Research article

Quantitative analysis of vegetation structure, composition and species diversity of moist Sal bearing tropical forest of Sumbuk reserve forest in South Sikkim, India

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Abstract: A total of 28 tree species were recorded in 0.024 ha in all along with the sampling plots. The higher individual plant density of trees was recorded for *Shorea robusta* followed by *Schima wallichii* and *Pinus roxburghii*. The high IVI exhibited by *Shorea robusta* is largely due to its higher relative frequency, relative density and relative dominance compared to other species. The occurrence of many species with low IVI values indicates that most species are rarely distributed in the forest. The result of species diversity showed the highest diversity index for trees (2.78) followed by sapling (2.55) and seedling (2.38). The value of species richness in the present study was found to be falling between ranges 15.81 to 37.81. According to girth classes, the tree species *Shorea robusta* and *Tectona grandis* followed almost a normal distribution curve with less trees belonging to smaller and big GBH classes suggesting a fairly stable population in the study area. A reverse J-shaped curve for *Lagerstroemia parviflora*, *Schima wallichii*, *Pinus roxburghii*, *Terminalia crenata* which depicts more of the characteristics of a stable population is found. Quantitative evaluation and analysis of the community structure are important for accurate assessment of biodiversity.

Keywords: Quantitative analysis - Vegetation structure - Species diversity - Biodiversity conservation.

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INTRODUCTION

Tropical forests are home to the greatest wealth of biological and genetic diversity (Hubbell & Foster 1983). Tropical dry forests form a major biome in India by covering around 38% of the total forest area of the country (Thakur & Khare 2006). The tropical and subtropical forest of Sikkim comprises the lower hills and valley enjoy a sub-tropical climate, warm in winter, hot and extremely humid in summer (Singh & Sanjappa 2011).

Quantitative evaluation and analysis of the community structure are important for accurate assessment of biodiversity. The structure and composition of forests change with the length of wet period, amount of rainfall, latitude, longitude and altitude (Thakur & Khare 2006). The structure of the forest is expressed in terms of the number of individuals present in each of the definite girth class distribution of tree species (Sarkar & Devi 2014). The plant diversity inventories in tropical forests have mostly been concentrated on tree species than other life-forms (Mani & Parthasarathy 2006, Bajpai *et al.* 2012) and mostly dominated by tree species in lower hills of Sikkim Himalayas. The plant diversity is influenced by species distribution and abundance (Palit & Chanda 2012) and the species richness is controlled by a variety of biotic and abiotic parameters (Rannie 1986, Huston 1994, Bajpai *et al.* 2020).

The northeast region of India is considered as one of the biodiversity hotspots of the Eastern Himalayan Region. According to Takhtajan (1969), it is the center of origin of angiosperms. Sikkim Himalayas is a

storehouse of biodiversity which includes a variety of plant and animal species and considered as a biodiversity hotspot in this region. In Sikkim, several botanical explorations have been made by early times. It was visited and documented the biodiversity of Sikkim by eminent botanists like J.D. Hooker, C.B. Clarke, G. King, T. Anderson, W.W. Smith, G.H. Cave, J.M. Cowan, R. Pantling, G.A. Gammie, D. Prain, B. Osmaston and I.H. Burkill. After so many years, the many researches and documentation have been done and recorded by (Cowan & Cowan 1929, Pradhan & Lachungpa 1990, Rai & Rai 1994, Singh & Chauhan 1997) and vegetation studies were done by (Chettri *et al.* 2008, Pradhan & Lachungpa 2015, Subba *et al.* 2015, Subba *et al.* 2016, Subba *et al.* 2017a) and life-form spectrum study by (Subba *et al.* 2017b) and inventory of biodiversity (Subba *et al.* 2018). The six broad vegetation types have been demarcated in Sikkim based on Champion & Seth (1986) as Tropical semi-evergreen forests, sub-tropical broad-leaved hill forest, Himalayan Wet temperate forests, Sub-alpine forest, moist alpine forests and dry alpine forest.

Therefore, the present study was undertaken to analyze the vegetation structure, composition and species diversity of the Moist Sal Bearing Tropical Forest of Sumbuk reserve forest in South Sikkim. The rapid biodiversity survey of quantitative data that provides information on species diversity, richness and evenness will represent an important tool for the conservation of biodiversity and information from this quantitative inventory will provide a valuable reference for forest assessment and forest management plan.

MATERIALS AND METHODS

Study area

Sumbuk Reserve forest is located in the south district between latitude to $27^{\circ} 06'00.58''$ N to $27^{\circ} 06'27.73''$ N and longitude $88^{\circ} 21'34.62''$ E to $88^{\circ} 21'53.16''$ E, the study area its height ranges from 475 m to 765 m asl. This reserve forests are very rich in floral and faunal diversity. The reserve forest showing the aspects of E, N and NE with the slope angle falling between 30 to 65 degree inclinations and the humus depth is not less than 0.5 and the average humus depth is 1.5 cm depth.

Figure 1. Showing the forest compartment boundary along sampling plots of Sumbuk Reserve Forest, South Sikkim, India.

Figure 2. Showing the forest density & forest types along the sampling plots of Sumbuk Reserve Forest, South Sikkim, India.

Methodology

Prior to field survey, the entire area (vegetation map) of the present study was prepared into $0.5 \text{ km} \times 0.5 \text{ km}$ grids in GIS laboratory (Table 1). Based on this, each vegetation/forest types and forest density on the total grids in the specific vegetation type was sampled for the rapid biodiversity assessment (flora and fauna) inventorization. The selection of grids was done by taking the following aspects of consideration.

1. Covering forest types, forest density (dense & moderate forest).
2. Based on the compartment

The present field survey was carried out in Sumbuk Reserve Forest, South Sikkim. The random sampling plots of $10 \text{ m} \times 10 \text{ m}$ were laid, depending upon the site feasibility. Within the main plot, all the standing tree species were enumerated & measured (CBH) at 1.37 m from the ground by using measuring tape. Within the subplots, $5 \text{ m} \times 5 \text{ m}$ were laid for recording the sapling (no. of species & its height) & shrub for the percent cover was recorded. Within this, $1 \text{ m} \times 1 \text{ m}$ were laid in 4 corners and 1 plot at the center point for seedling species were enumerated, in the same plot was used for recording the herb percentage in the area. The location and altitude of the plots were recorded by calibrate the global positioning system (GPS; Garmin eTrex) and the humus depth was measured with the help of measuring scale. Plant species were identified through herbarium record and flora published (Hooker 1849, Hooker 1888–1890, Pradhan & Lachungpa 1990, Kholia 2010, 2014). The unidentified plants species in the field were photographed, and later identified by consulting plant taxonomist, & BSI and web-references (www.efloras.org; www.flowersofindia.net & www.floraofchina.org) were made and by referring to local people too. All the sampling plots were geo-tagged for reference under long-term monitoring. All the quantitative data were analysed (Kent & Coker 1992).

Table 1. Site characteristics of Sumbuk reserve forest, South Sikkim.

Site Code	Forest types	Altitude (m) asl	Coordinates		Slope Angle (°)	Slope Aspect	Humus depth (cm)
			Latitude (N)	Longitude (E)			
SRF1	Moist Mixed deciduous forest	765	27° 06'27.73"	88° 23'00.96"	45	N	0.5
SRF2	Moist Mixed deciduous forest	748	27° 06'21.48"	88° 22'53.16"	30	SW	0.5
SRF3	Very moist Sal bearing forest	648	27° 06'16.84"	88° 23'01.87"	30	NW	1.5
SRF4	Very moist Sal bearing forest	593	27° 06'14.50"	88° 23'05.60"	26	SW	0.5
SRF5	Very moist Sal bearing forest	532	27° 06'17.13"	88° 23'14.30"	36	S	0.5
SRF6	Very moist Sal bearing forest	528	27° 06'19.51"	88° 23'20.93"	33	E	0.5
SRF7	Very moist Sal bearing forest	519	27° 06'18.04"	88° 23'18.31"	35	N	0.5
SRF8	Very moist Sal bearing forest	495	27° 06'16.05"	88° 23'17.80"	45	S	0.5
SRF9	Very moist Sal bearing forest	500	27° 06'13.76"	88° 23'15.43"	42	E	0.8
SRF10	Very moist Sal bearing forest	488	27° 06'09.02"	88° 23'11.61"	50	S	1.5

SRF11	Very moist Sal bearing forest	476	27° 06'02.35"	88° 23'09.92"	60	E	1.5
SRF12	Very moist Sal bearing forest	450	27° 06'00.58"	88° 23'07.05"	55	SE	0.5
SRF13	Very moist Sal bearing forest	475	27° 06'01.85"	88° 23'02.03"	25	S	1.5
SRF14	Very moist Sal bearing forest	512	27° 06'04.62"	88° 22'55.33"	30	S	1.2
SRF15	Very moist Sal bearing forest	550	27° 06'09.47"	88° 22'49.31"	35	SW	1.5
SRF16	Very moist Sal bearing forest	521	27° 06'06.83"	88° 22'31.49"	45	W	0.5
SRF17	Very moist Sal bearing forest	492	27° 06'08.76"	88° 22'24.78"	65	SW	1.2
SRF18	Very moist Sal bearing forest	518	27° 06'11.50"	88° 22'18.14"	45	NW	1.3
SRF19	Very moist Sal bearing forest	538	27° 06'14.30"	88° 22'08.44"	40	W	0.5
SRF20	Very moist Sal bearing forest	551	27° 06'16.60"	88° 22'00.52"	50	E	1.5
SRF21	Very moist Sal bearing forest	578	27° 06'24.84"	88° 21'34.62"	60	NE	0.5
SRF22	Very moist Sal bearing forest	640	27° 06'24.34"	88° 22'00.95"	40	NE	1.5
SRF23	Very moist Sal bearing forest	683	27° 06'27.41"	88° 22'07.49"	55	NW	0.5
SRF24	Very moist Sal bearing forest	696	27° 06'24.98"	88° 22'16.64"	65	W	1.5

RESULTS

A total of 58 plant species were recorded all along 24 sampling plots, and covering an area 0.024 ha. Regarding forest compartment boundary, randomly laid 19–23 sampling plots for compartment 1 and other remaining 1–18 & 24 sampling plots for compartment 2. In the forest density (dense) forest, randomly laid (1, 2, 4 & 11–18, 23–24) sampling plots and other remaining sampling plots were randomly laid for moderate dense forest. However, in the forest types, the sampling plots (Plot 1 & 2) were randomly laid in the East Himalayan Moist Mixed deciduous forest and other remaining was laid in the Very moist Sal bearing forest.

Plant density, frequency and importance value index

The tree species were recorded cumulatively, viz., adult, sapling and seedling in all the sampling plots. Of the 28 large tree species recorded in all the sampling plots, the adult individuals of *Shorea robusta* Gaertn. (316.67 Ind ha⁻¹; $\pm$ 0.506 SE) recorded the highest density followed by *Schima wallichii* Choisy (104.17 Ind ha⁻¹; $\pm$ 0.222 SE and *Pinus roxburghii* Sarg (104.17 Ind ha⁻¹; $\pm$ 1.315 SE) and *Lagerstroemia parviflora* Roxb. (66.67 Ind ha⁻¹; $\pm$ 0.494 SE). The lowest density (8.33 Ind ha⁻¹ each) were recorded for *Mangifera indica* L. and *Ficus benjamina* L. Other remaining density was showed in table 2. Regarding, the highest density of sapling and seedling was recorded for *Shorea robusta* Gaertn. (1250 Ind ha⁻¹; 3666.67 Ind ha⁻¹) followed by *Schima wallichii* Choisy (450 Ind ha⁻¹; 12500 Ind ha⁻¹) respectively.

Table 2. Availability and distribution of major tree species (dominant taxa) of Sumbuk RF, South Sikkim, India.

Scientific name and Family	Tree		Sapling		Seedling	
	Density (Ind ha ⁻¹)	Stdev Error	Density (Ind ha ⁻¹)	Stdev error	Density (Ind ha ⁻¹)	Stdev error
<i>Shorea robusta</i> Gaertn [Dipterocarpaceae]	316.67	0.506	1250.00	0.692	36666.7	0.888
<i>Schima wallichii</i> Choisy [Theaceae]	104.17	0.222	450.00	0.300	12500.0	0.559
<i>Terminalia myriocarpa</i> Van Heurck & Muller [Combretaceae]	20.83	0.500	100.00	1.000		
<i>Alstonia scholaris</i> (L.) R. Br [Apocynaceae]	12.50	0.500				
<i>Callicarpa arborea</i> Roxb. [Verbenaceae]	12.50	0.500				
<i>Ficus benjamina</i> L. [Moraceae]	8.33	0.000	50.00	0.500		
<i>Macaranga denticulate</i> Blume [Euphorbiaceae]	12.50	0.500				
<i>Pentapanax leschenaultia</i> (DC) Seem. [Araliaceae]	12.50	0.500	50.00	0.500		
<i>Diploknema butyracea</i> Roxb. [Sapotaceae]	12.50	0.500	33.33	0.000		
<i>Albizia procera</i> (Roxb.) Benth [Fabaceae]	16.67	0.000	50.00	0.500	5000.0	1.000
<i>Bombax ceiba</i> L. [Bombacaceae]	20.83	0.333	66.67	1.000	2500.0	1.000
<i>Phyllanthus emblica</i> Linn. [Phyllanthaceae]	54.17	0.183	183.33	1.202	3333.3	0.667
<i>Terminalia chebula</i> Retz. [Combretaceae]	25.00	0.577	100.00	1.000	5000.0	0.245
<i>Toxicodendron wallichii</i> (Hook.f.) Kuntze [Anacardiaceae]	45.83	0.401	133.33	0.333		0.645
<i>Terminalia crenata</i> Tul. [Combretaceae]	41.67	0.316	133.33	0.333	6250.0	0.707
<i>Bischofia javanica</i> Blume [Phyllanthaceae]	20.83	0.500	50.00	0.500	1666.7	1.000
<i>Mallotus philippinensis</i> Muell. Arg. [Euphorbiaceae]	25.00	0.000				
<i>Lagerstroemia parviflora</i> Roxb. [Lythraceae]	66.67	0.494	233.33	0.211	7916.7	0.477
<i>Toona ciliata</i> M. Roem [Meliaceae]	20.83	0.500				
<i>Bassia butyracea</i> Roxb. [Sapotaceae]	12.50	0.500	50.00	0.500		
<i>Terminalia belerica</i> Roxb. [Combretaceae]	12.50	0.500	83.33	0.500	2083.3	0.500
<i>Tectona grandis</i> L. [Verbenaceae]	62.50	0.500	200.00	2.000		2.906

<i>Daubanga grandiflora</i> (Roxb. ex. Candolle). [Lythraceae]	16.67	1.000	66.67	1.000		
<i>Chukrasia tabularis</i> A Juss. [Meliaceae]	12.50	0.500	66.67	1.000	2083.3	1.500
<i>Eugenia jambolana</i> Larn. [Myrtaceae]	12.50	0.500			1250.0	0.500
<i>Bridelia retusa</i> (L.) A. Juss [Euphorbiaceae]	12.50	0.500				
<i>Mangifera indica</i> L. [Anacardiaceae]	8.33	0.000				
<i>Pinus roxburghii</i> Farjon. [Pinaceae]	104.17	1.315	316.67	0.792	5000.0	1.000

Regarding frequency percentage of tree species, the maximum number of occurrences was recorded for *Shorea robusta* Gaertn (83.3%) followed by *Schima wallichii* Choisy (37.5%) and *Phyllanthus emblica* L. (33.3%) respectively. For sapling, the maximum number of occurrences was that of *Shorea robusta* Gaertn (75.0%) followed by *Schima wallichii* Choisy (41.7%) respectively. Whereas, in the seedling category, *Shorea robusta* Gaertn (62.5%) followed by *Schima wallichii* Choisy (11.95%) were recorded.

Shannon & Wiener (1963) species diversity, richness and evenness were calculated

A result pertaining to species diversity showed the highest diversity index of trees (2.78) followed by sapling (2.55) and seedling (2.38). Regarding the highest species richness was recorded for tree (37.81) followed by sapling (22.81) and seedling (15.81) as compared with species evenness of tree (0.817) followed by (0.749) and seedling (0.699) (Table 3).

Table 3. Different biodiversity measures of tree, sapling and seedling.

S.N.	Life form	Species diversity	Species richness	Evenness
1	Tree	2.78	37.81	0.817
2	Sapling	2.55	22.81	0.749
3	Seedling	2.38	15.81	0.699

The importance value index (IVI) was calculated as sum of relative frequency, relative density and relative dominance. The higher importance value index was recorded for *Shorea robusta* Gaertn (75.5) followed by *Schima wallichii* Choisy (22.4) and *Pinus roxburghii* Farjon (22.4) respectively. The lower IVI was recorded for *Ficus benjamina* L. (2.78) followed by *Bassia butyracea* Roxb. (3.17) respectively (Fig. 3).

Figure 3. Importance Value Index of major tree species of Sumbuk Reserve Forest, South Sikkim, India.

Girth classes

Based on girth class, other than the above additional sampling under different girth class was done for precise determination of stand structure with the gradient of 10 cm rise starting from 30 cm at gbh. Dominant species, as well as a few major tree species of the study site, was measured to understand the community structure.

The girth size classes were as follows:

30–40 = 1; 41–50 = 2; 51–60 = 3; 61–70 = 4; 71–80 = 5; 81–90 = 6; 91–100 = 7; 101–110 = 8; 111–120 = 9; 121–130 = 10; 131–140 = 11; 141–150 = 12; 151–160 = 13; 161–170 = 14; 171–180 = 15; 181–190 = 16; 191–200 = 17; 201–210 = 18; 211–220 = 19; 221–230 = 20; 231–240 = 21; 241–250 = 22; 251–260 = 23; 261–270 = 24; 271–280 = 25

The Girth Class profiles of the selected trees as showed in figure 4. The tree species *Shorea robusta* and *Tectona grandis* followed almost a normal distribution curve with less trees belonging to smaller and big GBH classes suggesting a fairly stable population in the study area. A reverse J-shaped curve for *Lagerstroemia parviflora*, *Schima wallichii*, *Pinus roxburghii*, *Terminalia crenata* which depicts more of the characteristics of a stable population is found. These tree species, there is larger proportion of smaller GBH class to moderate GBH class than fairly big to big GBH classes which does exits as the tree hardly grows to bigger GBH classes. Some of the species which showed an inverted J-shaped, with a higher density of lower diameter classes which suggests the characteristics of stable population in the forest. In the case of *Pinus roxburghii*, there is higher density of low diameter class and low density of high diameter class which depicts of an unstable population as there were very few or no trees in the smaller GBH class. This suggests that the population of these trees is more stable and can regenerate to mature trees under favorable conditions.

Figure 4. Girth size class-wise density (Ind ha⁻¹) of dominant tree species of Sumbuk RF, South Sikkim, India.

Distribution patterns (A/F) ratio

The distribution of species is one of the important aspects of ecological studies. In the present study, abundance to frequency ratio was observed for all the tree species showing contiguous distribution patterns. The tree species such as *Shorea robusta* (0.046) and *Phyllanthus emblica* (0.049) were random distribution in all the sampling plots. But none of the tree species showed regular distribution pattern.

Shrub/herb/ferns and fern-allies

A total of 30 Shrub/herb/ferns and fern-allies species belonging to 28 genera & 19 family were recorded in

all along with the sampling plots (Table 4). The changes in species diversity patterns reflect the moderate type of disturbance in the present forest. The lower value of shrub and herb in the forest indicates that the forest is under great pressure of anthropogenic disturbances. On the other hand, forest disturbance, reflecting, it might be under high interest of local peoples towards the utilization of herbs and shrubs. Finally, proper conservation and management actions should be taken immediately by concerned authorities to protect the endemic, endangered and threatened species in an ecosystem.

Table 4. Shrub/herb/ferns and fern-allies were recorded all along the sampling plots of Sumbuk RF, South Sikkim.

Scientific name and Family	Local name	Altitudinal gradients (m) asl
<i>Achyranthes aspera</i> L. [Amaranthaceae]		800–2300
<i>Acmella uliginosa</i> (Sw.) Cass [Asteraceae]		
<i>Ageratum conyzoides</i> L. [Asteraceae]	ElameyJhar	1000–1500
<i>Ageratum</i> sp. [Asteraceae]	ElameyJhar	
<i>Anisomeles indica</i> (L.) Kuntze [Lamiaceae]		
<i>Barleria</i> sp. [Acanthaceae]		
<i>Bidens pilosa</i> L. [Asteraceae]	Kuro	200–1900
<i>Boehmeria platyphylla</i> D. Don [Urticaceae]	Kamley	700–1500
<i>Chromolaena odorata</i> [Asteraceae]		
<i>Colebrookea oppositifolia</i> Sm. [Lamiaceae]	Dhure	200–2200
<i>Commelina benghalensis</i> L. [Commelinaceae]	Kane jhar	<2300
<i>Cycas</i> sp. [Cycadaceae]		1000–1800
<i>Cyperus compressus</i> L. [Cyperaceae]	mothejhar	900–1600
<i>Desmodium heterocarpon</i> L. [Fabaceae]	BakhreGhans	300–1800
<i>Drymaria cordata</i> (L.) Roem & Schutt [Caryophyllaceae]	Amilejhar	200–2400
<i>Fagopyrum</i> sp. [Polygonaceae]	Ban faper	
<i>Flemingia strobilifera</i> (L.) W.T. Aiton [Fabaceae]	Bhatmase	200–1600
<i>Gonestegia hirta</i> (Blume) Miq [Urticaceae]	Chiple	100–1000
<i>Imperata cylindrica</i> L. [Poaceae]	Siru	<1000
<i>Jasminum</i> sp. [Oleaceae]		
<i>Justicia</i> sp. [Acanthaceae]	Asuro	
<i>Lantana camara</i> L. [Verbenaceae]	Banmara	100–1500
<i>Leea asiatica</i> (L.) Ridsdale [Leeaceae]	Kaknasika	
<i>Lygodium flexuosum</i> (L.) Sw. [Lygodiaceae]		
<i>Lygodium japonicum</i> (Thunb.) Sw. [Lygodiaceae]		
<i>Oxalis corniculata</i> L. [Oxalidaceae]	Chari amilo	500–3400
<i>Rubus ellipticus</i> Sm. [Rosaceae]	Aiseule	1000–2600
<i>Thysanolaena maxima</i> (Roxb.) Kuntze. [Poaceae]	Thulovanso	600–1300
<i>Triumfetta homboidea</i> Jacq. [Malyaceae]		100–1500
<i>Woodfordia fruticosa</i> (L.) Kurtz [Lythraceae].	Amarphul	100–1500

DISCUSSION

In the present study, 28 tree species were recorded in 0.024 ha, whereas 200 tree species were reported by Gentry (1990) in a plot of 0.1 ha from tropical rain forest of central America and upper and central Amazonia. The tropical forest is home to many living animals as well as plant species. It has been estimated that many new species of plants, insects and micro-organisms are still yet to discovered. The tropical forest is a suitable and highly favorable environment for species (Linsenmair 1997). In the present study, the higher individual plant density of tree was recorded for *Shorea robusta* followed by *Schima wallichii* and *Pinus roxburghii*. Among them, the *Pinus roxburghii* was a higher standard error as compared to other species in the sampling plots. That means, the species was not uniformly distributed in all along with the sampling plots and it showed higher standard error. Out of 24 sampling plots, this species was distributed in 4 sampling plots. The standard error of balance can provide an uneven evaluation for intervals where the population balance is likely to decline. The statistical measures the accuracy with which a sample distribution represents a population by using standard deviation.

As per Dash & Singh (2011), the tropical forest of Sikkim has the maximum tree diversity is exhibited by *Shorea robusta*. Some places in the dry valley of South Sikkim, for example, Kitam forests, Chire pine (*Pinus roxburghii*), which are generally found elsewhere in subtropical and temperate regions, thrive well. In the present study of Sumbuk RF, *Shorea robusta* was highly dominated as compared to other species. Similarly, *Shorea robusta* exhibited higher sapling and seedling were recorded in all along the sampling plots. Tree

regeneration can be predicted by structure and composition of forest (Khan *et al.* 1987). Successful regeneration of tree species depends on the ability to produce large numbers of seeds and the ability of saplings and seedlings to survive and grow (Good & Good 1972). Forests with dense canopy may have affected the survival of seedlings (Pokhriyal *et al.* 2010) possibly by reducing the penetration of sunlight under the forest floor.

For frequency occurrences of tree, sapling and seedling, the maximum number of occurrences was recorded for *Shorea robusta* followed by *Schima wallichii*. Maximum number of plant species in tropical and subtropical forests is predicted to be predominantly by *Shorea robusta* and *Schima wallichii* in the surveyed areas.

The importance value index (IVI) is often used in ecological studies because it shows the ecological importance of a species in a particular ecosystem. The IVI is also used to prioritize species conservation, with low IVI species requiring a high conservation priority compared to the high IVI species. In the present study, the high IVI exhibited by *Shorea robusta* is largely due to its higher relative frequency, relative density and relative dominance compared to other species. In the present study, many species with low IVI values are reported which means the species are rarely distributed in the forest. The lower IVI were recorded for *Ficus benjamina* and *Bassia butyracea*. *Ficus benjamina* is houseplants in the tropical forest which is either planted in the forest or cultivated plants. Similarly, *Bassia butyracea* was second lowest importance value index in all along the sampling plots. There are many ecological reasons for the lowest IVI, 1) due to unsustainable harvesting of fruits of *Bassia butyracea* (Churi) for edible purpose; 2) the regeneration is decreased due to anthropogenic disturbance during the plant community development stage and 3) Sumbuk reserve forest is one of the fire-prone zone in Sikkim. So, this plant species needs to be conserved and preserved for further conservation plan and the fruits are also good feed for wildlife species. Lemenih (2011) has added that adequate regeneration status makes it possible for the occurrence of sustainable forest management.

The distribution of species is one of the important aspects of ecological studies. According to the Odum (1971), species distribution can be divided into three broad patterns, random, regular, and connected. In general, higher frequency and lower abundance indicates regular distribution pattern while low frequency and high abundance indicates contiguous distribution. These two tree species such as *Shorea robusta* (0.046) and *Phyllanthus emblica* (0.049) were randomly distributed in all the sampling plots.

In the present study, the result of species diversity showed the highest diversity index for trees (2.78) followed by sapling (2.55) and seedling (2.38). The species diversity ranges from 2.38 to 2.78 is more as compared to the tropical dry evergreen forest ($H = 2.28$) of South India (Parthasarathy & Sethi 1997) and almost equal to the tropical moist deciduous forests ($H = 0.56\text{--}2.79$) of Himalayan Terai (Bajpai *et al.* 2012, 2017, 2020). However, Pascal (1988) reported much higher Shannon Weiner's Index (4.3) for the wet evergreen forest of the Western Ghats. It is evident from the results that in general species diversity of tropical dry deciduous forests is much lower as reported in the present study. Species diversity is one of the most important indices used for evaluating the sustainability of forest communities (Rad *et al.* 2009). Shannon-Weiner diversity index usually fluctuates from 1.5 to 3.5 and rarely exceeds 4.5 (Kent & Coker 1992) and is generally higher in tropical forest. The results of beta diversity show that diversity index values of 0.2 to 2.35, a low index value compared to the values reported by others in different sites with different environmental gradients (Thakur & Khare 2006).

Regarding the highest species richness was recorded for tree (37.81) followed by sapling (22.81) and seedling (15.81) as compared with species evenness of tree (0.817) followed by sapling (0.749) and seedling (0.699). Species uniformity tells us how species are evenly distributed across the ecosystem that scarcely distributed species need to be focus. During the present study, observed the lowest species evenness in the study sites showed by seedling followed by sapling and tree. The high species evenness was recorded for tree; the number of individuals within a species is fairly constant throughout the community. The value of species richness in the present study was found to be falling between ranges 15.81 to 37.81. Species richness is the quantity of different species represented in a community, landscape or ecological region. According to girth classes, the tree species *Shorea robusta* and *Tectona grandis* followed almost a normal distribution curve with less trees belonging to smaller and big GBH classes suggesting a fairly stable population in the study area. A reverse J-shaped curve for *Lagerstroemia parviflora*, *Schima wallichii*, *Pinus roxburghii*, *Terminalia crenata* which depicts more of the characteristics of a stable population is found in the study area.

CONSLUSIONS

Through a rapid biodiversity survey, it is quite clear that the forest is highly dominant by tree species *Shorea robusta* as compared to other species. *Pinus roxburghii* has fragment distribution in all along with the sampling

plots. It may be noted that the trees might have a broad distributional range and the present survey only took up a small part of it. There might also be other reasons which may be connected to human infringement during the process of plant community development.

The floristic composition of the study site depicts tropical floral diversity in the Sikkim context despite habitat disturbance due to forest fire-prone zone, unsustainable harvesting of wild edible fruits, small landslide and landslide. Total plant diversity of 58 plant species on a small area of 0.024 ha is a value that can be said to be rich, even if the sampling performed was at best not close to one percent of the sampling intensity. However, it documents that rapid biodiversity survey needs to be conducted on a different season to get the overall picture of biodiversity value in the sub-tropical forest of Sikkim.

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