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Composition and Diversity Pattern of Climbers in Tropical Forest of Langchenphu, Jomotshangkha Wildlife Sanctuary

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Abstract

Since early civilization, climbers are well known and valued as non-wood forest products as well as medicinal plants. The study was conducted to determine the composition and diversity pattern of climbers along altitudinal gradient in the forest of Agoorthang and Jangsa *Chiwog* under Langchenphu *Gewog*. Three elevational transects with 10 x 10 m plots were assessed for presence of climbers. A total of 152 plant species from 30 plots were recorded. Asteraceae, Rosaceae, Fabacea and Viteacea were dominant families. Mean richness ranged from 0.78-1.28 between three elevational zones. Species richness and Shannon index were high in the lowest elevation and vice versa. One-way ANOVA showed a significant difference in climber richness and diversity at different elevations ($p < .05$). No significant relationship was found between the diversity indices of climbers and the diversity indices of associated species. Diversity of climbers was high in lower elevational zone where temperature was higher (23.89 ^{0}C). Exploitation of medicinal climbers is high in the study area. Conservation of climbers in the study area will be accelerated through attentions of proper management and monitoring process.

Keywords: altitudinal gradient, climbers, diversity pattern, environmental parameters

Introduction

Climbers are important medicinal plants. Climbers depend on other plants for support in their natural environment (Gentry, 1991). There are 12,382 climber species from 143 families and 1,415 genera in the Old World (Hu and Li, 2015). According to Rana and Rawat (2017), there are 858 climber species in the Himalayas of which 573 are woody and 285 herbaceous climbers. Among these, 313 species of climbers are reported from Bhutan (Grierson and Long, 1983, 1984, 1987, 1991, 1999, 2001; Noltie, 1994).

Climbers are widespread worldwide (Putz, 2012). According to Gentry (1991), climbers are abundant in the tropical forest with 133 families and 9,216 species in the neotropics. Climbers contribute significantly to composition, structure and functional diversity of tropical forest (Benavides *et al*., 2005). Climbers help in nutrient cycling and have medicinal values (Schnitzer and Bongers, 2002). Despite being very important plants, climbers are given less attention by researchers in Bhutan. Though the Flora of Bhutan has provided a comprehen-

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sive list of climbers, there is no detailed study and update so far.

According to Grierson and Long (1983), there are some species such as *Connarus paniculatus* Roxb., which is included in the Flora of Bhutan yet not confirmed to occur in the eastern Himalaya. In Jomotshangkha Wildlife Sanctuary (JWS), which is bordered with Assam and Arunachala Pradesh of India, extraction and exploitation of medicinal climbers is rampant. Consequently, it is of paramount importance to study the composition and diversity of climbers, for they are also important non-wood forest products, for their sustainable management and harvesting in Bhutan. This study aimed to assess the composition of climber species along an altitudinal gradient in the forest of Langchenphu in JWS and analyze their relationship with the associated species.

Materials and Methods

Study area

This study was conducted in Agoorthang and Jangsa *Chiwogs* (Figure 1) of Langchenphu *Gewog*, Jomotshangkha Wildlife Sanctuary (26°48'N, 26°60'N; 91°42'E, 92°08'E). The area borders with Assam and Arunachal Pradesh of India. The *Chiwogs* have hot and humid weather during summer. Langchenphu *Gewog* gets heavy precipitation from June till end of September and winter is cool and dry (Dzongkhag administration, Samdrup Jongkhar, 2018). The altitude of Langchenphu ranges from 200 to 2300 meter above sea level, which consists of sub-tropical, cool broad-leaved and warm broadleaved forests, and grassland on southern part of the sanctuary (DOFPs, 2018).

Study design

The field work was conducted in the forests of Langchenphu *Gewog* along its altitudinal gradient. Two vegetation types (grassland and broadleaved forest) were selected using Quantum Geographic Information System at four elevation levels (250 m, 750 m, 1250 m, and 1750 m) in natural forest following Homeier *et*

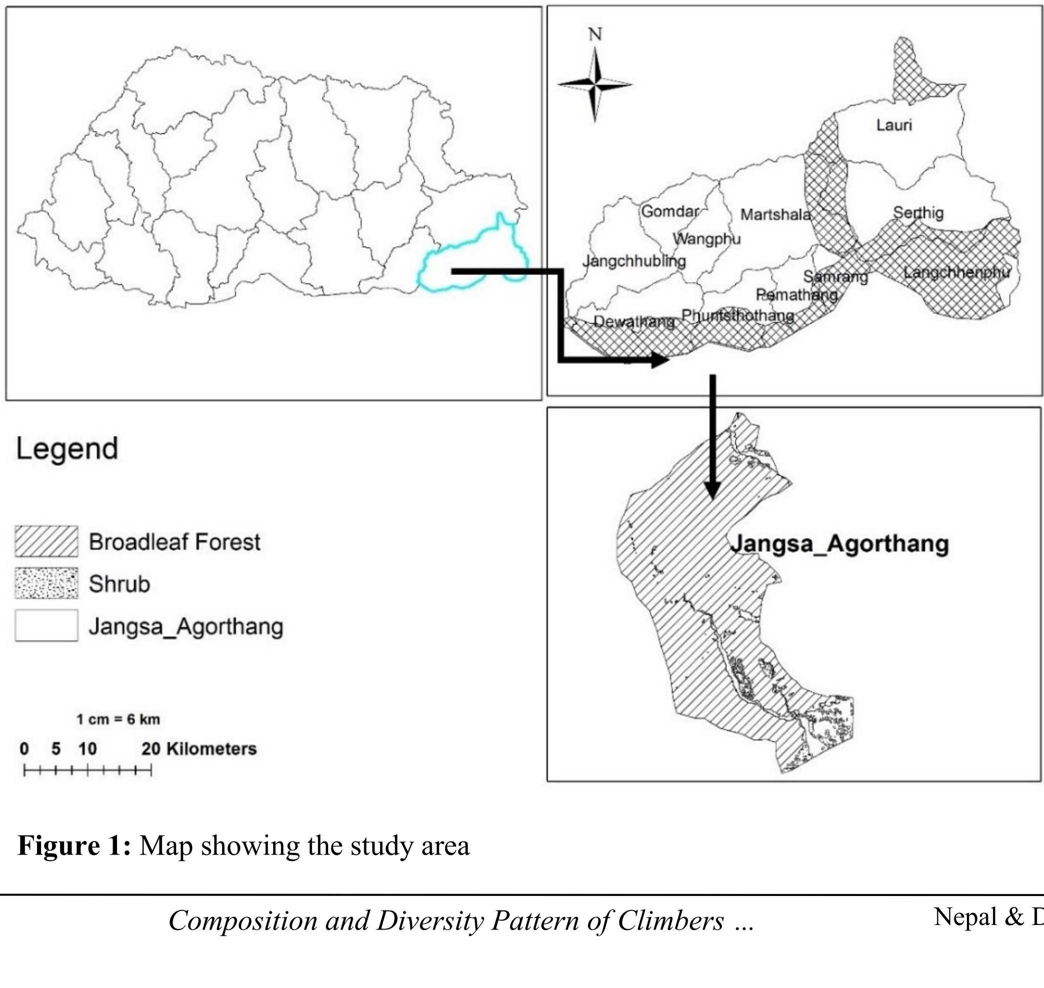

Figure 1: Map showing the study area

al. (2010). At each elevation, 10 sample plots of 10 x 10 m were systematically laid out at 100 m intervals in areas with less human disturbances (Homeier *et al.*, 2010). Field equipment such as digital hypsometer, compass, clinometer, Global Positioning System, diameter tape, measuring tape and digital camera were used for the collection of data.

Tree heights and diameters at breast height were measured (1.3 m above the ground) for determination of basal area. All the climbers included inside the quadrat 10 x 10 m were enumerated but those which are rooted outside the plots were not enumerated following Putz (1984). Diameters of lianas were measured at 1.3 m from their base following Parthasarathy *et al*. (2004).

Collection of vegetation data and processing
To study the species associated with climbers, diameters at 1.3 m above the ground level for each tree was measured for basal area calculation which was later on used for cluster analysis. Data collection for tree diameter was done in 10 x 10 m plot. Inside the tree plot, two nested plots of 5 x 5 m for shrubs and 1 x 1 m for herbs were laid out based on Mandal and Joshi (2014). Data processing was done using pivot table in MS Excel. Species from sample plots were grouped to find out diversity, evenness, and dominance.

Identification of specimens
Species were identified using Flora of Bhutan (Grierson and Long, 1983, 1984, 1987, 1991, 1999, 2001; Noltie, 1994). Unidentified species were collected from the field and taken to the National Biodiversity Centre for identification. Sterile and unidentified specimens were given species code for the analysis (e.g., UK1, UK2).

Estimating diversity indices
Species diversity (*H'*) and abundance were calculated following the Shannon and Weiner diversity index provided below (Shannon, 1948).

Shannon's diversity;

$$H' = -\sum_{i=1}^{s} (pi)(\text{Ln}pi)$$

Where, *P* is the proportion (*n*/*N*) of each species, *n* is the number of individual species, *N* is the total number of species, Ln is the natural log and Σ is the sum of the calculations.

Species richness;

$$S_R = (S-1)/\ \text{Ln}N$$

Where, *S* is the sum of species, *N* is the total number of all species observed. Species estimation was done using Jackknife's method (Tukey, 1958). The first and second order Jackknife estimators of species richness are based on incidences (Newton, 2007).

Dominance;

$$D = \frac{1}{N}\left\{\sum_{i \varepsilon T} (xi-x')^2 + \sum_{j \varepsilon U} xj^2\right\}$$

Where, χi is the actual percent share (relative basal area is adopted here) of the top dominant species (T), i.e., in the top dominant species in the one-dominant model, or the two top dominants in the two-dominant model and so on; χ' is the ideal percent share based on the model as mentioned above and χ is the percent share of the remaining species (*U*). *N* is the total number of species.

Measurement of relative abundance (RA)
Relative abundance was determined based on Mishra (1968);

$$RA = n / N \times 100$$

Where: *n* = the number of particular species
N = the total observation detected for all species.

Results and Discussion

Species composition and dominance

A total of 152 species were recorded from 30 plots in three elevational transects. From the 38 climbing plant species belonging to 20 families recorded, 36 species were identified up to species level (Table 1). Thirteen species of climbers were recorded as incidental which include *Mucuna macrocarpa* Wall., *Cissus* sp., *Ampelocissus divaricata* (Wall. ex Lawson) Planch., *Mimosa* sp., *Clematis* sp.1., *Clematis* sp.2., *Cissampelos* sp., *Ampelocissus* sp., *Pothos* sp., *Caesalpinata* sp., *Tetrastigma* sp., *Tinospora* sp., UK3. In all the three transects, trees were dominant (38.16%, *n* = 58), followed by shrubs (25.66%, *n* = 39), climbers (25%, *n* = 38), herbs (8.55%, *n* = 13), and pteridophytes (1.32%, *n* = 2), and graminoid (1.32%, *n* = 2) (Figure 2).

The number of climber species recorded in Table 1 accounts 17.17% of the total climbers (297) found in the country. This suggests that the study area is rich in climber diversity. High numbers of climbers were expected since climbers are mostly found in tropical and subtropical areas (Addo-Fordjour *et al*., 2012; Naidu *et al*., 2014). A study carried out in Dachigam National Park of Kashmir Himalaya, India by Shameem *et al*. (2010), showed that variables such as precipitation and altitude are the main factors responsible for the variation in species diversity. Since most of the vines were annuals, they die during winter. It could also be because of less precipitation and moisture that the number of climbers encountered was less during the study period.

Species dominance

Among 19 families recorded, species were abundant under Asteraceae, Piperaceae, Vitaceae, and Fabaceae families. The findings are similar to a study done by Kumar *et al*. (2013) in sub-tropical forest in Jharkhand where Asteraceae, Piperaceae, Vitaceae and Fabaceae were dominant families. In semi deciduous forest of southern Brazil, Asteraceae, Apocynaceae, Passifloraceae, Malpighiaceae were reported as dominant families. Santos *et al*. (2009) noted that most climbers belonged to Asteraceae, Apocynaceae, Passifloraceae and Malpighiaceae, which aligned to the finding. Similar finding was reported by Rahman *et al*. (2009) in semi-deciduous rainforest of Ghana, where dominant families were Apocynaceae and Passifloraceae.

Dominance curve (Figure 3) shows dominance diversity of each species at logarithmic sum computed based on relative abundance. The most dominant climbers were *Mikania micrantha, Piper mipigua, Paederia* sp., *Tetrastigma serrulatum, Tricosanthes* sp., *Hedyotis* sp., *Merremia* sp., *Caesalpinia cucullata,* and *Periploca calophylla.*

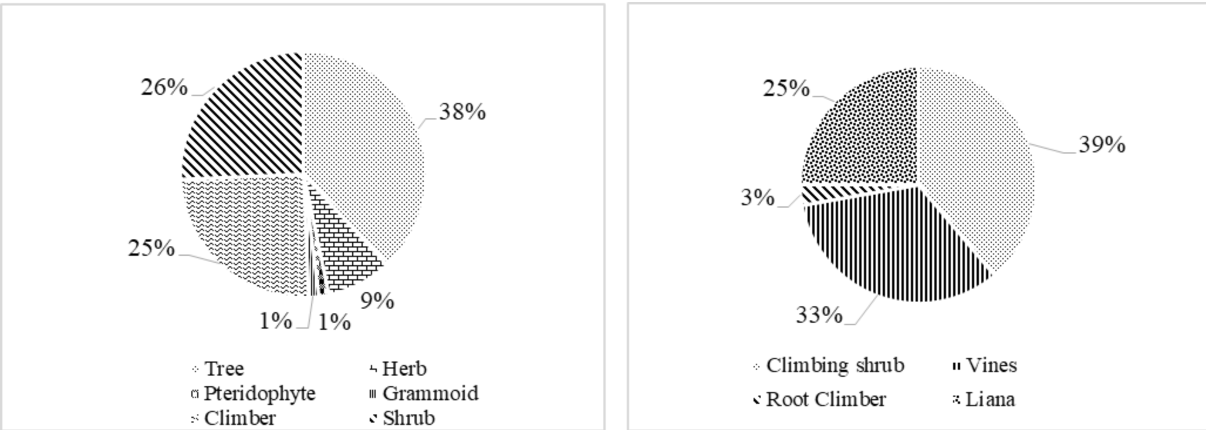

Figure 2: (A) Percentage of species in a plant group; (B) Percentage of different types of climbers

Table 1: List of climbers and their characteristics, Jangsa, Agoorthang Chiwog

Species	Family	Type	Mechanism
Acacia rugata (Lam.) Fawc. & Rendle	Fabaceae	Thorny liana	Twiner
Artabotrys sp.	Annonaceae	Climbing shrub	Twiner
Bridella stipularis (L.) Blume	Phyllanthaceae	Climbing shrub	Twiner
Caesalpinia cucullata Roxb.	Fabaceae	Climbing shrub	Hooker
Clematis smilacifolia var. andersonii C.B.Cl. ex Kuntze	Ranunculaceae	Liana	Twiner
Combretum wallichii var. flagocarpum (C.B. Clarke) M.G. Gangop. & Chakrab	Combretaceae	Climbing shrub	Twiner
UK2			
Dioscorea alata L.	Dioscoreaceae	Herbaceous vine	Twiner
Entada rheedi Spreng.	Fabaceae	Liana	Twiner
Meremia sp.	Convolvulaceae	Perennial climber	Twiner
Ficus sp.	Moraceae	Liana	Root climber
Gouania leptostechya Dc.		Climbing shrub	Twiner
Passiflora sp.	Passifloraceae	Climbing shrub	Twiner
Heterosmilax japonica kunth	Smilacaceae	Lianes	Twiner
Tricosanthes sp.	Cucurbitaceae	Vines	Tendril climber
Mucuna pruriens (L.) DC	Fabaceae	Liana	Twiner
Mikania micrantha Kunth.	Asteraceae	Creeping climber	Twiner
Milletia pachycarpa Benth.	Fabaceae	Climbing shrub	Hooker
Paederia sp.	Rubiaceae	Vines	Twiner
Hedyotis sp.	Rubiaceae	Climbing shrub	Tendril climber
Periploca calophylla (Wight) Falc.	Apocynaceae	Climbing shrub	Twiner
Maclura sp.	Moraceae	Climbing shrub	Twiner
Piper sp.1	Piperaceae	Creeping climber	Root climber
Piper sp.2	Piperaceae	Creeping climber	Root climber
Piper suipigua Buch.-Ham. ex D. Don	Piperaceae	Creeping climber	Root climber
Dischidia sp.	Apocynaceae	Epiphytic climber	Root Climber
Porana paniculata Roxb.	Convolvulaceae	Creeping climber	Twiner
Tetrastigma bracteolatum (Wall.) Planch.	Vitaceae	Liana	Twiner
Dioscorea sp.	Dioscoreaceae	Vines	Twiner
Schefflera pubigera (Brongn. ex Planch.) Frodin	Araliaceae	Climbing shrub	Twiner
Smilax prolifera Roxb.	Smilacaceae	Thorny Liana	Twiner
Tetrastigma serrulatum (Roxb.) Planch.	Vitaceae	Liana	Twiner
Actinida strigose Hook. f. & Thoms. ex Benth.	Actinidiaceae	Climbing shrub	Twiner
Tinospora cordifolia (Wild.) Miers	Menispermaceae	Climbing shrub	Twiner
UK1			
Secamone sp.	Apocynaceae	Vines	Twiner
Zehneria japonica (Thunb. ex Murray)	Cucurbitaceae	Vines	Tendril climber
*Merremia vitifolia (*Burm. Fil.) Hall.fil.			

Species area curve

Species area curve for 30 plots of three elevational transect was computed in PC-ORD based on Euclidean (Pythagorean) distance measure. The curve shows inadequate sampling since it did not reach asymptotic point (Figure 4). The first order Jackknife estimates presence of 56 species and second order Jackknife esti-

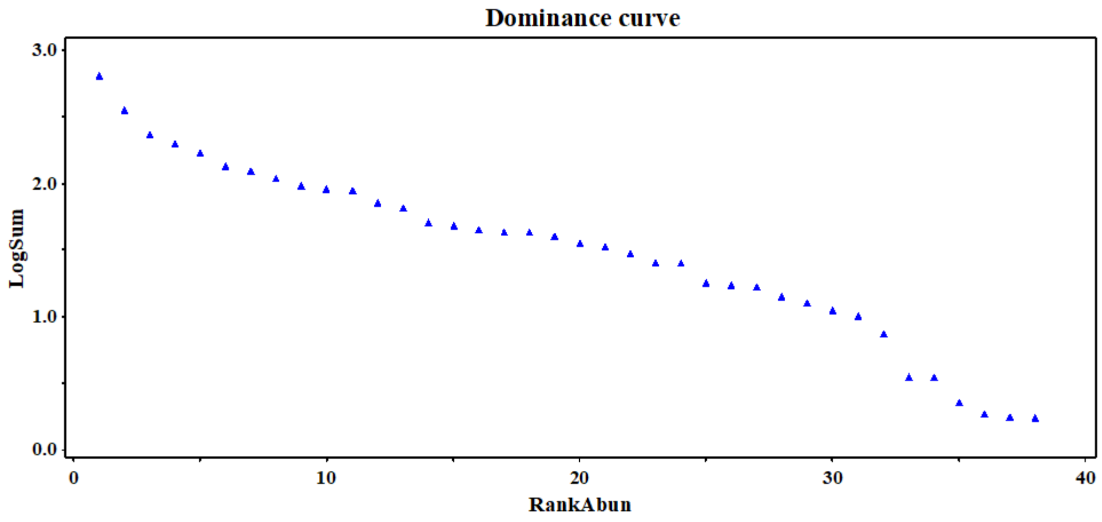

Figure 3: Dominance curve of 38 plant species based on abundance; each triangle denotes a species

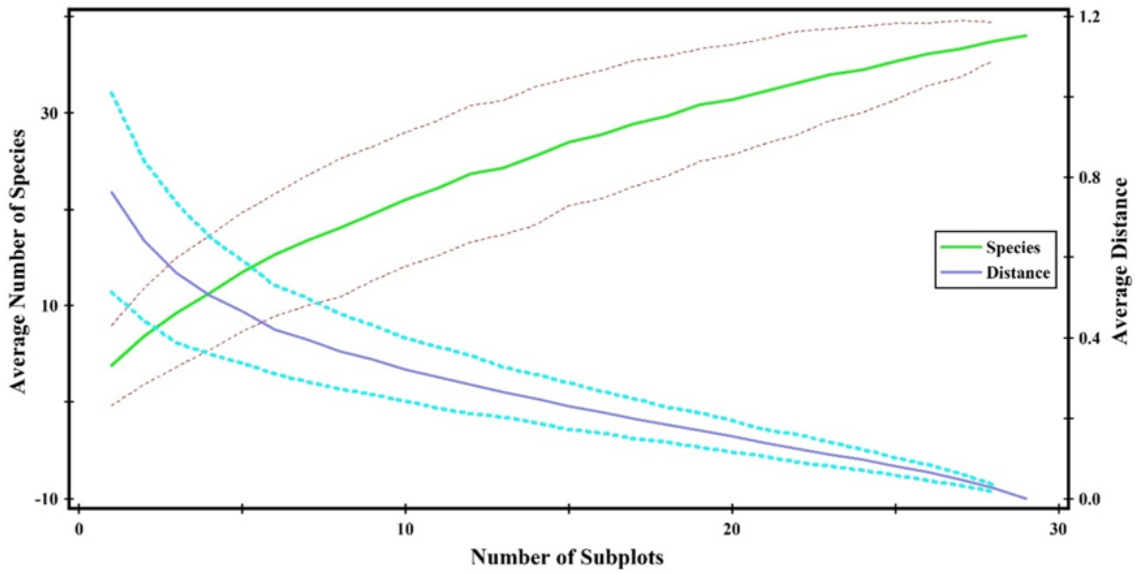

Figure 4: Species accumulation curve (green line) used to assess sample adequacy

mates 68 species. This variation in species composition and richness could be due to seasonal variation, low precipitation and moisture content as observed by Araujo and Alves (2010) and Shameem *et al*. (2010), since abundance and distribution of climber is affected by precipitation and seasonality (Durigon *et al*., 2013). Climbers are abundant in humid and moist areas. The number of climber species observed was low which could be attributed to the data collection in winter.

Species richness, diversity, evenness and dominance

Species richness, Shannon index, Evenness and Dominance were compared between three elevational zones. Mean richness ranged from $S_{R=}$ 0.77 to $S_{R=}$ 1.20, while Shannon (*H'*) ranged from 0.66 to 1.25 in three zones (Table 2). There was not much variation in evenness in three zones whereas the dominance was higher in higher elevation than in lower elevation.

One-way ANOVA showed a significant vari-

Table 2: Summary of species diversity at three elevational zones

Elevational zones	Richness	Shannon	Evenness	Dominance
250 m	1.21	1.26	0.79	0.26
750 m	0.83	0.84	0.8	0.35
1200 m	0.78	0.67	0.79	0.42

ation of species diversity along the elevational gradients (250, 750, and 1250 m); $F_{(2, 27)} = 5.7$, $p = 0.008$. Furthermore, a Bonferroni Post hoc on different elevation showed that the lowest elevation (250 m) had significantly higher climber species ($M = 56$, $SD = 17$) compared to mid-level with 750 m ($M = 0.39$, $SD = 0.17$) and at 1250 m ($M = 0.17$, $SD = 0.92$).

Diversity and composition of climbers are more at lower elevation than at higher elevation (Bhattarai and Vetaas, 2003; Chawla *et al*., 2008). In this study, richness and diversity were higher at lower elevation, but dominance increased with elevation, whereas evenness remained same for all the three zones. Higher diversity at lower elevation could be due to higher temperature, precipitation, and moisture (Shameem *et al*., 2010) and more human intervention (Schmitt *et al*., 2010).

Classification of forest types

The forest was classified according to relative basal area (Relative Dominance) of individual species inventoried within the sample plots (10 x 10 m). The classification using Sorenson distance measure gave two-vegetation types with 12% information remaining (Figure 5). Forest classification was done to study association of climbers with different habitats.

Classification of forest type was based on assumptions that the elevation below 1000 m is tropical and between 1000 to 2000 m is subtropical forest. However, considering the need to have rainfall on a daily basis does not qualify the forest to be a true tropical forest.

I. Tropical forest

The first group (considered as tropical forest) comprised of 250 m and 750 m groups. The annual mean temperature and precipitation in

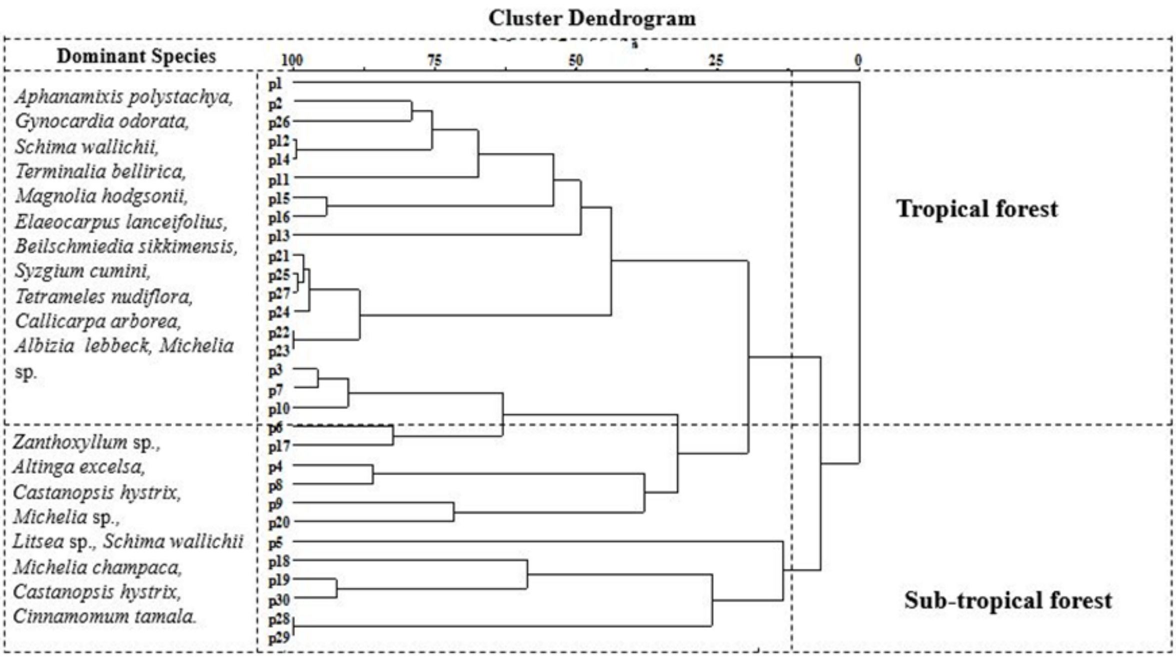

Figure 5: Classification of forest types based on Sorenson method

this forest was 22.53 ^{0}C and 3,085.52 mm respectively. This zone is relatively wet and moist compared to the other forest type. This forest type was dominated by tree species such as *Aphanamixis polystachya* (Wall.) R.N. Parker, *Gynocardia odorata* Roxb., *Schima wallichii* (DC.) Korth., *Terminalia bellirica* (Gaertn.) Roxb., *Magnolia hodgsonii* (Hook.f. & Thomson) H.Keng, *Eleocarpus lanceifolius* Roxb., *Beilschmiedia sikkimensis* King ex Hook.f., *Syzygium cumini* (L.) Skeels, *Tetrameles nudiflora* R.Br., *Callicarpa arborea* Roxb., *Albizia lebbeck* (L.) Bentham, and *Michelia* sp., which are indicators of tropical forest.

II. Sub-tropical forest

The sub-tropical forest was dominated by tree species such as *Zanthoxyllum* sp., *Liquidambar excelsa* (Noronha) Oken, *Castanopsis hystrix* Miq., *Michelia* sp., *Litsea* sp., *Schima wallichii, Michelia champaca, Cinnamomum tamala* (Buch.-Ham.) T.Ness & C.H.Eberm (Wangda and Ohsawa, 2006). Plots 21 to 30 which are located at 1250 m comprised of sub-tropical forest. The mean annual temperature and precipitation in this zone are 18.787 ^{0}C and 2,909.13 mm respectively.

Climber composition

Cluster analysis of climbers provided two categories. Climber diversity was high in lower altitude at 250 m (n = 22) followed by moderate diversity at altitude 750 m (n = 9). Climber diversity at 1200 m was the least (n = 7). Tropical forest mainly consisted of dominant species such as *Paederia* sp., *T. serrulatum,* and *P. mipigua* (Figure 6). A diverse group consisting of *Smilax* sp. and *Raphidophora grandis* Ridl. were encountered in sub-tropical forest at 750 m.

In sub-tropical forest, a study by Hu and Li (2015) observed that the dominant families in the Himalayan region are Fabaceae, Apocynaceae, Convolvulaceae, Cucurbitaceae, and Vitaceae which were also observed in the cur-

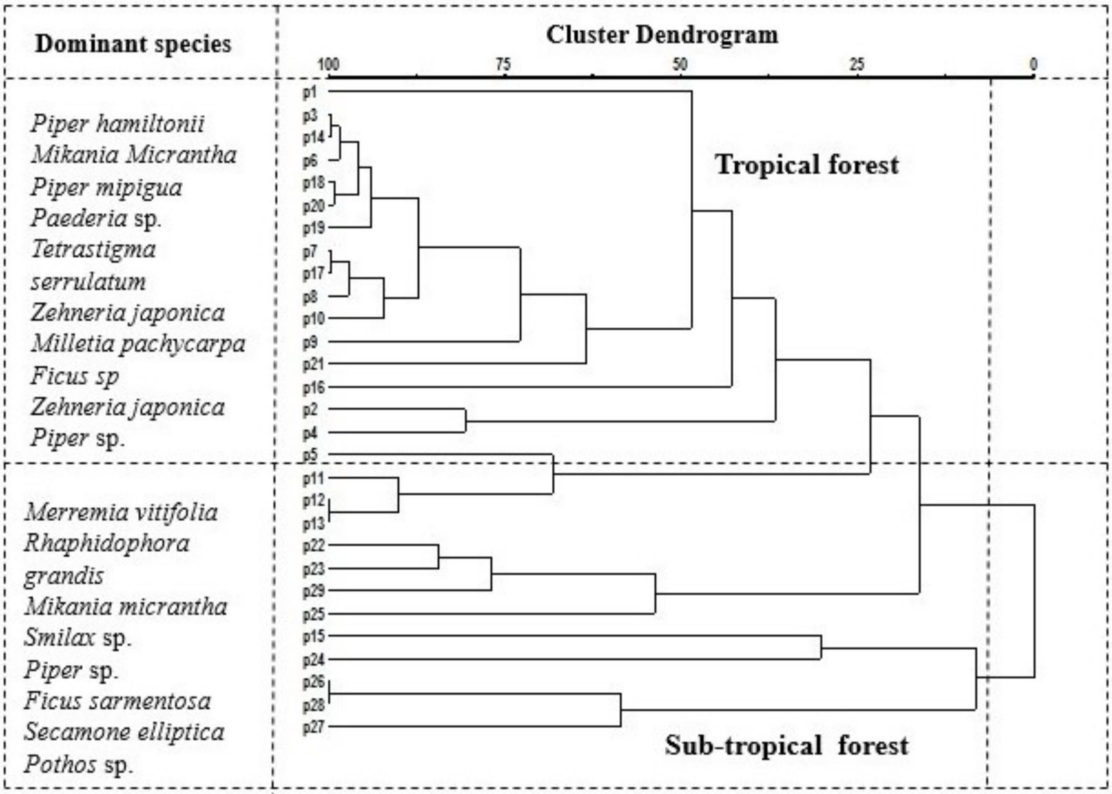

Figure 6: Cluster dendrogram of habitat association using Sorensen method

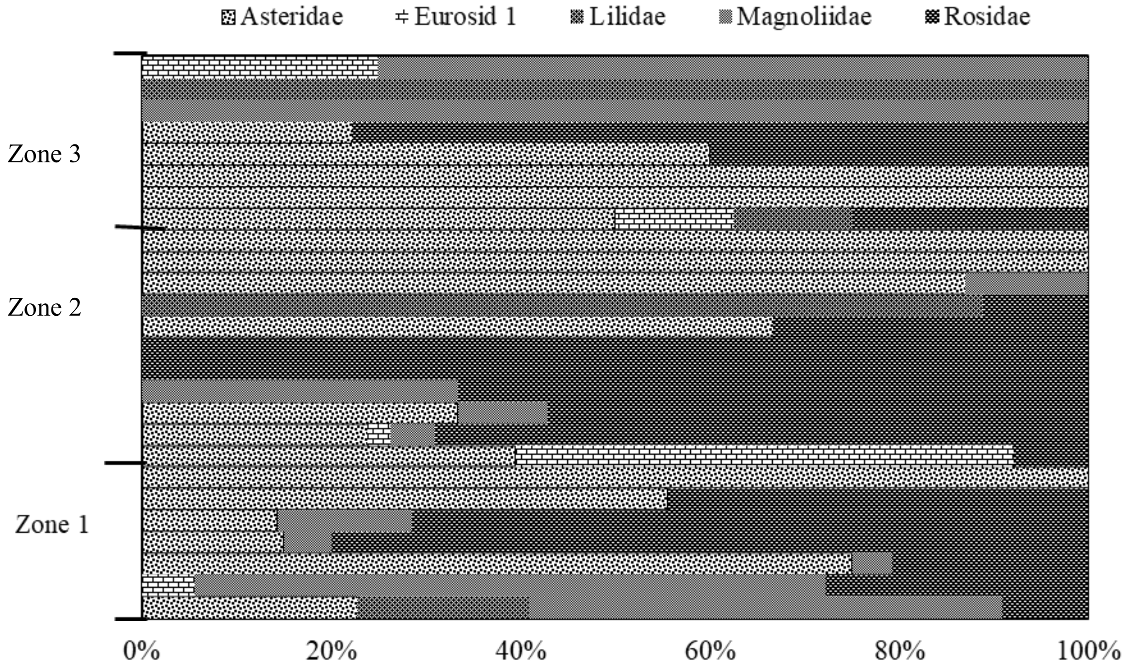

Figure 7: Species composition (%) in three elevational zones (Zone 1: 250 m; Zone 2:750 m; Zone 3; 1250 m)

rent study. Maximum number of climbers were encountered in tropical forest (n =22). Findings from Asia and Asia-Pacific also encountered maximum number of climbers from tropical forest (Santos *et al*., 2009).

The most dominant families from the area were Fabaceae, Vitaceae, and Convolvulaceae. The higher diversity at lower elevation could be due to higher temperature and precipitation. Man-made disturbances such as clearing of areas also promote climber diversity by reducing canopy coverage and increasing light interception.

Sub-tropical forest ranged from altitude 1000 to 2000 m. It was dominated by *Pothos* sp., *Piper* sp., *Smilax* sp., and *Raphidophora grandis.* The area experiences dry conditions unlike tropical forest. The forest is undisturbed and is not managed. Soil pH was acidic and bulk density was similar. Sub-tropical forest shares similar species of climber with tropical forest.

Species composition and distribution

The most dominant species was *Mikenia micrantha* Kunth. of Asteraceae family which was found in all three elevational zones. Several medicinal climber species such as *Smilax* sp., *H. japonica, T. serrulatum* were observed in all the three elevational zones.

Sub-class Rosidae composed of 34.04% of climber species in the tropical forest followed by Asteridae with 43.05%. Eurosid 1 had the least composition (3.40%). The second elevation zone was dominated by Asteridae followed by Rosidae. According to Hu and Li (2015), Himalayas has Leguminosae, Apocynaceae, Convolvulaceae, Cucurbitaceae and Vitaceae as dominant families. Diversity of climbers decreased with increasing altitude and decreasing temperature and precipitation. Durigon *et al*. (2013) and Shameem *et al*. (2010) observed that climbers grow well in areas where rainfall is high.

Relationship between climber and associated species

A total of 58 species of tree, 2 species of graminoid, 3 species of pteridophytes, 39 species of shrubs and 12 species of herbs were associated with climbers in all three elevational zones. There was no significant relationship between climber and tree diversity (r_s = -0.071 p = 0.711), shrubs (r_s = 0.212, p = 0.162) and herbs (r_s= 0.289, p = 0.260). Though there was no significant relationship between associate species, Garbin *et al*. (2012) found that diversity of associate tree species and shrubs is highly correlated. It also suggests that dominant tree species do not have much effect on the diversity of climbers. A study in secondary rain forest of the Biological Gardens of the Obafemi Awolowo University, Ile-Ife Nigeria, explains that climber diversity is related with tree and shrub diversities (Muoghalu and Okeesan, 2005). This difference could be due to seasonal variation, where most of the shrubs and herbs die (Araujo and Alves, 2010). Similar finding was reported by Ghollasimood *et al.* (2012) where association of associated species was not significant.

Climbing mechanism

Four climbing mechanisms were recorded; twiner (n = 27), hooker (n = 2), tendril climber (n= 3), and root climber (n = 6). Out of 38 species, 71% were twiners followed by root climbers (13%) and tendril climber (7%). Reddy and Parthasarathy (2003) and Parthasarathy *et al*. (2004) have reported similar findings in different tropical forests. Only few species belonging to Apocynaceae, Fabaceae and Piperaceae used roots to climb host plants. Twiners occurred in almost all the plots and the rattan in the highest elevation zone (1250 m).

Conclusion

Composition and diversity of climbers (lianas and vines) were relatively high in lower elevation. Richness and dominance of climber species increased with elevation, whereas evenness remained constant in all the three zones. Climbers' distribution was affected by associated shrubs, herbs and tree species. There was no association between climbers and associated species. However, climbers were abundant in area with human intervention. Climbers were classified into five categories; twiner (n = 27), hooker (n = 2), tendril (n = 3), and root climber (n = 6). Exploitation of medicinal climbers is high in the study area. Consequently, appropriate management and monitoring are deemed indispensable for climber diversity conservation in the study area.

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