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Analysis of Vegetation Dynamics of Tree Species inside the Forest of Institute of Forestry, Hetauda.

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KEYWORDS

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ABSTRACT

A vegetation analysis of tree species was undertaken in the 92.69 hectares (ha) of the forest connected to the Institute of Forestry (IOF), Hetauda Campus. The study separated the forest into two strata, and a total of 10 circular sample plots (each plot measuring 500 m^2) were constructed using systematic sampling with a sampling intensity of 0.5%. Enumeration of tree species was carried out within the sample plots. A total of 139 individual trees representing 16 (10 in stratum 1 and 12 in stratum 2) different tree species were recorded (60 in stratum 1 and 79 in stratum 2). Diversity indices were used for calculating vegetation parameters. According to the Importance Value Index, *Shorea robusta* was dominant in both strata, followed by other heterogenous species. The Shannon Wiener's index and Simpson's Diversity Index were higher in stratum 2, but the dominance index was lower than in stratum 1. Stratum 2 had a marginally higher measure of both evenness and richness than stratum 1. The study investigated the vegetation structure of the riverine and tropical moist deciduous forest in the study area. Increasing human interference had no significant effect on diversity and number of species among the strata. This study provides the baseline data necessary to characterize the phytodiversity of the forest area of the Institute of Forestry, Hetauda Campus for conservation and sustainable management.

Introduction

Forests are a critical component of the world's biodiversity as forests cover nearly one-third of terrestrial ecosystems globally, equivalent to 4.06 billion hectares (ha) (FAO, 2020). Tropical forests are recognized as the richest biological communities and harbouring a significant amount of global diversity (Naidu and Kumar, 2016).

One of the key analytical traits of the plant ecosystem is species diversity (Malik, 2014) and species richness is a straightforward and understandable indicator of biological diversity (Peet, 1974). Distinguishing plant communities has been at the heart of vegetation science

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for centuries, with a traditional focus on the distribution, composition and classification of plant communities (Kashian et al., 2003). The assessment of forest community composition and structure is pivotal in understanding the status of tree populations, regeneration, and diversity for conservation purposes (Mishra and Crews, 2014). Identification of plant communities aids learning of the species behaviour, habitat, niche, and structure (Khan et al., 2017). The conservation of natural regions also depends on the identification of vegetation species and analysis of species diversity patterns (Zhang et al., 2013). A quantitative evaluation of community structure is required for a precise assessment of biodiversity, and it is fundamental to conservation biology (Oosting, 1956; Mwavu et al., 2009; Dash, 2021). Because of its significant impact on conservation practice, biodiversity assessment has received a lot of attention (Naidu et al., 2018). Information on plant diversity and distribution underpins study of vegetation dynamics in a particular ecological environment (Sorecha and Deriba, 2017). Vegetation analysis is a crucial tool for plant ecologists in a wide range of applications and comparative studies (Tarin et al., 2017). To characterize diverse ecological processes and to simulate the operation and dynamics of forests, it is necessary to have a basic understanding of forest structure (Elourard et al., 1997). Therefore, a thorough investigation of the vegetation is needed to reveal details about a forest ecosystem's species diversity, community structure, allocation of niches resources, and species turnover rate (Mandal and Joshi, 2014). Research on species composition and diversity underpins habitat protection (Aosanen et al., 2021).

Detailed floristic and faunal studies underpin documentation of biological resources (Chalise et al., 2018; Ghimire, 2019). This study emphasizes biodiversity indices, viz. relative abundance, relative frequency, relative density, Important Value Index (IVI), Shanon's Diversity Index, and Simpson's Diversity Index. Few studies have been conducted for the analysis of vegetation in terms of species diversity in Nepal. Most of them are carried out in community forests while studies on national forests is lacking. The forest area of IoF supports 98 species of butterflies (Chhetri, 2017), 91 species of birds (Pokharel, 2017), and 11 species of snakes (Pradhan et al., 2020) and a population of spotted deer (*Axis axis*) (Bhusal et al., 2020). The study area is surrounded by human settlements on the north, east, and south sides, highlighting the urgent need for conservation intervention (Bajgain et al., 2020). According to Golodets et al. (2011), human settlements are reducing species diversity and increasing forest fragmentation at an alarming speed. Extension of roads inside forested landscapes to provide greater access for forest people is a key problem in the Hetauda area. Quantification of woody species is an important dimension in understand disturbance impact on forest structure. Woody species, as a dominant life form, provide resources and habitat for many animal species and is readily quantifiable (Sagar et al., 2003; Malik et al., 2016). Research on the vegetation dynamics of landscapes surround Hatauda campus are underdeveloped. This study attempts to fill the research gap on the structure, composition, and dynamics of the current tree species inside the forest area of IoF Hetauda as the foundation for further forest assessments and preparation for management planning.

Materials and Methods

Study area:

This study was conducted inside IoF, Hetauda Campus premises. It is situated in central Nepal within latitude and longitude of 27.4368˚N, 85.0026˚E and an elevation range of 430–480 m above mean sea level and covering an area of 92.69 ha. This forest lies in the tropical zone and represents typical species found in the inner terai region. The forest was divided into two portions, separated by a high voltage electricity line that crosses the forest area. The eastern portion was named Stratum 1 and the western named Stratum 2. Stratum 1 is more affected by disturbances as built infrastructure is concentrated in this block.

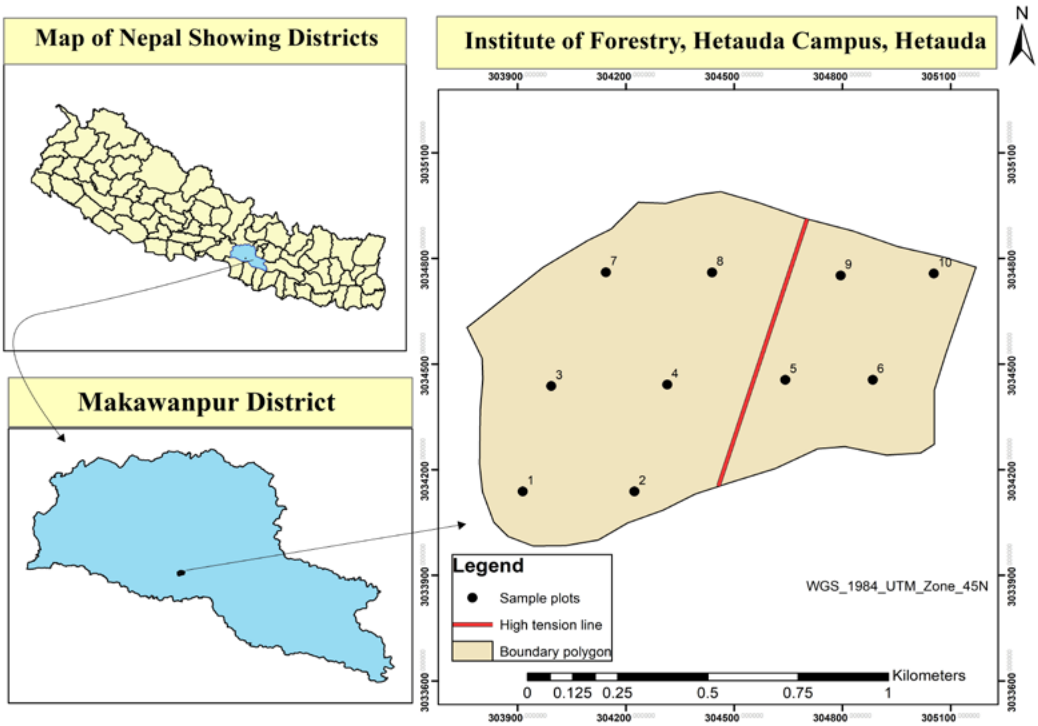

Figure 1: Map of Study Site

Data Collection

Information was collected from study site that describes the present situation. For the quantification of vegetation diversity, ten circular sample plots, each with a 12.62 radius, were laid out with sampling intensity of 0.5% as per CF Inventory guideline (MFSC, 2004). The area of each circular sample plot was 500 square metres. The number of sample plots in each community forest was determined by the formula given as:

$$\text{Number of sample plots} = \frac{\text{Area of Forest (sq.m.)} \times \text{sampling intensity (\%)}}{\text{Area of sample plot (sq.m.)} \times 100}$$

Sample plots were laid out through systematic sampling. All the tree species (dbh>30cm) were enumerated and recorded inside the plots.

Data Analysis

Collected data were organized and analysed to quantify the vegetation parameters.

Vegetation Parameters

The diversity and richness of species can be measured using a variety of indicators. In this study, Shannon-Wiener's (H'), Simpson's (D), Species Evenness (E), and Species richness were the diversity indices assessed in accordance with Shannon and Wiener (1963), Simpson (1949), Pielou (1975), Margalef (1958) respectively.

Shannon -Wiener diversity index (H')

The species diversity of the forest was quantified to quantify diversity in the forest community. For the calculation of the species diversity, Shannon-Wiener diversity index (H') was used, calculated as:

$H' = -\sum (ni/N) \ln(ni/N) = -\sum Pi \ln Pi$ (Shannon-Wiener 1963),

Where, N = total number of species,

ni = number of individuals of species,

Pi = ni/N.

The value of Shannon index usually varies between 1.5 and 3.5 and rarely exceeds 4.5. The higher the value, the greater the diversity, i.e. the value increases as diversity increases. The value of Shannon index is related to species richness but is also influenced by underlying species abundance distribution.

Index of dominance (c)

Index of dominance was calculated by the following formula:

$c = \sum (Pi)2$ (Simpson, 1949),

Where, c = Simpson index of dominance,

Pi = the proportion of important value of the ith species (Pi = ni/N, ni = number of individuals of each species and

N = total number of individuals.

Simpson index of dominance is inversely related to diversity; therefore, it is usually expressed as 1-D or 1/D (Daly et al., 2018). The diversity increases as the species richness and evenness increase. The value of Simpson index ranges between 0 and 1.

Evenness index (e)

Species evenness describes the relative abundance of each species or refers to closeness in the number of each species in a community. Pielou's species evenness index (Pielou, 1975) compares the actual diversity value to the maximum possible values, which reflects the distributional pattern of the species in a community. It was calculated by the following formula:

$e = H'/\ln S$,

Where, H'= Shannon -Wiener Diversity Index,

S = numbers of species.

Species richness (D)

Species richness is generally measured in terms of a ratio of total number of species and total number of individuals of all species of a specified area. The species richness was calculated by using the method Margalef's (1958) index of richness (D).

$D = (S-1)/\ln N$,

Where, S = Total number of species,

N = Total number of individuals.

Quantitative Data Analysis (Tree Characteristics)

The plant community composition in both Stratum 1 and Stratum 2 was studied, and Frequency, Density and Abundance, were calculated for each species. Frequency and density were calculated according to Odum (1971).

Frequency and relative frequency

Frequency designates the dispersion of species in a community. It is the percentage of sampling units in which a particular species occurs.

$$\text{Frequency (\%)} = \frac{\text{Number of quadrants in which an individual species occurred}}{\text{Total number of quadrants sampled}} \text{x}100$$

Relative frequency relates to frequency of a particular species in relation to total frequency of all the species present in the community.

$$\text{Relative frequency (RF \%)} = \frac{\text{Frequency of individual species}}{\text{Sum of the frequencies for all species}} \times 100$$

Density and relative density

Density shows the number of individual trees per unit area and indicates the statistical strength of a species in a community.

$$\text{Density (Stem/ha)} = \frac{\text{Total number of individuals of a species in all plots}}{\text{Total number of plot studied} \times \text{Size of the plot (m2)}} \text{x}10000$$

The proportion of density of species with respect to the total density of all the species within an area is referred to as relative density. In other words, it is the numerical strength of a species in relation to the total number of individuals of all species

$$\text{Relative Density (RD \%)} = \frac{\text{Density of individual species}}{\textit{Total abundance of all species}} \text{x}100$$

Abundance and relative abundance

Abundance is the study of the number of individuals of different species in the community per unit area (Curtis and Mclntosh, 1950).

$$\text{Abundance} = \frac{\text{Total number of individuals of the species}}{\text{Total number of quadrants in which the species has occurred}} \times 100$$

Similarly,

$$\text{Relative abundance (RA, \%)} = \frac{\text{Abundance of individual species}}{\text{Total abundance of all species}} \times 100$$

Importance Value Index (IVI)

The Importance Value Index (IVI) is a reasonable tool for assessing a species' overall relevance because it considers numerous aspects of the species in the vegetation (Tauseef et al., 2012). It can be calculated by adding the relative values of the three parameters, viz. density, frequency, and abundance. IVI was calculated as per Curtis and McIntosh (1950).

IVI = Relative Density + Relative Frequency + Relative abundance

IVI is a reasonable measure to assess the overall significance of a species since it takes into account several properties of the species in the vegetation.

Distribution pattern

The distribution pattern of species was studied using the ratio of abundance to frequency. The ratio of abundance to frequency distribution was considered regular if < 0.025, random if it is within 0.025–0.05, or contiguous if >0.05 (Whitford, 1949).

Statistical analysis

Data analysis was performed using Microsoft Excel. Additionally, interpretation of tables, graphs, and data was done using Microsoft Excel spreadsheets. To evaluate whether there is a statistically significant difference between the means in two unrelated groups, independent t-test was used using IBM SPSS Statistics 23.

Results and Discussions

Vegetation parameters

Parameters above mentioned were calculated for the vegetation analysis of forest area of IoF, Hetauda. In this study, sixteen tree species

Table 1: Summary of vegetation parameters in study site

S.N.	Parameters	Stratum 1	Stratum 2
1	No. of species	10	12
2	No. of individual trees/ha	300	263.33
3	Richness Index	9.76	11.77
4	Evenness Index	0.67	0.75
5	Shannon Wiener's index	1.55	1.87
6	Simpson's Index	0.67	0.79
7	Index of Dominance	0.34	0.22

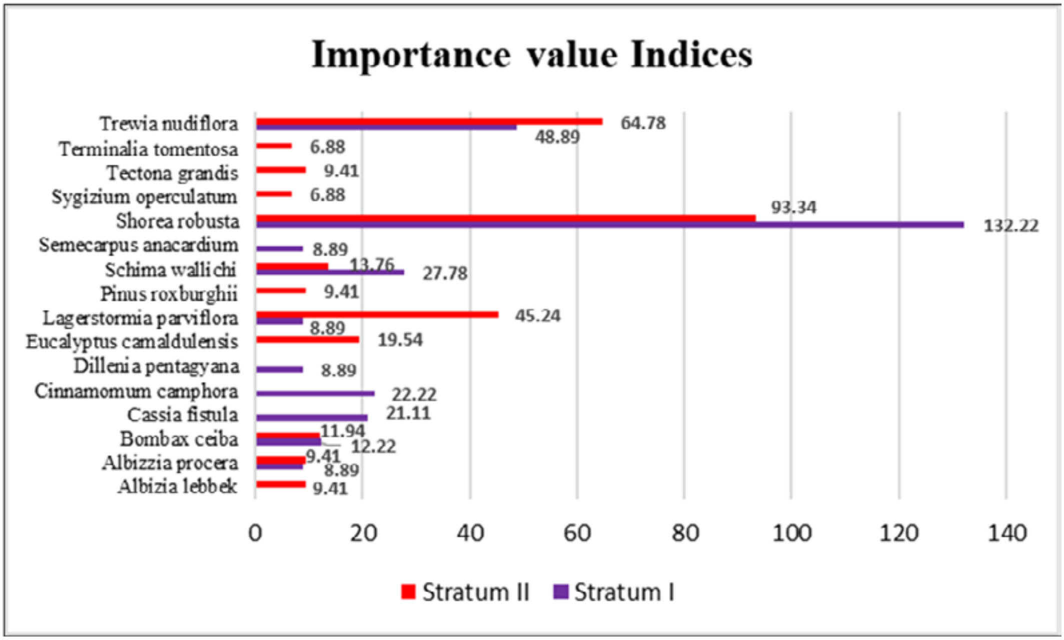

Figure 2: IVI of various species in both strata

Table 2: Species-level Relative density, Relative frequency, Relative abundance and Importance Value Index in both strata

S. N.	Species	Relative Density (%)		Relative Frequency (%)		Important Value Index		Relative abundance (%)	
		Strata 1	Strata 2	Strata 1	Strata 2	Strata 1	Strata 2	Strata 1	Strata 2
1	*Albizia lebbek*	-	2.5	-	4.4	-	9.4	-	2.5
2	*Albizzia procera*	1.7	2.5	5.6	4.4	8.9	9.4	1.7	2.5
3	*Bombax ceiba*	3.3	3.8	5.6	4.4	12.2	11.9	3.3	3.8
4	*Cassia fistula*	5	-	11.1	-	21.1	-	5	-
5	*Cinnamomum camphora*	8.3	-	5.6	-	22.2	-	8.3	-
6	*Dillenia pentagyana*	1.7	-	5.6	-	8.9	-	1.7	-
7	*Eucalyptus camaldulensis*	-	7.6	-	4.4	-	19.5	-	7.6
8	*Lagerstormia parviflora*	1.7	13.9	5.6	17.4	8.9	45.2	1.7	13.9
9	*Pinus roxburghii*	-	2.5	-	4.4	-	9.4	-	2.5
10	*Schima wallichi*	8.3	2.5	11.1	8.7	27.8	13.8	8.3	2.5
11	*Semecarpus anacardium*	1.7	-	5.6	-	8.9	-	1.7	-
12	*Shorea robusta*	55	37.9	22.2	17.4	132.2	93.3	55	38
13	*Sygizium operculatum*	-	1.3	-	4.4		6.9	-	1.3
14	*Tectona grandis*	-	2.5	-	4.4		9.4	-	2.5
15	*Terminalia tomentosa*	-	1.3	-	4.4		6.9	-	1.3
16	*Trewia nudiflora*	13.3	21.5	22.2	21.7	48.9	64.8	13.3	21.5

were identified and recorded from the ten sample plots of both strata of forest. In Stratum 1, ten species (Table 1) of trees with a total of 60 individuals were recorded. In Stratum 2, 12 species (Table 1) of trees within a total of 79 individuals were recorded. Altogether 16 species (Table 2) were recorded from both strata. *Shorea robusta, Trewia nudiflora, Bombax ceiba, Albizzia procera, Lagerstroemia parviflora, and Schima wallichi* were the common tree species in both strata.

Relative density, Relative frequency and Relative abundance

Shorea robusta was the dominant tree species in each forest strata (165 trees ha-1 and 100 trees ha-1), followed by *Trewia nudiflora* (40 trees/ha and 57 trees/ha). *Albizzia procera, Dillenia pentagyna, Lagerstormia parviflora,* and *Semecarpus anacardium* were the species with lowest density in Stratum 1 (5 trees per ha), whereas in Stratum 2, while *Syzigium operculatum* and *Terminalia tomentosa* had

Table 3. The distribution pattern of tree species in study area

Stratum 1			Stratum 2		
Species	Ab/Frequency	Distribution	Species	Ab/Frequency	Distribution
Albizzia procera	0.04	Random	*Albizia lebbek*	0.12	Contiguous
Bombax ceiba	0.08	Contiguous	*Albizzia procera*	0.12	Contiguous
Cassia fistula	0.06	Contiguous	*Bombax ceiba*	0.18	Contiguous
Cinnamomum camphora	0.2	Contiguous	*Eucalyptus camaldulensis*	0.36	Contiguous
Dillenia pentagyana	0.04	Random	*Lagerstormia parviflora*	0.165	Contiguous
Lagerstormia parviflora	0.04	Random	*Pinus roxburghii*	0.12	Contiguous
Schima wallichi	0.1	Contiguous	*Schima wallichi*	0.06	Contiguous
Semecarpus anacardium	0.04	Random	*Shorea robusta*	0.45	Contiguous
Shorea robusta	0.33	Contiguous	*Sygizium operculatum*	0.06	Contiguous
Trewia nudiflora	0.08	Contiguous	*Tectona grandis*	0.12	Contiguous
			Terminalia tomentosa	0.06	Contiguous
Ab=Abundance*			*Trewia nudiflora*	0.204	Contiguous

Ab; Abundance*

Table 4. Independent t-test for different vegetation attributes

Vegetation Attributes	Strata 1					Strata 2					p value
	No.	Mean	S.D.	S.E.M.	df	No.	Mean	S.D.	S.E.M.	df	
Shanon's-Wiener's Index	4	0.9075	0.4492	0.2246	3	6	1.0075	0.4885	0.2442	5	0.4014
Simpson's Diversity Index	4	0.675	0.2824	0.1412	3	6	0.4925	0.2584	0.1292	5	0.4875

Where,* $p< 0.05$ is considered as statistically significant, No. = number of observations. S.D = Standard Deviation, df = degree of freedom, S.E.M= Standard Error of Mean.

lowest number of trees (3 trees per ha) in Stratum 2. The relative frequency was found to be highest in *Shorea robusta* and *Trewia nudiflora* (22.22%) for stratum 1 and *Trewia nudiflora* (21.74%) for Stratum 2. In both strata, relative density and relative abundance of *Shorea robusta* (55% in Stratum 1 and 37.97% in Stratum 2) was found to be highest (Table 2).

Importance Value Index (IVI)

Summing relative density, relative abundance, and relative frequency yielded IVI. According to the inventory, *Shorea robusta* had the highest IVI, i.e. 132.22 in Stratum 1 and 93.34 in Stratum 2. *Albizzia procera*, *Dillenia pentagyna*, *Lagerstormia parviflora*, and *Semecarpus anacardium* had the lowest value of IVI, i.e. 8.89 in Stratum 1 whereas in Stratum 2, *Syzigium operculatum* and *Terminalia tomentosa* were least IVI, i.e. 6.88 (Table 2). Higher values of relative density, relative abundance and relative frequency resulted in a higher value of IVI in Shorea and Trewia species.

Detailed information on specific Relative density, Relative frequency, Relative abundance, and Importance Value Index is summarized in Table 2.

Distribution pattern of tree species

This study found that species in the study area were found to be moreover contiguous.

Statistical Analysis

Result of independent test for different vegetation attributes is given in Table 4.

Discussion

Species diversity is an important feature of ecology, which indicates the health of forest communities and is positively associated to forest stability (Uniyal et al., 2010). The present study observed that Stratum 2 had higher number of species (12) than Stratum 1 (10). Total of 16 species were recorded in both strata combined. The larger area in Strata 2 and greater number of samples led to skewed data. Strata 1 had a higher stem density than Strata 2 despite encompassing almost all structural components of the institution. DFRS (2015) reported that tree density (DBH>10cm) was 274.19 stems/ha in terai landscapes, which is similar to the finding of this study, i.e. 281.67 stems/ha. Shannon-Wiener diversity index was higher in Stratum 2, whereas the index of dominance was greater in Stratum 1. Joshi et al., (2019) noted that Shannon-Wiener diversity index was higher in forest area where dominance index was low. A higher Simpson's diversity index in Stratum 2 also indicates that this forest patch has higher plant diversity. Simpson's diversity index of Stratum 2 is consistent with Ghimire and Lamichhane (2021), who calculated a Simpson's Diversity Index of tree species of 0.79 in Nawalpur Saraswati Community Forest of Makawanpur under similar environmental conditions. A Shannon–Weiner's index of 1.59 in the same study was similar to Stratum 1 and slightly lower than Stratum 2. Analysis of the evenness index showed that evenness was high in Stratum 2, indicating that species diversity was relatively evenly distributed in that area. An Evenness index of 0.76 in Kumorakata Reserve Forest in the tropical zone of Northeast India (Dutta and Devi, 2014) is comparable to the finding of our study. Species richness was found to be higher in Stratum 2. In our study the plant species diversity and their quantitative features shows that the overall community is heterogeneous. However, Shannon–Wiener's Index and Simpson's Diversity Index from each sample plots shows that they are not statistically significant (Table 4), which coincides with the result of Joshi et al. (2019). Shorea robusta in both the forest patches is the dominant species. S. robusta is noted as the dominant species of the tropical and subtropical broadleaved forests in Nepal (Jackson, 1994; DFRS, 2015). Ghimire and Lamichhane (2021) also reported *Shorea robusta* as the dominant tree species in Makawanpur district. In both strata, *Shorea robusta* and *Trewia nudiflora* have the highest IVI. The research site is adjacent to two rivers, viz. Rapti and Karra. Being near the river system, this area has been served by alluvial deposits in some region over time, leading it to be favourable for riverine species. In the riverine forests of Nepal, *Trewia nudiflora* is one of the most abundant tree species (Khadka and Lamichhane, 2020). The distribution pattern of tree species in the study areas was found to be moreover contiguous, exhibiting their clumped pattern of growth. Contiguous distribution is prevalent in nature and results from small but significant variations in the ambient environmental conditions. Random distribution only occurs in highly uniform environments and regular distribution happens in situations where there is intense competition between individuals (Odum, 1971).

Dominant tree species such as *Shorea robusta* are important from both biodiversity conservation and commercial points of view, whereas the infrequent, sparsely distributed species need greater protection and conservation (Sharma and Bhatta, 2020). *Shorea robusta* is historically present in the tropical forest of the lowland Terai region, but its prevalence is diminishing due to poor regeneration and changes in species composition in Nepal (Sapkota et al., 2009). The formidable presence of softwood species such as *Trewia nudiflora* in the study site could be a case of concern from management point of view. This study could only assess diversity at the tree species level, but it does pave the way for further research on other vital aspects for management planning. Studies have stressed the need for also assessing the regeneration dynamics at understory level to balance understanding of species diversity and species regeneration for sustainable productivity (Awasthi et al., 2020; Kharel et al., 2021) and are recommended for the future long-term conservation and management of the study site.

Conclusion

This study examined the status of biodiversity and phytosociological parameters of tree species in the forest area of IoF, Hetauda Campus, through analysis of vegetation diversity. The forest area is a heterogenous forest and stratification did not demonstrate significant difference in tree diversity. Tremendous human influence and disturbances were observed in the forest adjacent to nearby roads and human settlements; however, this has not yet had a considerable effect on the number of individuals of trees and their diversity. This implies a similar level of anthropogenic impact throughout the forest. Assessment of vegetation parameters revealed that the forest was fairly diverse and species were evenly distributed and contiguous. The forest study area is highly dominated by *Shorea robusta* as typically observed in tropical lowlands in this region. *Trewia nudiflora* has fragmented distribution reflect the occurrence of riverine habitats in different parts of forest patches. The study highlights the need for maintaining the overall diversity and the presence of naturally dominant species in the study site. The study also suggests further studies on the understory layer and regeneration dynamics to inform long-term management and conservation of tree diversity objectives for the forest patch in IoF, Hetauda.

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