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Species diversity, population structure, and regeneration status of trees in Fakim Wildlife Sanctuary, Nagaland, Northeast India

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Abstract. *Ao A, Changkija S, Tripathi SK. 2020. Species diversity, population structure, and regeneration status of trees in Fakim Wildlife Sanctuary, Nagaland, Northeast India. Biodiversitas 21: 2777-2785.* The plant species composition and diversity represent the overall health of the forest ecosystems and provide useful insight on forest conservation, and the species regeneration is important in assessing the potential of the forests to serve the society on sustained basis. This present study aimed to assess the species diversity, population structure, and regeneration status of the trees in temperate forest of Fakim Wildlife Sanctuary, Nagaland, Northeast India. Tree species composition, population structure and regeneration status were analyzed by randomly establishing eight plots of 0.1 ha within the sanctuary. Density, basal area, abundance, evenness, and other diversity indices were calculated for mature trees with girth at breast height (GBH) ≥ 30 cm. A total of 60 tree species belonging to 40 genera and 27 families were recorded. The most dominant families recorded were Lauraceae and Rosaceae. The total tree density recorded from the forest was 432.5 individuals ha^{-1} with a basal area 42.8 m^2 ha^{-1}. *Cinnamomum zeylanicum* and *Lithocarpus pachyphyllus* had the highest density with 17.58 individuals ha^{-1} and *Lithocarpus pachyphyllus* had the highest basal area with 2.64 m^2 ha^{-1}. The species with the highest IVI was *Betula alnoides* (17.13). Girth class of 30-60 cm had the highest density and basal area with 280 individuals ha^{-1} and 20.7 m^2 ha^{-1}. The diversity indices such as Shannon-Wiener index, Simpson index, Pielou evenness index, and Margalef species richness index were 3.90, 0.93, 0.92, and 11.59, respectively in the wildlife sanctuary. The present study showed that 41% of tree species exhibited good regeneration status, 31% as fair regeneration, 8% as poor regeneration and 20% had no regeneration. The present data will be useful to understand the current status of tree species and will serve as baseline information to the forest department, policymakers and conservationists to develop management plans for the conservation of priority species in the area.

Keywords: Fakim Wildlife Sanctuary, temperate forest, population structure, regeneration potential, tree diversity

INTRODUCTION

Forest is an association of plant community dominated by trees of different sizes and other woody and non-woody vegetations like shrubs and herbs occupies various storeys (Zhang et al. 2017). Plant composition in a forest ecosystem is largely influenced by geographical location of the region, soil, climate, stand structure, tree diversity, and regeneration pattern of species (Sarkar and Devi 2014, Siregar et al. 2019). Species diversity is an important component of the forest ecosystems as it reflects the overall health of forest, and provides useful information that serves as primary information for the conservation of tree species and habitats including other organisms of the forest ecosystems (Roy et al. 2004, Sharma and Kant 2014). Vegetation analysis of the forest ecosystem will help us to understand the population structure (Sahu et al. 2019) and regeneration potential of the species which can be useful in forest management and species conservation (Borogayary et al. 2017) and their economic valuation (Palit et al. 2012).

Regeneration is the most integral part of any forest ecosystem as it determines the existence of species in the region (Malik and Bhatt 2016) and it plays a major role in forest management (Ahmadi et al. 2016, Saroinsong 2020). Successful regeneration of species is one of the main driving forces to achieve future sustainability of the forest community (Saikia and Khan 2013). Regeneration status of a forest is determined by the density of seedling, sapling, and population of species in lower girth classes (Deb and Sundriyal 2011; Maua et al. 2020). The higher density of seedlings and saplings, and the presence of young trees in lower girth class indicate a good regeneration status of forest whereas the absence of seedling results in no regeneration (Senbeta et al. 2014; Pokhriyal et al. 2010; Chaturvedi et al 2017; Sharma et al. 2018). The population structure of individual species present in different girth classes (e.g. 30-60 cm, 60-90 cm, 90-120 cm, etc.) in association with regeneration behavior of the forest helps us to provide better understanding on the potential of the forest (Dutta and Devi 2013) to serve the society and the anthropogenic pressure faced by the forest. For instance, the population structure characterized by least number of seedling and saplings as compared to mature trees suggests a poor regeneration status, whereas, absence of seedlings depicts no regeneration in the forest (Rahman et al. 2011). Therefore, forest stand structure and regeneration status of the species is a key element to determine the health of forest ecosystem and also important parameters of stand biodiversity (Rahman et al. 2019).

According to World Conservation Monitoring Centre, India is one of the 17 mega biodiversity countries in the world and the country has four biodiversity hotspots

consisting of Western Himalaya, Eastern Himalaya, Indo-Burma, and Western Ghats (Arisdason and Lakshminarasimhan 2017). Northeast India is comprised of eight states, namely Arunachal Pradesh, Nagaland, Manipur, Meghalaya, Assam, Tripura, Mizoram, and Sikkim, which harbors 75% of the floral and faunal diversity of the country. Northeast India covering an area of 262179 km^2 (Upadhaya et al. 2012) is a part of Indo-Burma biodiversity hotspots. The region is rich in biodiversity with majority of endemic species are facing high degree of threats. Further, the region is characterized by high variation in altitudes, soil types, and ecological conditions along with diverse life forms which provide necessary conditions for the region to serve as storehouse of varieties of plant and animal species (Tynsong and Tiwari 2010; Saikia and Khan 2017). According to World Wildlife Foundation, the entire Eastern Himalayas, which consists of entire eight states of Northeast India and the neighboring countries like Bhutan, Southern China, and Myanmar, have been listed among 200 Global Ecoregion (Saikia et al. 2017, Roy et al. 2015). One protected area within this region is Fakim Wildlife Sanctuary.

Fakim Wildlife Sanctuary has been named after Fakim village, which is located at the foothills of Mount Saramati in the Eastern part of Kiphire District, Nagaland, and shares international boundary with Myanmar. The sanctuary is very rich in flora and fauna with many rare, endangered, and endemic species but most of the area in the sanctuary is unexplored due to its high altitude and slopes. Therefore, it is important to conduct detailed documentation and analysis of vegetation of the sanctuary which will serve as baseline information to the forest department, researchers, ecologist, and conservationist. The main aim of this study is to assess species diversity, composition, population structure and regeneration potentials of the tree in wet temperate forest of Fakim Wildlife Sanctuary, Nagaland, Northeast India.

MATERIALS AND METHODS

Study area

The Fakim Wildlife Sanctuary lies between N 25°47'-25°48' and E 95°02' to 95°04' (Figure 1) at altitudes of 1700-3000 m above sea level with an area of 6.42 km^2. It was declared sanctuary in the year 1986. The sanctuary is composed of thick virgin primary forest of wet temperate to sub-alpine forest types (Champion and Seth 1968). The area is part of the Indo-Burma border which is considered as one of world's biodiversity hotspots (Rongsensashi et al. 2013). The Fakim Wildlife Sanctuary is known for the habitat of rare and endangered bird species Blyth tragopan (*Tragopan blythii*), which is also known to be the state bird of Nagaland. The forest receives an annual rainfall of 200-300 cm with temperature varying from 5°C in winter to 29°C in summer. The whole region lies in the biogeographic zone of Northeast India and also acts as a transition zone between India, Indo-Burma, and Indo-China biogeographic zones (Chatterjee et al. 2006). The sanctuary harbors many important faunal species, such as Chinese goral, leaf deer, bay woodpecker, wedge-tailed green-pigeon, Blyth tragopan, wild dog, sun bear, hoolock gibbon, Himalayan black bear, etc. There were few sightings of top predators, like tigers, in the region between Mt. Saramati and Fakim Wildlife Sanctuary, but occasionally only bug marks were spotted and there is no proper documentation of tigers from the sanctuary. Due to very rough terrain, less road accessibility, and unaccountable challenges, the floral community of the sanctuary has not been explored despite the rich biodiversity of the region.

Data collection

The present study was conducted during the month of May-July, 2017 in wet temperate forest of Fakim Wildlife Sanctuary, Nagaland. Random quadrats measuring 20m x 25 m were used to study the vegetation of the area. A total of 8 quadrats of 0.1 ha each was established randomly with help of metal tapes using the ropes for making the grids and all individuals of tree species were identified, recorded, and collected. Measuring tape was used to measure the girth of trees (1.37 m girth at breast height) and identification of species was made by experts in the field and herbarium was prepared and deposited in herbarium laboratory, Nagaland University, Medziphema.

All the individuals ≥ 30 cm girth (GBH) were considered as adult trees, individuals ≥ 10-≤30 cm girth were considered as old sapling/young trees/shrubs as the case may be depending on nature, individuals with > 10 cm height and 3 to < 10 cm girth (GBH) were considered as saplings and individuals with up to 10 cm tall and < 3 cm girth (GBH) were considered as seedlings.

Data analysis

Community parameters such as frequency, density, basal area, and dominance were quantitatively analyzed (Singh et al. 2015). The Important Value Index (IVI) of each tree species was also calculated. The number of individuals of all adult trees was recorded in different girth classes, such as 30-60 cm, 60-90 cm, 90-120 cm, 120-150 cm, 150-180 cm, and ≥ 180 cm to understand the population structure of species in the area. Regeneration status of each individual species was studied based on the size of population of seedling, sapling, and adult trees (Shankar 2001). Regeneration was considered as "good" if seedlings > saplings > trees; "fair" if seedlings > or < saplings < trees; "poor" if there is no seedling but species survives in sapling stage and "no regeneration" if species survives only in adult tree stage (Khumbongmayum et al. 2006).

Important diversity indices were also computed to study the species richness, diversity, dominance, and evenness of the plant community.

Shannon-Weiner diversity index (Shannon and Weiner 1963)

$$H'=-\sum^{s}_{i=1} (pi)ln (pi); \text{ (ln is a natural log)}$$

Where, P_i is the proportion (n/N) of individuals of one particular species (n) divided by total number of individuals found (N)

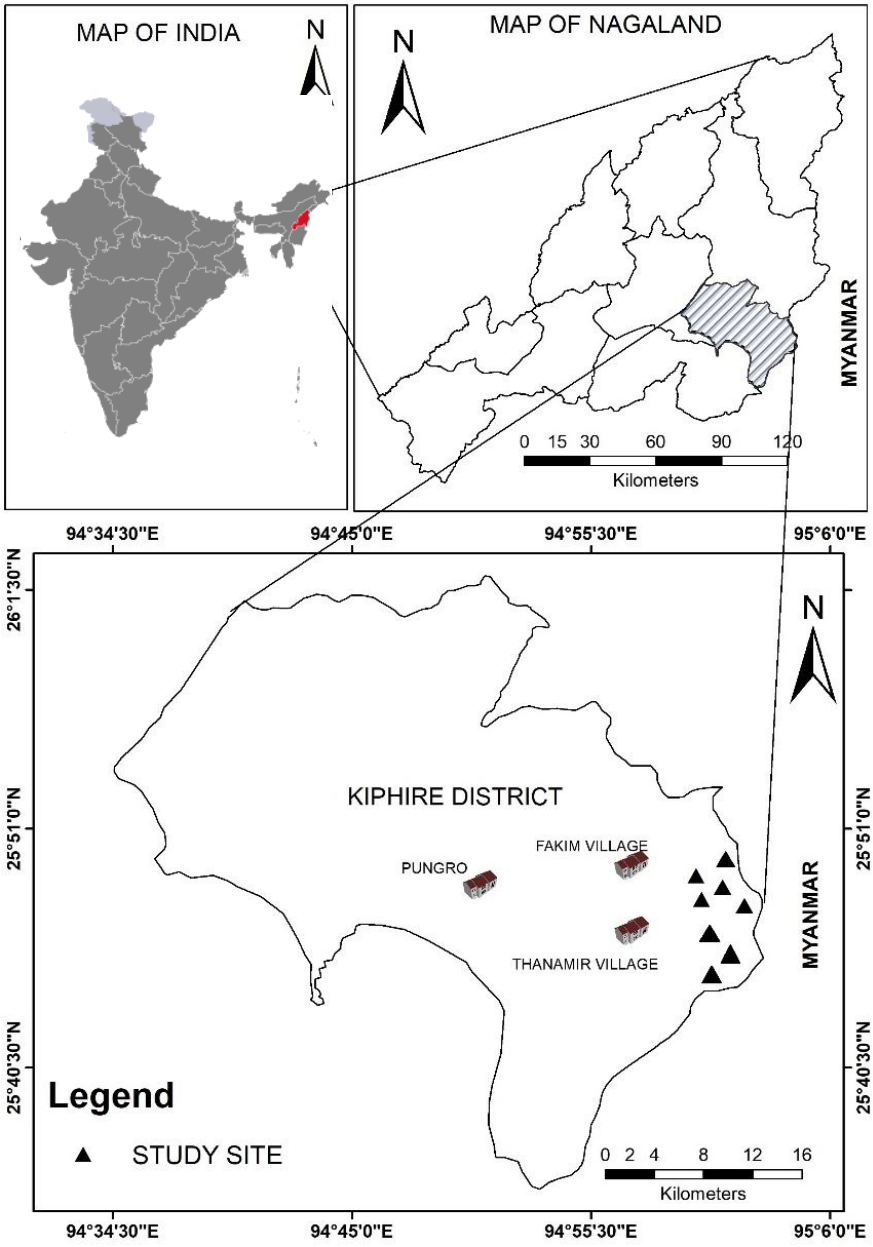

Figure 1. Map showing the study site and surrounding villages of Fakim Wildlife Sanctuary, Kiphire District, Nagaland, Northeast India

Simpson dominance index (Simpson 1949)

$Cd = \sum^{s}_{i=1} (pi)^2$

Margalef species richness index (Margalef 1958)

$d = S\text{-}1/\ln (N)$

Where, S is the total number of species and N is the total number of individuals

Pielou evenness index (Pielou 1966)

$E = H'/\mathrm{Ln}\ (S)$

Where H' is the Shannon-Weiner diversity index and S is the total number of species

RESULTS AND DISCUSSION

Floristic diversity and composition

A total of 60 tree species belonging to 40 genera and 27 families was recorded from the temperate forest of Fakim Wildlife Sanctuary, Kiphire Nagaland (Table 1). The most dominant families recorded were Lauraceae and Rosaceae (6 species each), followed by Sapindaceae, Fagaceae, and Magnoliaceae (4 species each), and Elaeocarpaceae, Fabaceae, Meliaceae, Moraceae and Theaceae (3 species each). The number of tree species recorded in this study was comparable to Montane wet temperate forest of the Southern Western Ghats, India (Somasundaram and Lalitha 2010, 67 species) and Temperate forest of Talle wildlife sanctuary, Arunachal Pradesh, Eastern Himalaya (Yam and Tripathi 2016, 63 species); whereas, the values were lower

compared to 13 montane forests of Bawean Island Nature Reserves, Indonesia (Trimanto and Hapsari 2016, 237 species), plant species diversity along with altitude range in West Himalaya, Uttarakhand, India (Rawal et al. 2018, 106 species), forest composition along altitudinal gradient in Eastern Himalaya, Sikkim, India (Bhutia et al. 2019, 114 species) and tropical dry deciduous forest of Eastern Ghats, India (Gandhi and Sundarapandian 2020, 75 species). However, the tree species richness of the present study was found to be higher as compared to plant diversity recorded in a southern temperate forest in Tierra del Fuego Island, Argentina (Mestre et al. 2017, 46 species); a wet temperate forest in Pakistan (Raja et al. 2014, 44 species) and in a temperate forest in Bertiz Natural Park, Spain (Gazol and Ibanez 2010, 28 species).

Betula alnoides showed the highest importance value index (IVI) with 17.13 followed by *Lithocarpus pachyphyllus* (12.50), *Quercus lamellosa* (10.58) and *Lithocarpus xylocarpus* (9.00) (Table 2). The total tree density recorded from the forest was 432.5 individuals ha^{-1}. *Cinnamomum zeylanicum* and *Lithocarpus pachyphyllus* contributed the highest density with 17.58 individuals ha^{-1}, followed by *Acer oblongum* and *Magnolia insignis* with 16.04 individuals ha^{-1} and *Betula alnoides* and *Michelia oblonga* with 15.03 individuals ha^{-1} each. The tree density of present study was lower than that of a temperate forest in West Himalaya, India (Airi and Rawal 2017, 393-789 individuals ha^{-1}), and a temperate forest of *Quercus leucotrichophora* in Dewalgarh watershed, Garhwal Himalaya (Uniyal et al. 2010, 804-2144 individuals ha^{-1}). However, it was comparable to density recorded in a temperate forest in Dhanaulti, Garhwal Himalaya (Saha et al. 2016, 83.33-211.67 individuals ha^{-1}).

The total basal area recorded from the present study was 42.8 m^2 ha^{-1}. *Lithocarpus pachyphyllus* contributed the highest basal area with 2.64 m^2 ha^{-1}, followed by *Michelia oblonga* (2.03 m^2 ha^{-1}), *Exbucklandia populnea* (1.80 m^2 ha^{-1}) and *Cinnamomum zeylanicum* (1.53 m^2 ha^{-1}). Similar study was conducted by various workers where the basal area of tree species ranged from 24.2-75.3 m^2 ha^{-1} (Tropical forest of Western Ghats, India; Subashree et al. 2020); 22.21-46.73 m^2 ha^{-1} (Tropical moist deciduous forest of Saptasajya Hill range, Eastern Ghats, India; Sahu et al. 2019) and 94.18 m^2 ha^{-1} (Tropical forest of Baratang Island, India; Mane et al. 2019).

The species diversity indices are very essential to determine the health status of a forest ecosystem. In this study, various diversity indices were also enumerated to understand the richness of the forest (Table 1). According to Sobuj and Rahman (2011), an ecosystem with rich species diversity has higher value of H' index whereas an ecosystem with lower species diversity has of lower value of such index. In the present study, tree species diversity (H') in Fakim Wildlife Sanctuary was 3.90, which can be considered as high for temperate and tropical forests. For example, species diversity reported from mixed forest of Batuputih Nature Tourism Park, Indonesia was 3.31 (Arrijani and Rizki 2020), Takamanda rainforest in Southwest Cameroon was 3.87 (Ndah et al. 2013) and temperate forest of Rudraprayag district of Garhwal Himalaya was 3.45 (Raturi 2012). The variation in species diversity with respect to environmental gradient acts as a major ecological investigation (Deb et al. 2015; Erenso et al. 2014; Gairola et al. 2008), and various factors, such as climate, habitat, biotic interaction, edaphic, physiography, and productivity of the forest, play a major role in determining the species growth and production (Monson 2014; Sharma et al. 2014).

The dominance value (Ds) recorded in present study (0.93) corresponds well with that recorded from other temperate forests, which ranged from 0.135-0.97 (Saha et al. 2016; Ndah et al. 2013). The Pielou evenness index (e) recorded from the present study (0.92) revealed that there is an even distribution of species within the forest. Higher value of evenness indicates more consistency in species distribution (Sarkar and Devi 2014). Margalef richness index (d) to determine the species richness of the study site showed a value of 11.45, which was similar to those reported from Meghalaya (Lynser and Tiwari 2015), Eastern Ghats (Naidu and Kumar 2016), and Western Ghats (Sathish et al. 2013) (Table 1).

Population structure

The highest number of tree species was recorded at the adult stage (60 species), followed by young sapling (34 species), old sapling (18), and seedling (29 species). The maximum density was recorded at the seedling stage (3100 individuals ha^{-1}), followed by the young sapling (2800 individuals ha^{-1}), old saplings/young trees (1550 individuals ha^{-1}) and trees (432.5 individuals ha^{-1}) (Figure 2). Among the seedling, *Berberis aristata*, *Lithocarpus pachyphyllus*, *Acer pectinatum*, *Elaeocarpus lanceifolius*, *Litsea monopetala*, and *Toona sureni* contributed about one-third of the total seedling density. Further, among the sapling species, *Albizia odoratissima*, *Cephalotaxus griffithi*, *Elaeocarpus lanceifolius*, *Michelia* spp., *Rhododendron arboretum*, *Schima khasiana*, *Shorea assamica* contributed about one-third of the total sapling density. The old saplings of dominant species like *Acer laevigatum*, *Acer thomsonii*, *Betula alnoides*, *Cephalotaxus grifithii* and *Prunus cerasoides* indicate an established species population with a good regeneration potential of the forest. Similar species structure has been reported in temperate forests of Western Himalaya (Tripathi et al. 1987).

Table 1. Phytosociological attributes of tree community in Fakim Wildlife Sanctuary, Nagaland, Northeast India

Parameters	Value
Number of species	60
Number of genera	40
Number of families	27
Stand density (Individuals ha^{-1})	432.5
Basal area (m^2ha^{-1})	42.8
Shannon-Wiener index (H')	3.9
Simpson index (Ds)	0.93
Margalef index (d)	11.45
Pielou evenness (e)	0.92

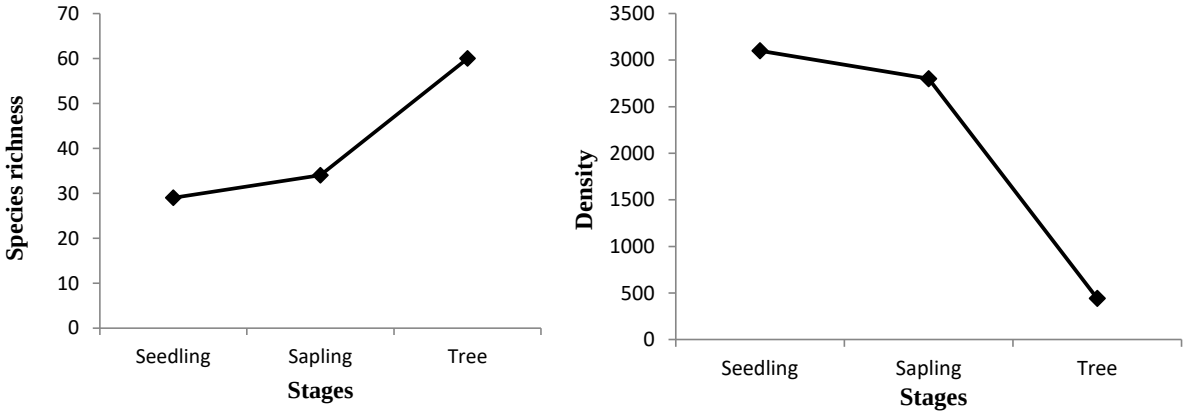

Figure 2. Species richness and density of seedling, sapling and tree species in Fakim Wildlife Sanctuary, Nagaland, Northeast India

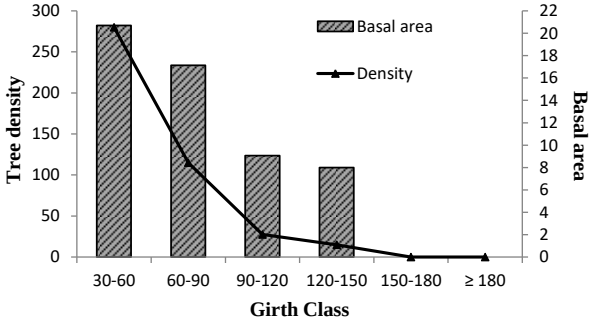

Figure 3. Tree density (individuals ha^{-1}) and basal area (m^2 ha^{-1}) in different girth classes

However, among the trees, *Aglaia perviridis, Beilschimedia roxburghiana, Brassaiopsis hainla, Cinnamomum zieylanicum, Exbucklandia populnea, Lithocarpus elegans, Magnolia insignis, Rhododendron arboretum* contributed about one-fifth of the total tree density. Vegetation analysis of natural forest in North Sulawesi, Indonesia by Siregar et al. (2019) and Kedarnath Wildlife Sanctuary, Western Himalaya, India by Malik and Bhatt (2016) reported almost similar results. The overall population structure of tree vegetation in Fakim Wildlife Sanctuary showed a reverse J-shaped curve which signifies that the forest harbors a hale and hearty growth of population with no anomaly of species mortality rate.

The highest tree density (280 individuals ha^{-1}) was recorded in 30-60 cm girth class showing that the two-third individuals were young. Corresponding values of tree density were: 115, 28, and 15 individuals ha^{-1} for girth class 60-90, 90-120, and 120-150 cm, respectively. The maximum basal area (21 m^2 ha^{-1}) was recorded in 30-60 cm girth class followed by (17 m^2 ha^{-1}) in 60-90 cm girth class, (9 m^2 ha^{-1}) 90-120 cm girth class and the lowest (8 m^2 h^{-1}) 120-150 cm girth class (Figure 3). Similar patterns were reported in temperate forest of Western Himalaya India (Tripathi et al 1987).

The study found that the density, species richness, and basal area of tree stand in Fakim Wildlife Sanctuary was the highest at the girth class of 30-60 cm and it consistently decreased as the girth size increased (Figure 3). This reflects that the area was facing anthropogenic pressure before the establishment of wildlife sanctuary in 1986. After the creation of wildlife sanctuary, the vegetation of the area regenerates well which is showed by the inverse J-shaped population density curves, indicating the growth of individuals at a lower girth class into a higher girth. A study conducted in Hollongapar Gibbon Wildlife Sanctuary, Assam showed a similar result where the overall density of tree in different girth class yielded a reverse J-shaped curve, indicating a good normal distribution of trees in various girth classes (Sarkar and Devi 2014).

Regeneration status

The regeneration potential of trees in a forest ecosystem reflects the future of the forest to provide goods and services to the society on sustained basis (Ali et al. 2019; Ballabha et al. 2013). Successful regeneration potential of a tree species depends on the ability of the species to produce large number of seeds and its ability to grow (Bogale et al. 2017; Jayakumar and Nair 2013). From the present study, 41% of tree species showed good regeneration status, 31% showed fair regeneration status, 8 % showed poor regeneration status and 20% showed no regeneration (Figure 4). Tree species exhibiting good regeneration potential included *Acer pectinatum, Acer thomsonii, Berberis aristata, Caryota urens, Elaeocarpus floribundus, Litsea monopetala, Magnolia insignis, Prunus nepalensis, Sterculia coccinea*, etc. Species showing fair regeneration status included *Acer laevigatum, Acer oblongum, Albizia odoratissima, Betula alnoides, Cephalotaxus griffithii, Illicium griffithii, Magnolia tetracoccus, Prunus cerasoides, Rhododendron arboretum, Schima khasiana, Shorea assamica, Taxus baccata*, etc. Species showing poor regeneration were *Aglaia perviridis, Docynia indica, Litsea polyantha, Pyrus communis,* and *Quercus lamellosa.* Species such as *Cinnamomum zeylanicum, Ficus hirta, Ficus lamponga, Ilex excelsa, Lithocarpus xylocarpus, Rhamnus nepalensis, Turpinia spp. etc* showed no regeneration (Table 2).

Table 2. Tree species density (individual ha^{-1}), basal area (m^2ha^{-1}), important value index (IVI) and regeneration status of Fakim Wildlife Sanctuary, Nagaland, Northeast India

Species	Family	Density	Basal area	IVI	Regeneration status
Acer laevigatum Wall.	Sapindaceae	7.5	0.601131	3.903751	F
Acer oblongum Wall. ex DC.	Sapindaceae	16	0.883534	7.078191	F
Acer pectinatum Wall. ex G. Nicholson	Sapindaceae	7.5	0.534889	3.752177	G
Acer thomsonii Miq.	Sapindaceae	7.5	0.981771	6.441394	G
Aglaia perviridis Hiern.	Meliaceae	10	1.189646	6.648688	P
Albizia odoratissima (L.f.) Benth.	Fabaceae	10	1.249350	6.785302	F
Bauhinia divergens Baker	Fabaceae	2.5	0.204657	1.866599	G
Beilschmiedia roxburghiana Nees	Lauraceae	5	1.020596	4.298593	F
Betula alnoides Buch.-Ham. ex. D. Don	Betulaceae	15	1.270084	17.12936	F
Berberis aristata DC.	Berberidaceae	5	0.332526	2.72416	G
Brassaiopsis hainla (Buch.-Ham.) Seem.	Araliaceae	10	0.829999	5.825749	G
Camellia oleifera Abel.	Theaceae	10	1.500154	8.192525	G
Caryota urens L.	Arecaceae	7.5	0.648792	4.846141	G
Cephalotaxus griffithii Hook.f.	Cephalotaxaceae	5	0.235902	2.503065	F
Cinnamomum zeylanicum Blume	Lauraceae	17.5	1.346128	9.534999	G
Cinnamomum spp. Schaeff	Lauraceae	12.5	1.531408	8.829011	NR
Docynia indica (Wall.) Decne.	Rosaceae	12.5	1.612068	8.180243	P
Elaeocarpus floribundus Blume	Elaeocarpaceae	5	0.320467	2.696565	G
Elaeocarpus lanceifolius Roxb.	Elaeocarpaceae	12.5	0.774638	7.097377	G
Elaeocarpus tectorius (Lour.) Poir.	Elaeocarpaceae	10	1.263883	7.651891	G
Eurya acuminata DC.	Pentaphylacaceae	2.5	0.133186	1.703059	G
Exbucklandia populnea (R.Br. ex Griff.) R.W.Br.	Hamamelidaceae	12.5	1.795894	8.600871	G
Ficus hirta Vahl	Moraceae	2.5	0.140446	1.719672	NR
Ficus lamponga Miq.	Moraceae	2.5	0.143134	1.725822	NR
Ficus racemosa L.	Moraceae	5	0.280657	3.438806	G
Garcinia anomala Planch. & Triana	Clusiaceae	5	0.274994	2.592516	G
Garcinia cowa Roxb. Ex Choisy	Clusiaceae	2.5	0.126118	1.686887	F
Hydnocarpus kurzii (King) Warb.	Achariaceae	2.5	0.193510	1.841093	G
Ilex excels (Wall.) Voigt	Aquifoliaceae	2.5	0.093670	1.612639	NR
Illicium griffithii Hook.f. & Thomson	Schisandraceae	5	0.254581	2.545807	F
Lithocarpus elegans (Blume) Hatus. ex Soepadmo	Fagaceae	10	1.111982	8.137647	G
Lithocarpus pachyphyllus (Kurz) Rehder	Fagaceae	17.5	2.641110	12.49816	G
Lithocarpus xylocarpus (Kurz) Markgr.	Fagaceae	10	1.308088	8.586374	NR
Litsea monopetala (Roxb.) Pers.	Lauraceae	5	0.510902	3.132318	G
Litsea polyantha Juss.	Lauraceae	2.5	0.110771	1.651771	P
Macropanax dispermus (Blume) Kuntze	Araliaceae	5	0.605295	3.348307	F
Magnolia champaca (L.) Baill. ex Pierre	Magnoliaceae	2.5	0.188054	1.828609	G
Magnolia campbelli Hook.f. & Thomson	Magnoliaceae	5	0.398905	2.876048	G
Magnolia insignis Hook.f. & Thomson	Magnoliaceae	16	1.218196	9.510627	F
Mallotus tetracoccus (Roxb.) Kurz	Euphorbiaceae	2.5	0.202242	1.861073	F
Michelia oblonga (Wall.) Hook.f. & Thomson	Magnoliaceae	15	2.032598	11.37413	F
Phoebe lanceolata (Nees) Nees	Lauraceae	7.5	0.796020	6.01636	NR
Prunus cerasoides Buch.-Ham. ex. D. Don	Rosaceae	7.5	0.898029	6.249775	F
Prunus nepalensis Hook.f.	Rosaceae	2.5	0.221962	1.906196	G
Pyrus pashia Buch.-Ham. ex. D. Don	Rosaceae	10	0.494212	5.057404	NR
Pyrus communis L.	Rosaceae	5	0.256957	2.551243	P
Quercus lamellose Sm.	Fagaceae	12.5	1.932982	10.58122	P
Rhamnus nepalensis (wall.) Lawson	Rhamnaceae	5	0.348371	2.760416	NR
Rhododendron arboretum Sm.	Ericaceae	12.5	1.240419	8.163172	F
Rhododendron spp. L.	Ericaceae	2.5	0.227886	1.919752	NR
Schima khasiana Dyer	Theaceae	2.5	0.164829	1.775465	F
Schima wallichii Choisy	Theaceae	7.5	0.744736	4.232347	F
Shorea assamica Dyer	Dipterocarpaceae	2.5	0.201440	1.859239	F
Sterculia coccinea Roxb.	Malvaceae	2.5	0.197455	1.85012	G
Taxus baccata L.	Taxaceae	12.5	1.096753	7.001104	F
Toona ciliata M.Roem.	Meliaceae	5	0.717998	4.439525	F
Toona sureni (Blume) Merr.	Meliaceae	2.5	0.201440	1.859239	G
Turpinia spp. Vent.	Staphyleaceae	5	0.386380	2.847387	NR
Ziziphus incurva Roxb.	Rhamnaceae	2.5	0.152045	1.746214	NR

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

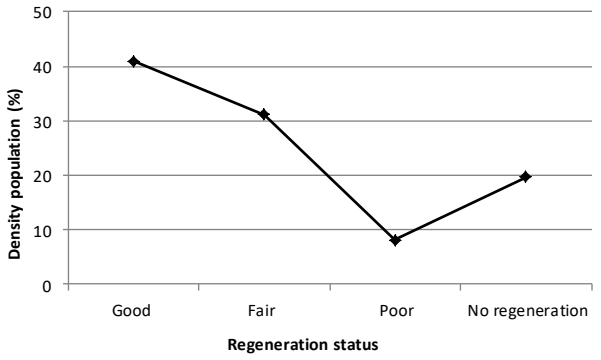

Figure 4. Regeneration status of tree species in Fakim Wildlife Sanctuary, Nagaland, Northeast India

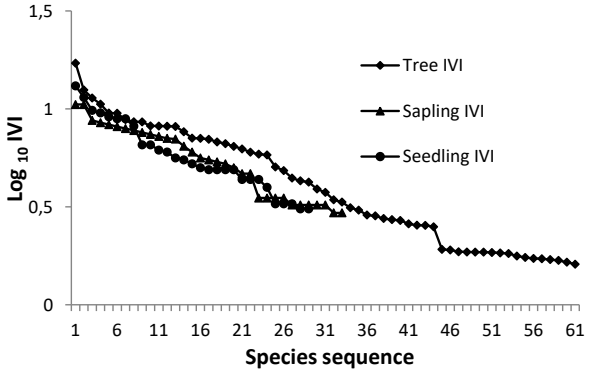

Figure 5. Dominance-diversity curve of trees, saplings, and seedlings in Fakim Wildlife Sanctuary, Nagaland, Northeast India

The overall regeneration status of the Fakim wildlife sanctuary showed reversed J-shaped curve with a higher percentage of species exhibiting good regeneration status. This condition is referred to as good health of forest where majority of the species showed good regeneration status. Similar results were reported on regeneration status of the sub-tropical forest of Alaknanda valley in Garwhal Himalaya, India (Ballabha et al. 2013). The tree species from the sanctuary showing poor and no regeneration may be accorded due to the large canopy cover that reduces the sunlight which may inhibit the growth of the species because of the limitation of sunlight (Fiorucci and Fankhauser 2017).

The dominance-diversity curve (i.e. the percentage of IVI on log scale plotted against species rank) of trees, sapling and seedling in Fakim Wildlife Sanctuary showed a reasonable amount of diversity (Figure 5). The dominant tree species with the highest IVI were *Beilschimedia roxburghiana, Lithocarpus elegans, Michelia oblonga, Quercus lamellosa, Magnolia campbelli, Exbucklandia populnea, Lithocarpus xylocarpus, Acer oblongum, Albizia odoratissima, Prunus cerasoides* and *Phoebe lanceolata*, whereas species such as *Brassaiopsis hainla, Pyrus pashia, Mallotus tetracoccus, Ilex excelsa, Eurya acuminata, Ficus hirta, Bauhinia divergens* had the lowest IVI. The sharp decline on the curve is found in species with lower girth class which is likely due to the impact of anthropogenic factors.

The dominance-diversity curve for saplings and seedlings showed a gentle slope which is a normal characteristic of vegetation having a positive regeneration potential of a species. The dominant sapling and seedling of with the highest IVI were *Acer pectinatum, Acer thomsonii, Berberis aristata, Elaeocarpus floribundus, Litsea monopetala, Magnolia insignis, Prunus nepalensis, Michelia oblonga* and *Lithocarpus elegans*. The gentle decline in the dominance-diversity curve of saplings and seedlings indicates the disturbance due to grazing by the wild herbivores such as Mithuns (*Bos frontalis*) which were found abundant in the sanctuary. The dominance-diversity curve of all the tree, sapling and seedling follows S-shaped log series model which indicates that the sanctuary is a species-rich region.

In conclusion, the forest of Fakim Wildlife Sanctuary is rich in tree diversity with higher density in seedlings, sapling and young trees, indicating a good regeneration potential that can be sustained for a longer time with proper management plans to provide good and services to the society. Attention is required to facilitate the regeneration of species which are not performing well due to environmental constrains, particularly light as a result of shade from canopy trees. Decreased numbers of individuals in the upper girth class draw attention of the forest managers towards any logging activities in the border area of the sanctuary by the local people residing in the surrounding villages. Therefore, an efficient management plan is needed to conserve the vegetation and health of the Fakim Wildlife Sanctuary in order to provide sustainable use of the forest resources.

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