavunga Park, Mizoram

Family	Species name	Density	Basal area	IVI	Regeneration
Aceraceae	*Acer oblongum* Wall. ex DC.	16	0.58	6.18	P
Rutaceae	*Aegle marmelos* (L.) Correa	20	0.15	5.12	P
Mimosaceae	*Albizia chinensis* (Osbeck) Merr.	16	0.62	4.73	G
Combretaceae	*Anogeissus acuminata* (Roxb. ex DC.) Guill.	16	0.66	6.34	G
Phyllanthaceae	*Aporosa octandra* (Buch.-Ham. ex D. Don) Vickery	12	1.37	5.63	G
Moraceae	*Artocarpus heterophyllus* Lam.	4	0.62	2.43	N
Styracaceae	*Bruinsmia polysperma* (C.B.Clarke) Steenis	16	1.66	7.45	P
Verbenaceae	*Callicarpa arborea* Roxb.	24	1.78	9.45	G
Theaceae	*Camellia sinensis* (L.) Kuntze	16	0.20	5.46	F
Fagaceae	*Castanopsis indica* (Roxb. ex Lindl.) A.DC.	4	1.19	3.49	G
Rutaceae	*Citrus spp.*	12	0.59	4.92	P
Papilionaceae	*Dalbergia spp.*	36	0.52	8.63	F
Leguminosae	*Derris robusta* (DC.) Benth.	12	0.52	3.28	G
Juglandaceae	*Engelhardia spicata* Lesch. ex Blume	12	10.24	23.01	G
Leguminosae	*Erythrina variegata* Lam.	12	0.70	5.13	F
Moraceae	*Ficus auriculata* Lour.	20	1.26	6.45	G
Moraceae	*Ficus elastica* Roxb. ex Hornem.	20	0.33	5.47	N
Moraceae	*Ficus acuminata* Roxb.	36	1.23	9.96	F
Lamiaceae	*Gmelina oblongifolia* Roxb.	28	1.11	9.46	F
Rubiaceae	*Haldina cordifolia* (Roxb.) Ridsdale	4	0.37	1.96	G
Araliaceae	*Heteropanax fragrans* (Roxb.) Seem.	40	0.29	8.71	G
Iteaceae	*Itea macrophylla* Wall.	12	0.18	4.15	G
Lythraceae	*Lagerstroemia speciosa* (L.) Pers.	12	0.73	5.19	F
Oleaceae	*Ligustrum robustum* (Roxb.) Blume	20	0.51	7.32	P
lauraceae	*Litsea cubeba* (Lour.) Pers.	32	0.28	10.71	G
lauraceae	*Litsea lteodaphne* (Nees) Hook. f.	12	0.23	3.49	P
Euphorbiaceae	*Macaranga peltata* (Roxb.) Müll.Arg.	60	2.34	18.14	G
Magnoliaceae	*Magnolia champaca* (L.) Baill. ex Pierre	24	0.30	8.21	G
Magnoliaceae	*Magnolia schiedeana* Schltl.	12	0.01	2.31	F
Anacardiaceae	*Mangifera sylvatica* Roxb.	8	0.25	3.02	N
Cornaceae	*Nyssa Javanica* (Blume) Wangerin	28	2.33	11.76	P
Euphorbiaceae	*Phyllanthus emblica* L.	8	0.06	1.90	F
Lamiaceae	*Premna racemosa*Wall. ex Schauer	20	0.43	4.88	G
Rosaceae	*Prunus cerasoides* D. Don	16	1.59	6.54	N
Gesneriaceae	*Rhynchotechum ellipticum* (Wall. ex D. Dietr.) A. DC.	24	0.12	4.81	G
Theaceae	*Schima wallichii* Choisy	64	14.80	44.30	G
Bignoniaceae	*Spathodea campanulata* P.Beauv.	20	1.27	6.47	N
Anacardiaceae	*Spondias pinnata* (L.f.) Kurz.	4	0.73	2.65	N
Styracaceae	*Styrax serrulatus* Roxb.	4	0.32	1.87	N
Myrtaceae	*Syzygium cumini* (L.) Skeels	16	0.22	4.75	G
Ulmaceae	*Trema orientalis* (L.) Blume.	12	0.68	4.33	F
	Total	784	53.4	300	

*G=Good regeneration, *F=Fair regeneration, *P=Poor regeneration, *N=No regeneration

Population structure: The tree density and basal area varied in different girth classes. However, majority (over 90%) of the total tree density was contributed by lower to middle girth classes of 10-90 cm showing high dominance of young individuals in the area (Fig. 1). Similarly tree basal area was recorded highest in 10-90 cm girth class which together contributed 54% of the total basal area of the tree community. The contribution of older tree density was only 6% where only three individuals were recorded each from girth class 120-150, 150-180 and 180-210 cm. However, the distribution of tree basal area in higher girth classes was almost evenly distributed. Tree basal of 5.08, 3.52, 6.12 and 9.52 $m^2 ha^{-1}$ represented girth class of 90 – 120, 120 – 150, 150 – 180 and 180 – 210 cm, respectively (Fig. 1). The overall population structure showed a reverse *J*-shaped population curve indicating a good forest health and high species richness in the area.

Regeneration status: The study showed that density (individuals ha^{-1}) of seedling was highest (5800) followed by sapling (1456) and trees (784). The maximum species (37% of the total species) exhibited good regeneration followed fair regeneration by 22%, and poor and no regeneration by 17%. Only 7% of the total recorded species exhibited new regeneration (Table 2).

Species distribution pattern: The Whitford similarity index revealed that most of the species in the present study exhibited clumped/contagious distribution pattern. About 80% of the total plant species exhibited clumped distribution, while 12% of the species distributed randomly and only 7% species showed regular distribution pattern (Fig. 2). Das et al (2017) observed that most of the plant species in natural forest follows clumped/contagious distribution pattern. Clumped distribution pattern are considered as the most universal pattern in a natural forest whereas random distribution are general found in uniform environment where individuals are distributed without any apparent pattern and regular distribution indicates high competition among species (Odum 1971). Several workers have also reported similar type of distribution pattern for different tropical and subtropical forest in the country (Gazal 2015, Da et al 2017, Joshi 2020).

Total tree above ground biomass and carbon stock: Tropical forests are distinguished for their rich biodiversity and high carbon storage over the world. In the present study, out of total standing biomass of 314 Mg ha^{-1} (AGB + BGB), the total tree above ground biomass and below ground biomass were 256.64 and 57.26 Mg ha^{-1}, respectively (Table 1). The estimated above ground biomass in the present study is well within the range reported (32.75 – 280.71 Mg ha^{-1}) for various tropical forest of Northeast India (Thokchom and Yadava 2017, Deb et al 2019, Sajad et al 2021). The distribution of tree biomass across different girth classes showed higher biomass in 30 – 60 cm girth class (33%) followed by 60 – 90 cm girth class (28%) and lowest in 120 – 150 cm girth class (only 5%) (Fig. 3). The domination of the biomass in the girth class was mainly depended on the density in these girth classes. Various studies also reported that species wood density plays a vital role in variations of forest biomass and contribute largely in the total living biomass of forest (Robiansyah 2018, Joshi and Dhyani 2019). In addition, there are also reports suggesting factors such as change in stand structure and species composition because of various anthropogenic pressures can lead to variation in total biomass and carbon stock in a forest ecosystem (Bradford et al 2012, Deb et al 2021, Ao et al 2023).

The tree biomass carbon recorded in the present study (147.53 Mg C ha^{-1}) also showed well within the reported range (90.1 – 291.6 Mg C ha^{-1}) of various tropical and subtropical forest of Northeast India (Giri et al 2014, Hrasel et al 2018, Deb et al 2021). Species such as *Schima wallichii* (61.01 Mg ha^{-1}) and *Engelhardtia spicata* (25.93 Mg ha^{-1})

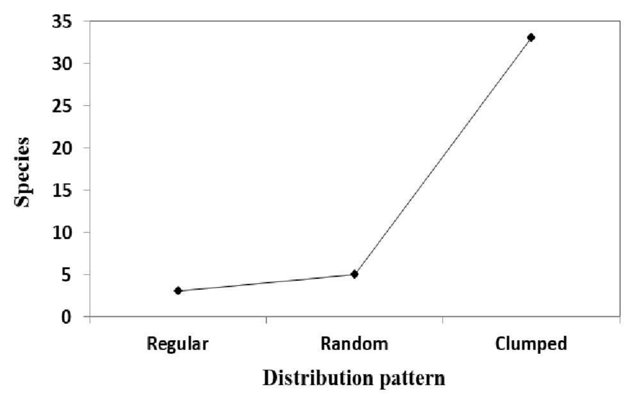

Fig. 1. Tree density and Basal area in different girth classes of Lalsavunga Park, Mizoram

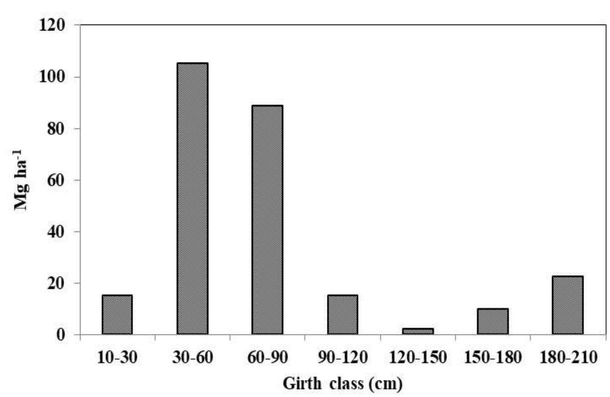

Fig. 2. Distribution pattern of species at Lalsavunga Park, Mizoram

recorded the maximum carbon stock and these two species together contributed about 40% of the total above ground biomass carbon in the forest.

CONCLUSION

The present study provides important insight about rich biodiversity of Lalsavunga Park and its potential to store high biomass carbon within the tree community. The lower and middle girth classes (10 – 30 cm and 30 – 90 cm) stored significantly greater carbon than other girth classes in the forest, and thus these girth classes may be protected to have considerable potential to sequester greater amount of carbon in the biomass in the future. Species such as *Schima wallichii* and *Engelhardtia spicata* exhibited maximum (40%) carbon storage as compared to other species indicating that these species need to be conserved to act as a potential species for carbon sink with possible implication in future climate mitigation programs. The study also suggest that the species has good regeneration potential in the present forest with higher density of seedling, sapling and young trees that can be endured with proper management technique and sustainable use. At the same time, about one-fourth of the species has poor and no regeneration in the area because of prevailing stress conditions due to various anthropogenic disturbances such as timber felling, agriculture expansion, stone quarry and forest fire in the region. Special ecological emphasis is required to promote the regeneration of these species to ensure the proper ecological balance of the region. Finally, the present findings provide baseline information to prepare a proper management plan to conserve the vegetation and sustainable use of natural resources and climate change mitigation.

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