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COMPARISON OF FOREST STRUCTURE, SPECIES COMPOSITION, AND DIVERSITY INDICES IN MOIST–TEMPERATE FORESTS OF SWAT AND SHANGLA DISTRICTS

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Abstract

Forests are the cradle of life on earth for both humans and wildlife. Humans' survivals and livelihood on this fragile planet depends on forest structure and composition. Disentangling differences in forest structure and composition between Swat moist–temperate forest and Shangla moist–temperate forest was ascertained using the quadrat method. Tree density, diameter, height, diversity index, basal area, IVI, DBH, and regeneration status in moist–temperate forest's structure and composition of Swat and Shangla were examined to identify significant differences in forest structure and composition. The data was collected on above aspects from 18 random sample plots having a size of 500 m2 (20m x 25m), spread over six forest subdivisions (3 sample plots in each study site). The results revealed that forest stand density in both districts ranged from 660 to 800 trees/ha and the species number ranged from 2 to 11 in Swat district, and 4 to 12 in Shangla. The IVI ranged from 2.10 to 90.80% in Swat district, whereas in Shangla district it was 0.20 to 71.10%. *Pinus roxburghii* (Chir pine) was the most dominant species in Swat and *Ailanthus glandulosa* (tree of heaven) in Shangla moist–temperate forest. Tree diversity index (H' = 3.109) and species richness (R_1 = 2.840) was higher, and species evenness (E_1 = 0.966) was lower in Swat moist–temperate. The regeneration rates in Swat moist-temperate forests ranged between 781 and 2,031 seedlings/ha, and in Shangla moist-temperate forests ranged between 625 and 2,187 seedlings/ha, which illustrates that Swat moist-temperate forests are richer in regeneration than Shangla moist-temperate forests. The findings of this study indicated that Swat forest was characterized by greater species diversity and species richness as well as greater IVI, DBH, mean height, and regeneration than Shangla forest.

Key words: Biodiversity; Moist–temperate; Stand structure; Floristic characteristics; Regeneration; Basal area

Introduction

The natural forests are the richest in biological communities all over the world. These are known to contain a sizable amount of the world's biodiversity (Myers *et al*., 2000; Baraloto *et al*., 2013). These provide numerous ecosystem services, including species protection, preventing soil erosion, and maintaining plant and animal habitat (Armenteras *et al*., 2009). Overexploitation is recorded as one of the major environmental and economic issues facing the world today and this has contributed to the rapid loss of forests (Mani and Parthasarathy, 2006). Globally, The natural forests are disappearing at an alarming rate globally and the loss is 1.0–4.0% of their present land area (Laurance, 1999). An increase in the anthropogenic forces has resulted in the expansion of agriculture and livestock overgrazing (Anitha *et al*., 2010).

The forest structure includes the trees, shrubs, and ground layers which are horizontally and vertically distributed in a forest. Understanding the relationship between forest structure and ecosystem functioning is of great importance, because the forest stand structure is a key element in understanding these ecosystems and also an important element of stand biodiversity (Ozcelik, 2009; Shugart *et al*., 2010). One of the reasons in this connection is recognizing a forest's structure which has a significant impact on how well it functions (Guillemot *et al*., 2014). In natural forests, interactions between individual trees can use tree size inequality as a mechanism for simultaneously regulating aboveground biomass and species diversity. In fact the biodiversity of an entire forest is largely dependent on the diversity of trees because the species diversity and forest productivity are correlated at large scales (Huang *et al*., 2003; Zhang & Chen, 2015). A key component of the diversity of forest ecosystems is the diversity of tree species as it affects the geomorphology, species composition, stand structure of a forest community and the structures may vary with successional stages (Kalacska *et al*., 2004; Rahbek, 2005; Tchouto *et al*., 2006; Bruelheide *et al*., 2011). Although species diversity is one of the potentially limiting characteristics of a natural forest ecosystem, there is ongoing discussion about how it affects productivity (Loreau *et al*., 2001; Schmid, 2002). The species composition along with the diversity of forest trees is very important for scheduling and completion of conservation plan of the tree cover (Malik *et al*., 2014).

Pakistan is bestowed with natural habitats of conifer and broad–leaved species. Their composition, structure, and diversity changes with human and natural activities (Timilsina *et al*., 2007). The area of Malakand division especially in the district Swat and nearby areas, the forest is a mixture of different species but there is lack of interest and scientific studies and observations. As one of the main ecological zones of Pakistan, the moist temperate Himalayas demand special consideration for preservation

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of its environment together with the sustainable use of natural resources. The moist–temperate coniferous forests are characterized by evergreen coniferous and broadleaves tree species that thrive at higher altitudes particularly 4900–10,800 feet in ecoregions where high precipitation falls (266.8mm–1071.6mm), and temperature ranged from -40ºC–20ºC. A significant amount of rainfall and snowfall occurs in these forests, which contributes to their moist conditions. These forests are widely distributed in hilly terrain where mild winters and heavy rainfall are common.

Himalayan moist–temperate forest is the forefront of ensuring sustainable management, biodiversity conservation, ensuring the survival of native communities, existence of wildlife species, and mitigates the effects of climate change (Gallai *et al*., 2009). The moist temperate forest is dominated by evergreen conifers and deciduous broad–leafed trees, especially in mountainous areas (Hayat *et al*., 2021; Haq *et al*., 2024). Evergreen conifers, including Himalayan cedar (*Cedrus deodara*), Himalayan blue pine (*Pinus wallichiana*), Himalayan spruce (*Picea smithiana*), and silver fir (*Abies pindrow*), thrive at higher elevations and are often associated with broadleaved tree species, including khasru oaks (*Quercus semecarpifolia*), Himalayan horse chestnuts (*Aesculus indica*), holy oak (*Quercus dilatat*), walnut (*Juglans regia*), Himalayan aspen (*Populus ciliata*), maple tree (*Acer caesium*), and Himalayan alder (*Alnus nitida*). A majority of these forests are located in Western Himalayas, mainly in the lower and upper zones, defined by their coniferous and deciduous broadleaved species (Siddiqui *et al*., 2010). Moreover, these forests are rich and dense undergrowth shrubby vegetation comprised of true indigo (*Indigofera tinctoria*), Indian barberry (*Berberis lyceum*), little leaf cotoneaster (*Cotoneaster microphyllus*), wild rose (*Rosa webbiana*) and Himalayan raspberry (*Rubus biflorous*). Moisture-temperate forests provide a wealth of resources, including timber, firewood, wildlife habitat, watershed protection, erosion control, and organic matter. Understanding the composition, diversity, and dispersion of vegetation relies heavily on environmental factors. In addition, forest elevation also significantly affects the trees and shrubs' structure (Lovett *et al*., 2001). By regulating river and reservoir flow, they protect upland watersheds from erosion, which in turn contributes greatly to the local economy.

These forests has experienced significant structural changes over the past 100 years, which have resulted roughly 50 percent reduction, where the conifers and broad–leaved species make up these forests, which are fast degrading mostly as a result of human activity, according to several reports (Khan *et al*., 2010; Khan *et al*., 2012; Hussain *et al*., 2017). More than 60% deforestation, degradation, and fragmentation have been reported in the Himalayan moist–temperate and dry–temperate forests since last decade the last century (Pokhriyal *et al*., 2010). In addition, the recent military operations in Swat and Shangla districts have badly affected the forest in Swat, destroying many of the valuable and precious species of the forest. According to Ilyas *et al*. (2012) the left over temperate forests as logs, followed by continuing tree cutting has resulted in the loss of fodder for the animals and we see a lowering number of forest for terrace farming in the district Swat which is already under harsh human pressure. The plant diversity of Swat and neighboring areas have a variety of dissimilar forest types which have been investigated to some extent (Rashid *et al*., 2011). The information on composition, allocation, and large quantity of woody taxa is very important and essential for recording the data on structure, composition and also plan the ways of conservation for better establishment and development (Singh *et al*., 2016). The forest managers can effectively manage the forest only by having a greater understanding of its structure, composition, and biodiversity. It is important to identify the species which are ecologically beneficial and those which are of particular concern to ensure that conservation efforts are effective towards forest biodiversity sustainability.

The purpose of this study was to compare the moist temperate forests in the districts of Shangla and Swat specifically with the following objectives: 1) to compare characteristics of forest structure of moist temperate zone in both study area; 2) to assess and compare tree species composition and diversity of moist temperate forest in Swat and Shangla districts and 3) to analyze the structure of regeneration of moist temperate zone in the study area, in order to provide valuable information for the conservation of the biodiversity and sustainable forest management of the moist temperate forests in this area.

Material and Methods

Study area: Two districts (Swat and Shangla) were selected for this study. In each district, 3 forest subdivisions, namely Bahrain, Kalam and Mingora in Swat; and Alpuri, Puran and Besham subdivisions were selected in Shangla.

District Shangla: This area is located between 34^0 53’ 14” N and 72^0 35’ 56” E (Fig. 1). It is bordered to the east by the districts of Battagram and Kala Dhaka (Spin–Gher); to the west by the district of Swat; to the south by the district of Buner and portions of Kala Dhaka; and to the north by the district of Kohistan. District Shangla cover 158600 hectares, out of which mountainous area encompassing of small and narrow valleys covering 4665 hectares and 44405 hectares as forests. The high mountain terrains dominated with moist–temperate and coniferous types of vegetation. The elevation varies from 2000–3500 masl.

District Swat: It is situated at the northwest corner of Pakistan, covering an area of 5337 km^2 between 35^0 22’ 59.99” N and 72^0 10’ 60” E (Fig. 1) and covers 533700 hectares; out of total 138282 hectares are forests. This district is bordered with Buner and the Malakand Protected Area to the south; Ghizer and Chitral to the north; Indus Kohistan and Shangla to the east; and Dir to the west. The altitude ranges between 500–6,500 masl. The district is the meeting point of 3 major mountain ranges, i.e., Himalayas, Hindukush, and Karakorum. The flora of Swat is incredibly varied and distinctive due to diverse landscape, elevation, and weather conditions. The altitudinal variation of the valley has a substantial impact on the weather patterns, which range from mild to severe winter and pleasant summer. The distribution of forest is mainly influenced by climatic conditions and altitude variation. The forest types comprised of subtropical Chir pine forest, dry–temperate forest, moist–temperate forest, sub–alpine forest and alpine pastures. The vegetation structure, species composition, and species diversity of moist–temperate forests were ascertained that future conservation and sustainable management can be more effective.

Data collection: Due to the sparse and uneven distribution of vegetation, a random quadrat method with different sizes was used for data collection. Random quadrat method is method is convenient, effective and widely used application quantifying various aspects of forest stand vegetation structure, i.e., species diversity, species richness, species distribution, temporal changes, and biomass index (Sanjerehei, 2011; Aune–Lundberg and Bryn, 2018). In each forest subdivision, 3 sample plots with an area of 500 m^2 (20 m x 25 m) were randomly set up for forest inventory. In upperstorey trees having diameter greater than 5 cm were measured at breast height (DBH) by using the diameter tape and caliper in each plot. The height for 50 trees were randomly selected in each sample plot and measured through Abneys level. To investigate the regeneration 5 sub–plots, each measuring 16 m^2 (4 m x 4 m), were set up for regeneration in each sample plot in which 4 sub–plots were at the four corners of the sample plots, and the 5th sub–plot was in the center of the plot. The regeneration in this study was followed by studying a plant species with diameter smaller than 5 cm. The height was assessed and regeneration identified by species in each sub–plot. The environmental variables (topographic, edaphic, and soil nutrient) were examined to understand the importance of each factor. To obtain the data from each sampling site, three soil samples were collected from a depth of 10 cm, and a composite sample was made of 500gm analysis. Clinometer was used to ascertain the slope. Using the methodology of Ghorbani *et al*., (2011), Hoffmann *et al*., (2019) and Hao *et al*., (2023), the study was conducted.

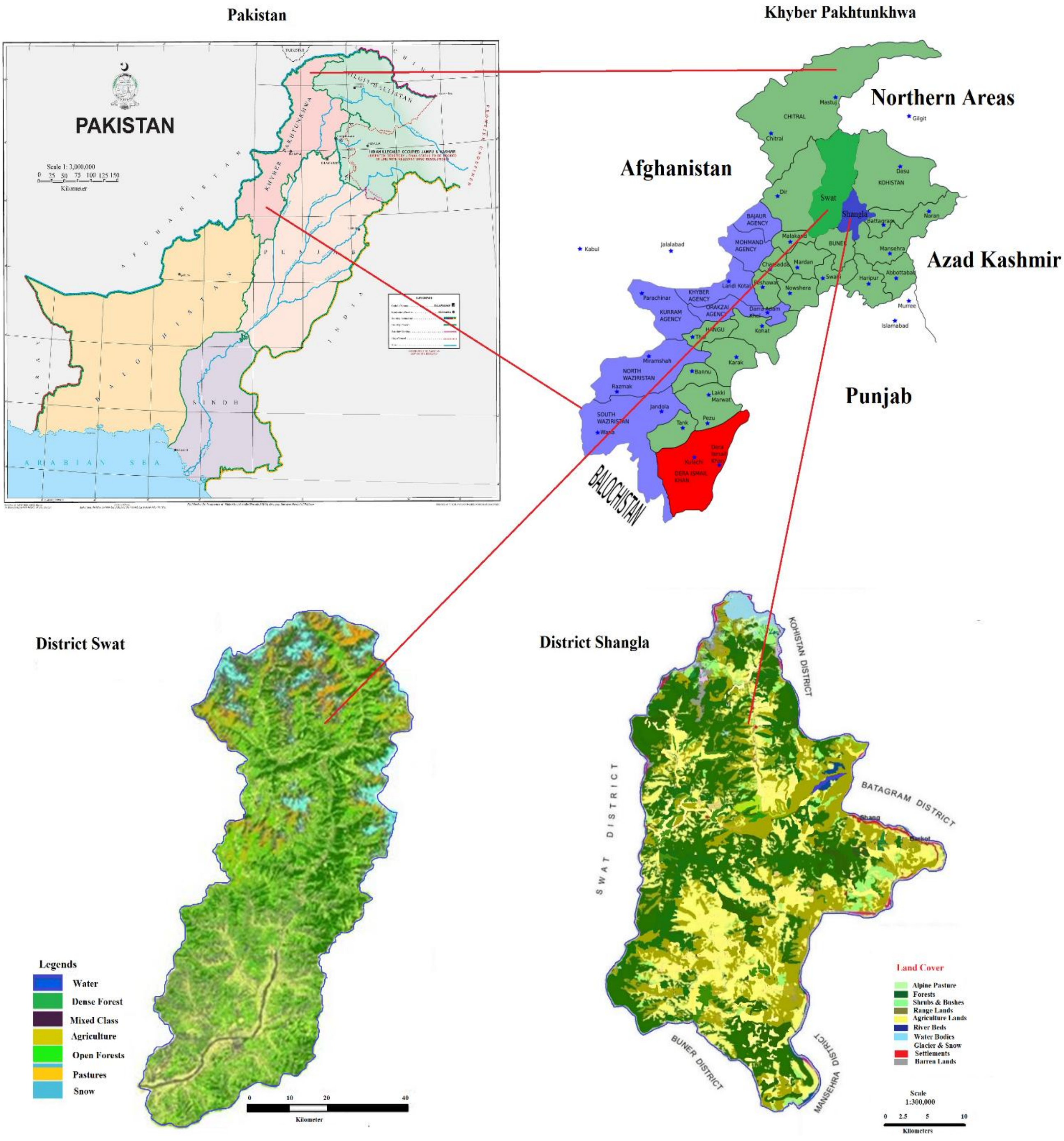


Fig. 1. Location map of the study area.

Statistical analysis

Importance value index (IVI): The ecological importance of a tree species within a community by integrating a variety of aspects such as distribution, abundance, and dominance was measured using importance value index (IVI). IVI was calculated using given below formula;

IVI = Relative Density + Relative Frequency + Relative Dominance

The IVI varies from 0 to 100 percent; the larger the importance value, the more dominant a species is within that particular community. Trees with IVI % ≥ 5% were important species.

Correlation between DBH and height of trees: A Pearson's correlation coefficient was used to determine the correlation between DBH and tree height. Since it has been widely used to examine the strength of a linear association between two variables, where r = 1 indicates a perfect positive correlation and r = -1 indicates a perfect negative correlation. The formula is as follows;

Equation

$$r = \frac{\sum_i (x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_i (x_i - \overline{x})^2}\sqrt{\sum_i (y_i - \overline{y})^2}}$$

where, r = Pearson correlation coefficient, n = number of samples, xy = x + y, x^2 = square root of each x value, y^2 = square root of each y value, d = difference between d and d^2

Frequency distribution: Forest structure was analyzed by frequency distributions (number of trees per diameter at breast height (DBH class and height class). A class width was selected to calculate the number of classes. If number was equal to or less than the upper limit of classes, it was counted in a particular class. For each class, the frequency, percentage, and cumulative frequency were calculated. Therefore, for diameter, class width was 0.610m, for height 1.219m.

Tree species diversity indices

Species diversity indices: Community Analysis Package Software (Version 4.5) was used to calculate tree species diversity indices, which included species diversity, species richness, and species evenness (Henderson & Seaby, 2007).

Tree species diversity index: The Shannon–Weiner index (H′) was used to determine tree diversity in the study area (Shannon, 1949).

$$H' = -\Sigma\,(pi * \ln(pi))$$

In this equation, H': represent the Shannon-Wiener diversity index, Σ: denote the summation of all species occurrence in study area, pi: is the proportion of individuals belonging to the *i*th species, and ln: is the natural logarithm (log base e).

Simpson's diversity index (1949): Simpson's Diversity index considers the number of tree species occurring in the study areas and the relative frequency of each species. A value of 0 to 1.0 is considered infinite diversity, whereas a value of 0 denotes no diversity. Simpson's index was calculated using the following formula;

$$D = 1 - \left(\frac{\sum n(n-1)}{N(N-1)}\right)$$

where, N is denoting as the total number of individuals for all tree species, while n represent the number of individuals for tree particular species.

Tree species richness index: The species richness in the study area was determined using Margalef's Species Richness Index (Margalef, 1958),

$$R = \frac{(S-1)}{N}$$

Here, S = Total number of trees detected in the study region, and N = Total number of tree individuals detected

Menhinick's richness index: Menhinick's Richness Index was used to estimate the diversity of tree species in Swat and Shangla districts (Menhinick's, 1964). The formula is given below;

Menhinick's Formula; $M = \frac{S}{\sqrt{(n)}}$

where, S represents the total number of tree species found in the study area, while N represents the total number of tree individuals found.

Tree species evenness index: The McIntosh's Evenness Index formula was used to calculate tree distribution in the study area (McIntosh, 1967)

$$D_{Mc} = \frac{N - \sqrt{\sum_{i-1}^{s} n_i^2}}{N - \sqrt{N}}$$

whereas; S = The number of trees in the study area, ni = The relative abundance of detected tree individuals, and N = The total relative abundance of each tree species.

Comparison of partridge relative abundance: Using Statistix Analytical Software; Version 8.1 (McGraw–Hill, 2008), the significant difference between vegetation relative abundances in Swat and Shangla districts was determined by Kruskal–Wallis Nonparametric H test and Tukey's Honestly Significant Difference (HSD) test.

$$H = \frac{12}{n(n+1)}\Sigma\frac{R^2 i}{ni} - 3(n+1)$$

The number of observations, "n," represents the total number, "R," represents the rank sum of each sample, and "ni," represents the number of trees in each sample and district.

Regeneration: For regeneration, species composition was analyzed by calculating number of seedling of each species per hectare. Species composition is based on the percentage number of seedlings where the percentage number of regenerations by height class and percentage number of regenerations are based on quality (Anderson, 2017).

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

where, n denotes the number of a particular seedling of individuals of partridge species and N denoted the total number of all recorded numbers of four partridge's species.

Results

Stand structure characteristics

Density, diameter and height in Swat and Shangla: Maximum stem density was recorded in plot 8 (800 tree/ha) (Kalam Subdivision), while minimum (660 tree/ha) was in plot 2 at Mingora Subdivision. In comparison, maximum stem density (740 trees/ha) and minimum stem density (680 trees/hectare) was recorded in Besham forest subdivision in Shangla district respectively. In Swat district, the mean DBH ranged from 9.33 to 19.30 inch; while in Shangla district, the mean DBH varied from 13.62 to 16.06 inch. The mean height ranged from 33.09 feet to 69.20 feet in Swat district, while in Shangla district, the mean height varied from 42.68 feet to 59.43 feet (Table 1). Furthermore, tree density, minimum and highest diameter, and minimum and maximum height were compared using Kruskal–Wallis Nonparametric H test and Tukey's Honestly Significant Difference (HSD) test. The results revealed that tree density ($F_{1, 17}$ = 0.72, $p<0.409$), minimum DBH ($F_{1, 17}$ = 0.47, $p<0.502$), minimum height ($F_{1, 17}$ = 0.05, $p<0.835$), and maximum height ($F_{1, 17}$ = 0.41, $p<0.533$) was not significantly different. However, only the maximum DBH was significantly different ($F_{1, 17}$ = 4.64, $p<0.05$) in Swat and Shangla districts.

Correlation ship between DBH and height of the trees: It was observed that DBH and tree height were moderately correlated in Swat and Shangla moist–temperate forest (Fig. 2), with a coefficient (R = 0.6901, $p<0.05$).

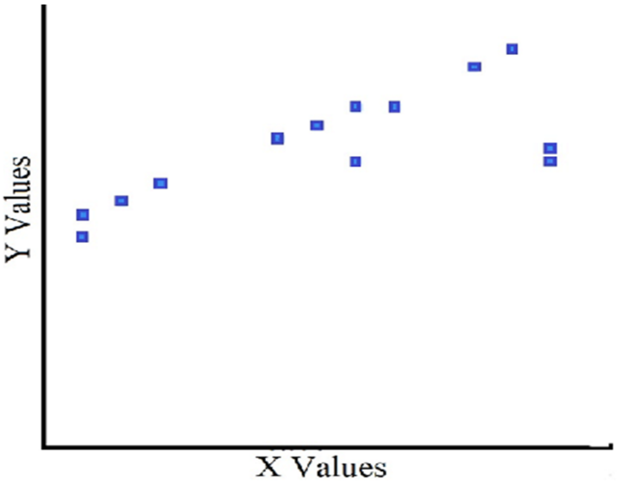


Fig. 2. Correlation ship between DBH and height of trees in Swat and Shangla moist-temperate forest.

Comparison of mean tree diameters, total heights and density in Swat and Shangla district: The result indicated that tree species in Shangla had higher mean diameter at breast height (DBH = 17.0; 8.0–26.0 inches), mean height (H = 52.5 feet) while the prevalent tree density (D = 730 trees/hectare) were detected in Swat district. The results clearly demonstrated that mean tree DBH, total height and density varied in both study areas (Table 2).

A Mann–Whitney U test revealed that there was a significant difference in mean diameter between Swat and Shangla districts because Z = –3.020 with Sig = 0.003 and is much smaller than 0.05 (Table 3).

Table 1. Descriptive statistics of stem density (tree/ha) and mean DBH (inches) and height of tree in district Swat and Shangla.

District	Subdivision	Plot	N (trees/ha)	DBH (inches)			Height (feet)		
				Min	Max	Mean (x̄)	Min	Max	Mean (x̄)
Swat	Mingora	1	700	8	15	11.5 ± 1.60	31	55	40.37 ± 6.03
		2	660	6	14	9.3 ± 1.80	10	47	33.09 ± 7.90
		3	700	8	16	10.8 ± 2.30	31	59	39.60 ± 7.23
	Bahrain	4	700	8	20	11.0 ± 2.30	28	72	40.31 ± 8.60
		5	700	8	14	11.8 ± 1.80	30	52	44.49 ± 6.50
		6	700	8	16	13.1 ± 1.80	38	59	49.03 ± 5.40
	Kalam	7	700	10	21	16.6 ± 3.32	30	76	59.00 ± 1.40
		8	800	12	24	19.3 ± 2.39	56	85	69.20 ± 7.04
		9	780	14	25	18.6 ± 2.41	52	89	67.31 ± 8.11
Shangla	Alpuri	10	700	9	19	14.4 ± 2.96	31	69	50.74 ± 1.10
		11	700	8	26	15.0 ± 4.08	30	67	50.34 ± 1.08
		12	700	10	20	16.1 ± 2.54	35	72	56.71 ± 1.00
	Puran	13	700	8	19	15.6 ± 3.25	30	69	55.69 ± 1.00
		14	700	10	21	15.8 ± 3.13	38	76	59.43 ± 1.03
		15	700	10	22	16.0 ± 3.72	38	76	58.06 ± 1.27
	Besham	16	680	8	21	13.7 ± 3.71	29	64	42.68 ± 1.03
		17	700	9	26	14.4 ± 5.39	36	64	46.34 ± 6.90
		18	740	9	26	13.6 ± 4.28	30	67	49.19 ± 1.15
	Total		**12,760**						

Table 2. Comparison mean tree diameters, total heights and density in Swat and Shangla districts.

District	DBH (inches)		Height (feet)		Density (trees/ha)	
	Mean (x̄)	Range	Mean (x̄)	Range	Mean (x̄)	Range
Swat	15.50	6.0 – 25.0	49.50	10 – 89	730.00	660 – 800
Shangla	17.00	8.0 – 26.0	52.50	29 – 76	710.00	680 – 740

Table 3. Mann–Whitney U test for comparing the mean DBH between district Swat and Shangla.

Statistics	Value
Mann–Whitney U	4.402E4
Wilcoxon W	9.634E4
Z	–3.020
Asymp. Sig. (2–tailed)	.003

Frequency distributions for diameter

Trees diameter frequency distributions in Swat district: The number of trees per DBH class is presented in the Fig. 3. In plot 1 maximum frequency was recorded as 16 with a DBH from 9–11 inches; the minimum frequency was 5 with 7–9 inches DBH. In plot 2, the highest frequency was 19 with a DBH of 9–11 inches. In plot 3, frequency was 8 with a DBH ranging from 15–21 inches. Similarly, highest frequency was 17 in plot 7 with a DBH 17–19 inches and lowest was 1 in plots 4, 5 and plot 8 with a DBH of 7–9 inches, 11–13 inches and 19–21 inches respectively in the district Swat (Fig. 3).

Tree diameter frequency distributions in Shangla district: The highest diameter frequency distribution was 17 in plot 11 with a DBH of 9–11 inches, while lowest frequency diameter was found 1.0 inches in plots 13, 14 and 17 with a DBH of 7–9 inches, 11–13 inches and 19–21 inches respectively in Shangla district (Fig. 4).

Comparison of canopy cover, soil moisture, pH, slope, organic matter, and phosphorus of Swat and Shangla moist–temperate forest: The canopy covers of swat forest encompassing of coniferous trees. It plays a crucial role in filtering sunlight and creating a unique forest environment that provide ample services for local communities and wildlife species. Coniferous trees contributing significantly to the canopy cover of Swat dry–temperate forest. Swat and Shangla moist–temperate forests were compared in terms of canopy cover, soil moisture, slope, pH, organic matter, and phosphorus. Based on the study findings, these parameters varied from site to site in the moist–temperate forests of Swat and Shangla. The Swat moist–temperate forest had higher canopy cover, soil moisture, slope, pH, organic matter, and phosphorus values than the Shangla moist–temperate forest (Table 4).

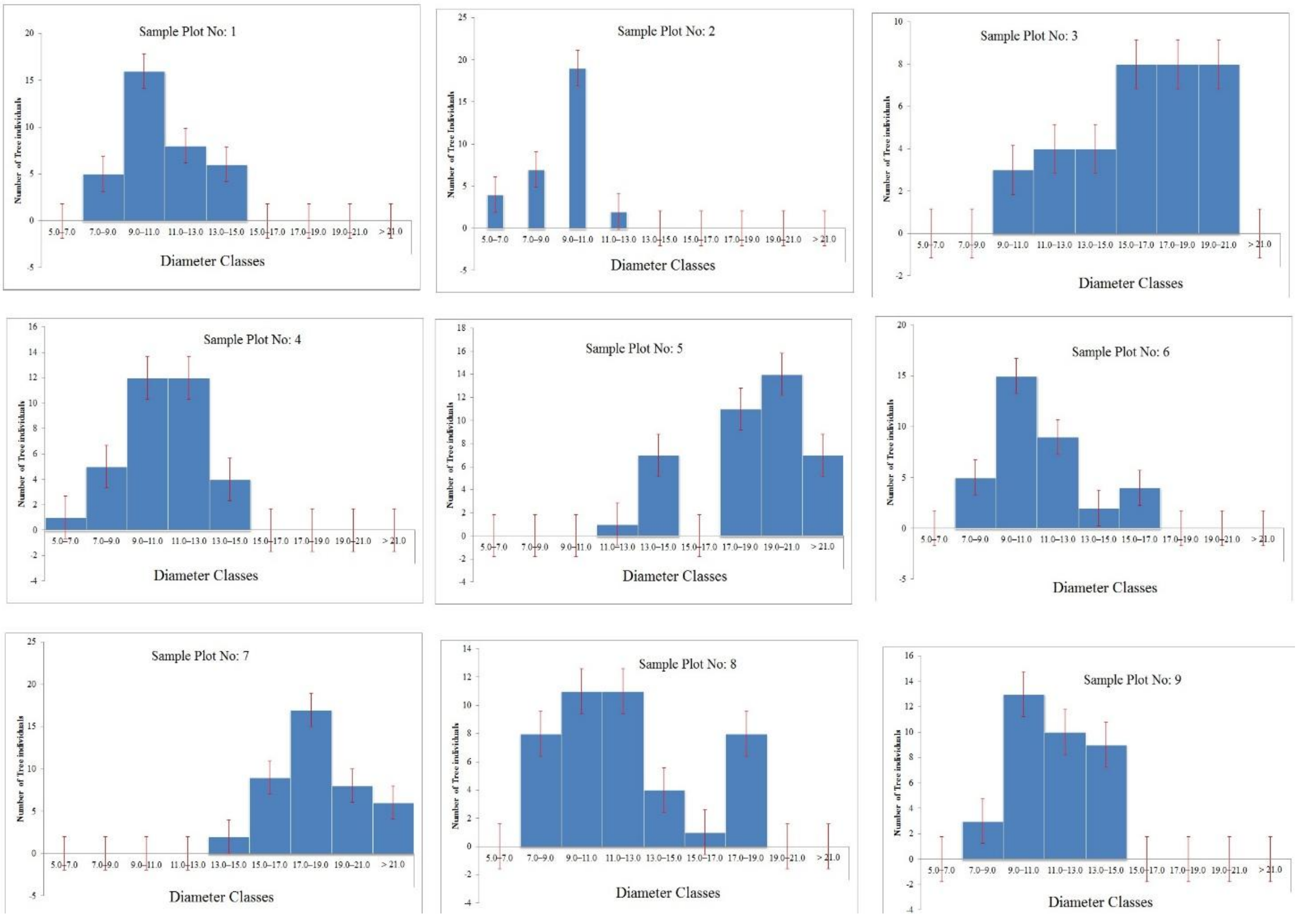


Fig. 3. Frequency distributions for diameter in Swat district.

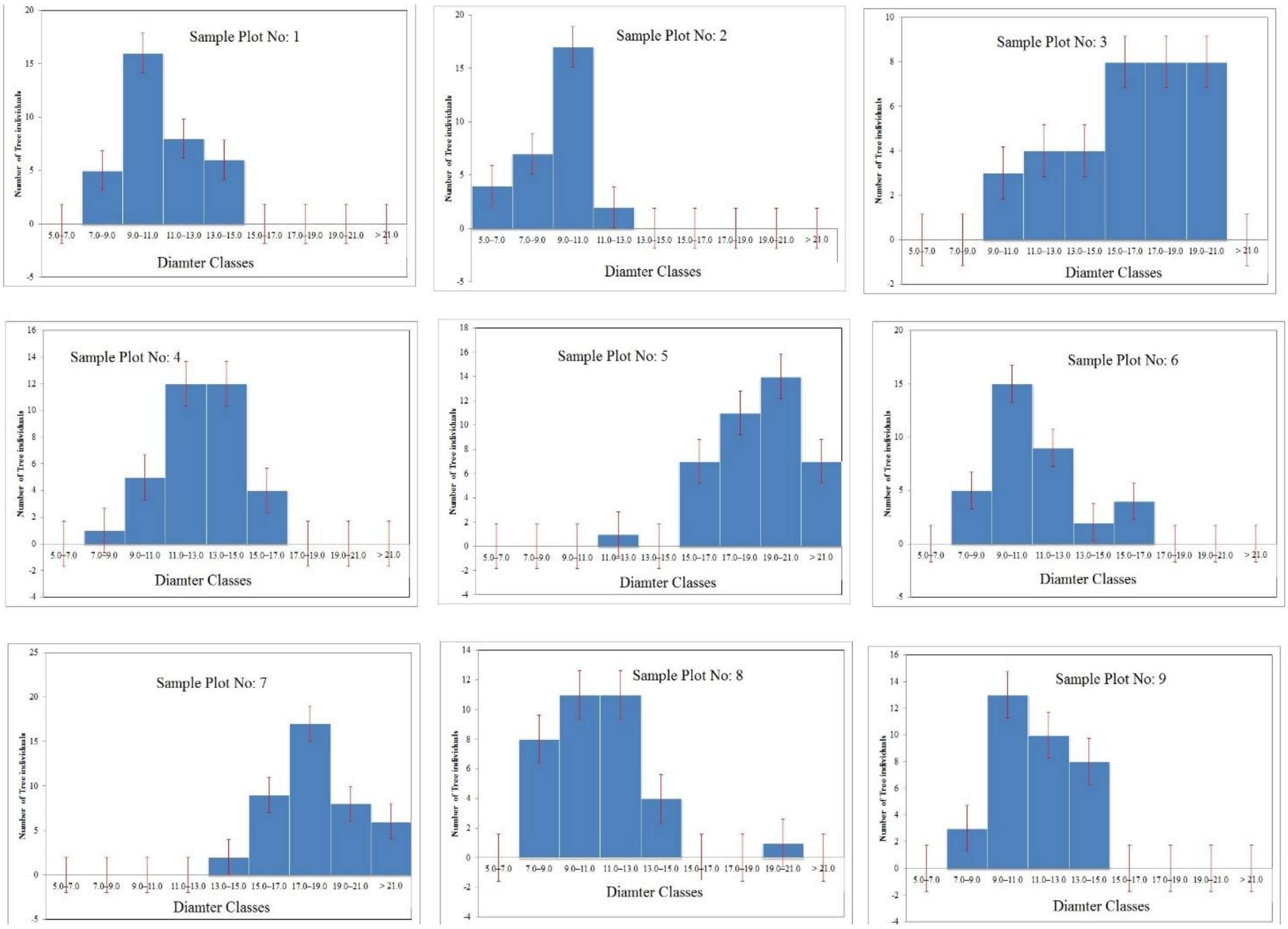


Fig. 4. Frequency distributions of diameter for Shangla district.

Species composition in stands

Tree species composition in swat district: The total number of species was from 2 to 11, while important species were 2 to 5 with IVI percentage from 61.0% to 85.0% in Swat district. The representative species in the area were Himalayan cedar – *Cedrus deodara*, Himalayan blue pine – *Pinus wallichiana*, Chir pine – *P. roxburghii*, Tree of Heaven – *Ailanthus glandulosa*, River Red Gum Tree – *Eucalyptus camaldulensis*, Wild fig – *Ficus palmata*, Persian walnut – *Juglans regia*, White bulberry – *Morus alba*, Bluejack oak – *Quercus incana*, Ghaz – *Tamarix* sp., and Indian barberry – *Berberis lycium* were the most prominent species, found in all 9 plots, while *C. deodara, P. wallichiana* and *P. roxburghii* were the most dominant tree species in sample plot 6. The highest important value index was determined for *P. roxburghii* (IVI = 90.80%) in sample plot one and the lowest one was for *M. alba* (IVI = 2.10%) for others in sample plot 5 of the study area (Table 5).

Species Composition in Shangla district: The total number of species in Shangla district ranged from 2 to 12, however, the important species varied from 2 to 8 and the IVI% value ranged from 6.0% to 71.1%. Some important species were *Acacia modesta*, *Ailanthus glandulosa*, *Cedrus deodara*, *Celtis australis*, *Dalbergia sisso*, *Euclyptus camaldulensis*, *Ficus palmata*, *Juglans regia*, *Melia azedarach*, *Morus alba*, *Pinus gerardiana*, *Pinus roxburghii*, *Pinus wallichiana*, and *Populus* sp. Out of these species *A. glandulosa* was the most dominant species, which appeared in 7 plots out of 9 plots, the second prominent tree species was *E. camaldulensis* and *J. regia* which appeared in 5 plots, while third dominant tree species was *P. roxburghii*. The most abundant tree species was *A. glandulosa* which had the highest important value index in plot number 18 (IVI = 71.10%) and lowest one was detected for others vegetation in sample plot number 12 (IVI = 0.20%) respectively (Table 6).

Tree species diversity in Swat and Shangla districts: The vegetation diversity indices, i.e., species diversity, species richness and species evenness of moist–temperate forests located in Swat and Shangla district were quantified using Community Analysis Package (CAP = Version 4.5). The results evidently indicated that the tree diversity index (Shannon's Index; H' = 3.109 & Simpson's Index; D = 18.420), species richness (Margalef's Index; R_1 = 2.840 & Menhinick Index; R_2 = 0.242) and species evenness (McIntosh's Evenness Index; E_1 = 0.946) of Swat moist–temperate forests was higher than Shangla moist–temperate forests. This discrepancy is a noteworthy observation when comparing stands, and it can be attributed to the stands' lack of inherent variety ordering (Table 7).

Species rank abundance: A species rank abundance analysis of vegetation was undertaken to determine its distribution in Shangla and Swat districts. The results showed that species abundance varied in both districts, as shown in Fig. 5.

Table 4. Comparison of canopy cover, soil moisture, slope, pH, organic matter, and phosphorus of Swat and Shangla moist–temperate forest.

	Canopy cover	Soil moisture % (range)	Slope	pH	Organic matter	Phosphorous
	Swat moist–temperate forest					
Mingora site	90.0%	28.8 ± 3.4	36.5 ± 1.4	8.2 ± 0.3	0.62 ± 0.08	0.43 ± 0.05
Bahrain site	86.0%	25.5 ± 1.6	33.4 ± 3.3	7.9 ± 0.4	0.43 ± 0.05	0.23 ± 0.06
Kalam site	83.0%	23.4 ± 1.8	31.2 ± 3.1	7.8 ± 0.2	0.75 ± 0.03	0.33 ± 0.08
	Shangla moist–temperate forest					
Besham site	88.0%	24.1 ± 1.7	35.0 ± 4.6	7.8 ± 0.9	0.42 ± 0.08	0.53 ± 0.12
Puran site	85.0%	18.9 ± 1.2	32.0 ± 3.9	7.6 ± 0.6	0.48 ± 0.04	0.46 ± 0.09
Alpuri site	81.0%	17.4 ± 8.4	30.8 ± 3.5	7.4 ± 0.2	0.42 ± 0.02	0.34 ± 0.04

Table 5. Species composition, basal area and important value index in Swat district.

Subdivision	Plot	No of species	Species	BA%	N%	IVI%
Mingora	1	3	*Pinus roxburghii*	77.2	77.1	90.8
			Quercus incana	13.6	14.3	6.8
			Others	9.2	8.6	2.4
	2	11	*P. roxburghii*	38.2	39.4	38.8
			Tamarix sp.	8.7	12.1	10.4
			Juglans regia	13.2	6.1	9.6
			Ficus palmata	8.1	6.1	7.1
			Morus alba	6.1	6.1	6.1
			Berberis lycium	10.5	12.1	11.3
			Others	15.2	18.2	16.7
	3	2	*P. roxburghii*	91.0	88.6	89.8
			Pinus wallichiana	9.0	11.4	10.2
Bahrain	4	9	*B. lycium*	2.3	2.9	14.1
			Cedrus deodara	2.7	2.9	6.2
			Ailanthus glandulosa	2.7	2.8	64.1
			Others	92.3	91.4	15.6
	5	4	*C. deodara*	18.6	14.3	66.3
			J. regia	1.3	2.9	16.4
			P. roxburghii	64.0	68.6	15.2
			Others	16.1	14.3	2.1
	6	4	*P. roxburgii*	54.9	57.1	56.0
			C. deodara	31.3	31.4	31.4
			P. wallichiana	10.6	8.6	9.6
			Others	3.2	2.9	3.0
Kalam	7	5	*C. deodara*	19.9	25.7	22.8
			P. roxburghii	48.7	40.0	44.4
			P. wallichiana	20.2	17.1	18.7
			A. glandulosa	19.9	8.6	14.2
			F. palmata	7.7	8.6	8.1
	8	4	*C. deodara*	57.6	55.0	56.3
			P. wallichiana	18.5	17.5	18.0
			P. roxburghii	14.0	15.0	14.5
			Eucalyptus camaldulensis	9.8	12.5	11.2
	9	3	*C. deodara*	82.5	87.5	85.0
			P. roxburghii	12.9	7.5	10.2
			Others	4.6	5.0	4.8

Note: BA% = Relative dominance, N% = Relative density and IVI = Important value index

Table 6. Species composition, basal area and important value index in Shangla district.

Subdivision	Plot	No of species	Species	BA%	N%	IVI%
Besham	10	12	*Acacia modesta*	1.4	2.9	36
			A. glandulosa	7.8	5.9	18.6
			Celtis australis	2.1	2.9	9.4
			E. camaldulensis	45.5	26.5	6.8
			Others	39.3	55.9	20.2
	11	10	*A. glandulosa*	10.0	14.3	46.6
			E. camaldulensis	61.7	31.4	12.1
			Melia azedarach	4.4	11.4	14.5
			M. alba	3.0	5.7	6.0
			Other	16.6	34.3	11.9
	12	10	*A. glandulosa*	7.7	5.4	41.2
			Dalbergia sissoo	8.3	10.8	12.1
			E. camaldulensis	50.0	32.4	6.6
			M. azeadarach	3.8	8.1	5.9
			A. glandulosa	7.7	5.4	41.2
			Others	37.8	11.6	0.2
Puran	13	5	*C. deodara*	20.0	17.1	59.8
			F. palmata	0.7	2.1	18.6
			J. regia	10.4	11.4	10.9
			P. roxburghii	6.4	11.4	8.9
			Other	62.5	57.1	1.4
	14	2	*C. deodara*	11.8	11.4	44.4
			P. wallichiana	88.2	88.6	6.0
	15	4	*J. regia*	1.3	2.9	63.8
			Pinus gerardiana	2.8	5.7	29.9
			Others	95.9	91.4	6.3
Alpuri	16	6	*A. glandulosa*	7.6	5.7	42.5
			F. palmata	2.7	5.7	22.1
			J. regia	12.7	11.4	12.5
			P. gerardiana	13.5	11.4	12.1
			P. roxburghii	21.3	22.9	6.7
			Others	42.1	42.9	4.2
	17	8	*A. glandulosa*	12.2	11.4	22.5
			E. camaldulensis	27.9	17.1	16.8
			F. palmata	7.9	14.3	14.5
			J. regia	8.1	8.6	11.8
			M. alba	3.9	2.9	11.1
			P. roxburghii	13.6	20.0	8.3
			P. wallichiana	14.7	14.3	6.3
			Populus spp	11.7	11.4	8.6
	18	4	*A. glandulosa*	7.7	8.6	71.1
			J. regia	7.7	8.6	12.6
			P. roxburghii	11.0	14.3	8.1
			P. wallichiana	73.7	68.6	8.1

Table 7. Comparison of the vegetation diversity indices between Shangla and Swat moist–temperate forests districts.

Indices	Shangla district	Swat district
Diversity indices		
Shannon's Index; H' =	2.601	3.109
Simpson's Index; D =	12.43	18.420
Richness indices		
Margalef's Index; R_1 =	1.476	2.840
Menhinick Index; R_2 =	0.131	0.242
Evenness indices		
McIntosh's Index; E_1 =	0.966	0.946
Brillion's J Index; E_2 =	0.960	0.933

Regeneration species composition in districts

Regeneration species composition in Swat district: In swat district the number of regenerations per plot ranged from 781 seedlings/ha to 2,031 seedlings/ha and the number of species was from 1 to 4. The important regeneration species were *P. roxburghii, C. deodara, P. wallichiana*, and *F. palmata* (Table 8).

Regeneration species composition in Shangla district: In Shangla district the number of regenerations per plot ranged from 625 seedlings/ha to 2,187 seedlings/ha and the number of species was from 2 to 4. The important regeneration species in this District was *E. camaldulensis*, *A. glandulosa, C. deoara, J. regia, M. azedarach, M. alba, P. roxburgii, P. wallichiana*, and *Populus* spp. (Table 9).

The present study revealed some differences between the forests of Swat and Shangla districts in terms of the density of regeneration. This was evidenced by the 781 stems/ha – 2,031 stems/ha which belonged to the Swat district, while in Shangla district, it was 625 stems/ha – 2,187 stems/ha.

Hierarchical clustering of tree species in Swat and Shangla moist–temperate forests: A Ward's cluster analysis carried out through Community Analysis Package software (version 4.0) to determine the hierarchical clustering of tree species in Swat and Shangla moist–temperate forests. Noticeably, the topological changes and branch lengths of the dendrogram graph revealed that the diversity and abundance of tree species differed across the Swat moist–temperate forest. According to the hierarchical clustering analysis, Swat moist-temperate forest consisted of two main clusters. Branches and topological changes indicated slight differences between these two vegetation groups (Fig. 5). The hierarchal curve clearly distinguished significant variation in tree species abundance among the three subdivisions of Shangla moist–temperate forest. Based on the branch lengths and topological changes on the dendrogram hierarchical clustering chart, we found that the abundance of trees varied across the Shangla moist–temperate forest (Fig. 6).

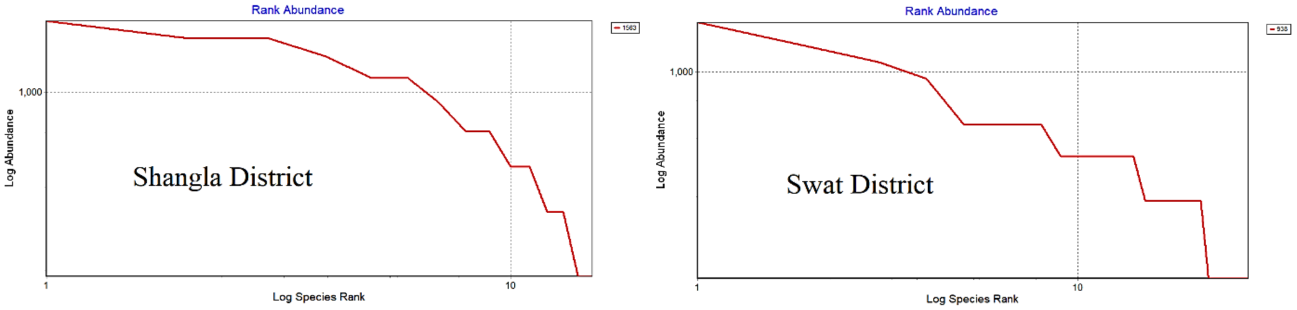
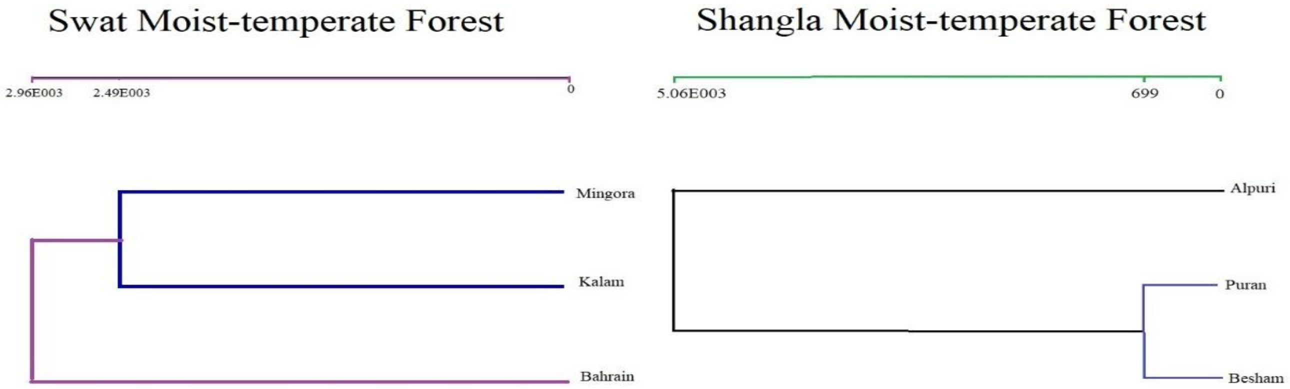


Fig. 5. Tree species rank abundance in Shangla and Swat district.



Comparison of vegetation clustering between Swat and Shangla moist-temperate forest.

Fig. 6. Comparison of vegetation clustering between Swat and Shangla moist–temperate

Table 8. Percentage numbers of regeneration (seedlings) in Swat district.

Subdivision	Plot	No of species/ plot	Specie name	Seedlings /ha	%	Total no seedlings /ha
Mingora	1	1	*P. roxburghii*	1563	100.0	1563
	2	2	*P. roxburghii*	1406	75.0	1875
			F. palmata	469	25.0	
	3	2	*P. roxburghii*	1094	53.87	2031
			P. wallichiana	938	46.13	
Bahrain	1	2	*P. roxburghii*	313	16.7	1875
			P. wallichiana	1563	83.3	
	2	3	*P. wallichiana*	625	33.3	1875
			P. roxburghii	469	25.0	
			C. deodara	781	41.7	
	3	1	*P. roxburghii*	781	100.0	781
Kalam	1	2	*C. deodara*	1250	80.0	1562
			P. roxburghii	313	20.0	
	2	1	*P. roxburghii*	1406	100.0	1406
	3	2	*P. roxburghii*	1094	63.6	1718
			C. deodara	625	36.4	

Table 9. Regeneration trees percentage numbers in Shangla district.

Subdivision	Plot	No. of species/plot	Specie name	Seedlings /ha	%	Total no. seedlings /ha
Alpuri	10	4	*E. camaldulensis*	938	50.0	1718
			Populus spp.	313	16.7	
			M. azedarach	156	8.3	
			M. alba	313	16.7	
	11	4	*E. camaldulensis*	1094	50.0	2187
			Populus spp.	156	7.1	
			M. azedarach	625	28.6	
			M. alba	313	14.3	
	12	3	*E. camaldulensis*	938	54.5	1718
			M. azedarach	469	27.3	
			A. glandulosa	313	18.2	
Puran	13	2	*P. wallichiana*	469	75.0	625
			C. deodara	156	25.0	
	14	4	*E. camaldulensis*	625	33.3	1875
			P. wallichiana	313	16.7	
			P. roxburghii	469	25.0	
			J. regia	469	25.0	
	15	2	*P. wallichiana*	1563	90.9	1718
			E. camaldulensis	156	9.1	
Besham	16	2	*A.glandulosa*	156	11.1	1406
			P. wallichiana	1250	88.9	
	17	4	*P. wallichiana*	625	40.0	1562
			P. roxburghii	313	20.0	
			J. regia	469	30.0	
			E. camaldulensis	156	10.0	
	18	4	*P. wallichiana*	625	40.0	1562
			P. roxburghii	313	20.0	
			A. glandulosa	156	10.0	
			E. camaldulensis	469	30.0	

Discussion

Forest ecosystems play an important role in human and wildlife wellbeing through their functions and services. In moist–temperate forests, vegetation plays an integral role in ecosystem functions and services, such as timer for construction, fuelwood for energy, raw material for medicines, fodder for livestock, water for river, and habitat for wildlife. The Himalayan moist–temperate forest is a vital ecosystem to quantify Pakistan's biodiversity and productivity. It is crucial to quantify the biodiversity and productivity, i.e., floral species abundance, stand structure, species diversity indices (species diversity, richness, and distribution), tree density, regeneration potential and IVI for the better conservation and effective management. This information reveals forest health, productivity, threats, and the existing biodiversity resources of moist–temperate forests. The height and diameter of individual trees vary from forest to forest and indicate biodiversity and productivity.

Density and tree–size variable characteristics

Comparison of tree stem density: All stems of a specified diameter measured at breast height, and are expressed as a number per hectare. In Swat district, tree density ranged from 660–800 trees/ha ($\bar{x} = 730$ trees/ha), and in Shangla district, it was 680–740 trees/ha ($\bar{x} = 710$ trees/ha). Both districts had an overall stem density of 720 trees per hectare. The high tree density (1180 trees/ha) could be attributed to the presence of rich regeneration in the study area and the ideal climatic conditions. Comparatively, the results of this study are more striking than those of previous studies. Singh *et al*., (1994) found 420–680 trees/ha in *A. pindrow* community in Kumaun in India. Sharma & Baduni (2000) reported 440 to 550 trees/ha in pure *A. pindrow* forests in the Garhwal Himalayas. Ahmad and Nizami (2015) reported 428±65.87 trees/ha for a mixed conifer forest of Kumrat Valley. At the age of 50 and 46 years, Cheng *et al*., (2013) documented 617–17 trees per hectare for Japanese cedar. Sharma *et al*., (2010) recorded 507 trees per hectare and 447 trees per hectare in the conifer–dominated upper western Himalaya. A study by Lutz *et al*., (2012) estimated 956.3 trees/ha for *Abies concolor* in the mixed–conifer Yosemite forest. In contrast, Gairola *et al*., (2011a) noted that the overall tree density in the moist-temperate forests of western Himalayas ranged from 493 to 1180 trees/ha ($\bar{x} = 836$ trees/ha). A study conducted by Dhaulkhandi *et al*., (2008) found 820 trees/ha in *P. wallichiana* and *P. Smithiana* forests of Gangoteri Himalayas. Another study conducted by Iqbal *et al*., (2024) quantified the different vegetation clusters and driven factors, i.e., local gradients in topography and soil parameters which affected the plant communities in moist-temperate forests, Shangla district using multivariate analysis. Ward's clustering dendrogram illustrated the four significant vegetation clusters with respect to environmental factors, i.e., 1. *P. wallichiana,* the dominant group associated with *A. pindrow*; 2. *A. pindrow* and the *P. smithiana* group; 3. Dominant *C. deodara* associated with the *P. wallichiana, A. pindrow*, *P. smithiana,* and *Q. baloot* group; 4. *P. roxberghii* pure group. Their results stated that each cluster significantly affected by edaphic factors, topographic factors, soil physical properties, and soil nutrients. The results showed that the elevation (p<0.001) was the prominent factor in the composition of plant communities. Moreover, a significant correlationship between vegetation structure, soil pH, soil moisture, water holding capacity, and soil physical properties (structure) was determined by multivariate analysis (p<0.05). However, other environmental factor did not show significant relationship with vegetation. Ward's cluster dendrogram of understory species also demonstrated four groups. Group 1 encompassing of two subgroups, a and b, with the highest number of species, i.e., *Digeteria sanguinalis, Fragaria nubicola, Verbascum Thapsus, P. wallichiana* seedlings, and *Polygonatum multiflorium* respectively. The second large cluster comprised of 25 species out of 8 stands, and the dominant species was *Tagetis minuta*. Eighteen species out of 6 stands were found in group 3, which was to be the smallest group. Group 4 consisted of 7 stands containing 24 species of ground flora, with *Anaphalis scopulosa* followed by *Adiantum venustum* as the dominant species. The environmental characteristics of the understory vegetation showed a resemblance with the tree communities. With the exception of elevation, the other factors did not show a significant correlation.

Comparison of tree diameter at breast height (DBH*)*: In a forest inventory or research study, small-diameter trees should be included at the minimum DBH (diameter at breast height). Data collected from forest stand structure and vegetation composition are influenced by this parameter. Forests have been managed using different thresholds for different goals and characteristics. For effective forest management, measuring the diameter of trees is crucial. Diameter assessment provides information about existing timber volume, basal area, stand structure, potential threats, vegetation cover, carbon sequestration, productivity, and health. Further, it helps make decisions about when and how much timber volume can be harvested from the dwelling forest. In Swat district, the mean DBH ranged from 9.33 to 19.30 inches ($\bar{x}$ = 14.3 inches); while in Shangla district, the mean DBH varied from 13.62 to 16.06 inches ($\bar{x}$ = 14.8 inches). Based on measurements made with D–tape in the Georgia University research plots, Liu *et al*., (2011) recorded an average diameter of 13.08 inches. Cheng *et al*., (2013) also reported 14.3 inches DBH for Japanese cedar (*Cryptomeria japonica*) stand. Additionally, Wani *et al*., (2015) found an average height of 19.5 inches in both open and closed *P. wallichiana* forests in Kashmir Himalayas. In another instance, Siddiqui *et al*., (2013) determined 46.1 inches dbh in the *P. wallichiana* stand of various moist temperate forests in Pakistan and 18.1 inches dbh in other stands.

Comparison of tree height: Trees of moist–temperate forests in Swat district had mean heights ranging 33.09–51.1 feet. However, the average height in moist–temperate forests of Shangla district was 52.68 feet. There is a clear difference in tree height between the two districts. Variations in height may be influenced by soil fertility, topography, sun light, water availability, rainfall patterns, altitude, aspect, and biomass richness. In dry temperate forests of Chilas Gilgit–Baltistan, Raqeeb *et al*., (2014) found tree heights ranging 8.4–52.6 feet. The height of trees in the dry–temperate forest of Chilas Gilgit–Baltistan varies, i.e., *A. pindrow* (66.9 feet), *P. wallichiana* (52.7 feet), C. deodara (40 feet), and *Pinus gerardiana* (39.7 feet), respectively. Similarly, Ahmad *et al*., (2014) reported that *P. smithiana* grows up to 108.5 ± 6.266 feet tall in the Kumrat valley. In the Ghoragali and Lehterar forests, Nizami *et al*., (2009) estimated the height of *P. roxburghii* at (113.5 – 101.9 feet) with a maximum stem diameter of 64 cm. Previously, a study carried by Shaheen *et al*., (2017) revealed that Himalayan temperate forests significantly enhance local livelihoods while providing immense ecosystem services. From temperate forests, 56 plant species have been identified. Himalayan temperate forests were dominated by *P. wallichiana, A. pindrow, C. deodara, Vibrunum grandiflorum, Indigofera hateranthe*, and *Agrostris gigantica* tree species. As a result of high tree felling intensity, tree density in temperate forests was 344 trees/ha, and stem/stump value was 2.01. The average regeneration rate in temperate forests was 85 seedlings/ha. Significant disturbances were deforestation, overgrazing, trampling, and environmental changes.

Comparison of tree species composition and abundance: The composition and abundance of trees indicate forest structure as a result of complex interactions between physiological processes and competitive forces. Species abundance indicates whether a forest stand is pure or mixed, sparse and dense, single storey or multistory. Plant diversity indices are impacted by trees that dominate forests on a variety of ecological gradients (Palik & Engstrom, 1999). In Swat and Shangla districts, moist–temperate forests have different tree species composition and abundance. There was a distinct difference in the number of tree species ranging from 2–5 and the importance value index was 6.1–85% in moist–temperate forests with species such as *Ailanthus glandulosa, C. deodara, Juglans regia, P. roxburgii*, *P. wallichiana* and *Q. incana*. The number ranged from 2–8 species with IVI ranging from 6–71.1%, with species such as *Acacia modesta, Ailanthus glandulosa, C. deodara, Dalbergia sisso, Euclyptus camaldulensis*, *Juglans regia, Melia azedarach, P. roxburgii*, and *P. wallichiana* being among the most prominent. A study conducted in Yamanashi Prefecture, central Japan, revealed that *Qercus crispula* and *Larix kaempferi* are the two dominant hardwood species and the number of species is at a mean of 4.09 species (Nagaike, 2002). Furthermore, Qian *et al*., (2003) reported *Populus tremuloides, Picea mariana*, and *Herbaceous* sp. as dominant hardwood and conifer species in northern British Columbia's boreal forest with 14.2 mean species. The main dominant species in Kamikawa, Niigata Prefecture, and central Japan were identified by Nagaike

(2002) as *Q. crispula, Q. serrata*, and *Cryptomeria japonica*. A similar list of vascular plants, and bryophytes was found by Augusto *et al*., (2003) in northern France.

Furthermore, Shaheen *et al*., (2015) estimated the IVI of humid temperate forests of the Kashmir Himalaya dominated by *A. pindrow, P. wallichiana*, and *Taxus baccata*. In their study, they found that the mean IVI of three species varied, for example *T. baccata* (IVI = 7.82%), *P. wallichiana* (IVI = 19.40%), and *A. pindrow* (IVI = 72.80%). Another study by Lutz *et al*., (2012) examined the composition of tree species in the area and identified 11 species. These species include *Abies concolor, P. lambertiana, Cornus nuttallii, Calocedrus decurrens, Quercus kelloggii, Prunus* spp., *Salix scouleriana, Pseudotsuga menziesii, P. ponderosa,* and *Rhamnus californica*. As well, Gairola *et al*., (2011a) studied the compositions of tree species in moist temperate forests in the western Himalayas and identified 10 trees: *A. pindrow, Acer acuminatum, Aesculus indica, Betula alnoides, Lyonia ovalifolia, Neolitsea pallens, Persea duthiei, Quercus semecarpifolia, Rhododendron arboretum*, and *Sorbus cuspidata*. The IVI value of the founded forest was 82.20%. The community structure and species composition of western Himalayan moist–temperate forests in Kashmir were also determined by Shaheen *et al*., (2012). According to them, moist–temperate forests in Kashmir contain 73.20% IVI value and encompass 19 trees species. In other instance, Haq *et al*., (2024) used 20x20 m plots to determine the species composition of moist temperate forests in Shahpur Valley, District Shangla to determine tree density, size, density, tree diversity, altitude, and slope aspect. Furthermore, organic carbon, pH, and moisture content of soil were evaluated. The most prominent tree species were *P. wallichiana, Quercus dilatata*, and *Q. incana*. The highest diversity values were determined for *P. smithiana, R. pseudoacacia, Salix alba*, and *Diospyros lotus*. There was a positive correlation between 22 plant species and environmental variables identified by canonical correspondence analysis. A significant correlation was found between pH, electrical conductivity, moisture content, and organic carbon in shaping the composition of forests. Shangla's moist-temperate forest is threatened by illegal logging for fuel wood and construction. In order to promote sustainable forest management, the study contributes to understanding species composition and soil factors that influence forest ecosystems.

Tree species diversity: In the past few years, moist–temperate forest diversity assessment has perceived special attention all over the world for the sake of conserving this precious natural resource, vital to the survival and existence of mankind as well wildlife species. Vegetation diversity is a prominent indicator of moist–temperate forest ecosystem status and productivity. They are source of primary production, regulate gas exchange with the atmosphere, regulate water table, nutrient cycles. Moist–temperate biodiversity mitigates climate change, ameliorate environment, protect watershed, provide suitable habitat for wide range wildlife species, and serve as ecological barriers from storms and harsh weather. Understanding the biodiversity of moist–temperate forest allowed interpret the floristic structures, current status of biodiversity, potential threats and effectiveness of conservation actions.

The findings of this study illustrated that moist–temperate forest of Swat was rich in tree species diversity indices (species diversity, species richness and species evenness) due to heterogeneous and richness of the vegetation structure and composition than Shangla moist–temperate forest. It was evident that the diversity index results showed a range of species between the Himalayan moist-temperate forests of Swat and Shangla. It is clear that Himalayan moist-temperate forest Swat is more stable and resilient than Himalayan moist-temperate forest Shangla, which is less diverse and reflects disturbed or stressed habitats. It has been reported that vegetation diversity depends on vegetation diversity richness, structure, and complexity (Ehbrecht *et al*., 2017; Hakkenberg *et al*., 2018; LaRue *et al*., 2019). Complexity of vegetation facilitates biodiversity by creating diverse niche spaces for flora and fauna that thrive (Hyde *et al*., 2006; Torresani *et al*., 2020). As a result of topography, heterogeneous ecological gradients are created, which affect the structure and composition of vegetation and biodiversity (Homeier *et al*., 2010; Atkins *et al*., 2018; Gough *et al*., 2019). Various biophysical processes and functions are directly or indirectly impacted by vegetation structure, diversity, richness, and distribution. Moist–temperate forest ecosystems are influenced by several factors, including vegetation complexity, stand structural characteristics, biodiversity, and topography.

It has also been demonstrated that tree diversity is a reliable quantitative indicator of moist–temperate forest structure (Aguirre *et al*., 2003; Lexerod & Eid, 2006). Diversity of tree species is composed of two elements: richness (the number of species present) and evenness (the abundance of each species). Diverse tree species provide a range of ecosystem services, including carbon sequestration; water retention, wood provisioning, and soil erosion control (Bai *et al*., 2024). Plant biodiversity is also influenced by elevation and climate factors (Pandey *et al*., 2022; Hashim *et al*., 2023). Variables that influence the richness and diversity of vegetation are crucial to ecology and conservation biology (Gairola *et al*., 2011b). The findings of the present study are higher than previously conducted studies, namely, a study conducted by Gairola *et al*., in moist–temperate forests in the Western Himalaya. According to them, mixed *Abies pindrow* forests have higher diversity concentration dominance indexes and species abundances than mixed *A. pindrow* forests. There are 3.14, 0.145, 13; 3.09, 0.148, and 13 for mixed broad–leaved forests and 2.43, 0.253, and 10. An additional study by Gairola *et al*., (2011a) found that prevalence diversity dominance concentration index and species abundance in the same forests were 1.60, 0.413, and 5. For *Q. semecarpifolia*, they were 1.95, 0.33, and 5. *Acer acuminatum* dominated forests has 1.74, 0.47 and 9 species; *A. pindrow* dominated forests had 1.45, 0.461 and 5.0, and *Aesculus indica* dominated forests had 1.72, 0.399 and 5.0. A study conducted by Singh *et al*., (1994) stated that species diversity in Uttarakhand Himalayan forests varied from 0.4 to 2.8 and Mishra *et al*., (2000) stated a range of 1.55 to 1.97. Likewise, Shaheen *et al*., (2017) recorded tree species diversity 2.35, species richness 1.61, species evenness 0.75, and the maturity index 49.34% in Himalayan temperate forests.

Regeneration of moist–temperate forest: Seedling is a just emerged small plant from a seed having height less than 1.3 meters, while sapling is young tree that have grown beyond their seedling stage and become more established having height higher than 1.3 meters. The vulnerability of seedlings to environmental stress is higher than saplings. Himalayan moist–temperate forests are rich in seedlings and saplings, which indicate the different stages of young tree development and growth process. By using regeneration information, one can devise systematic plans to promote good–quality regeneration and manage the factors that may affect it. In addition, regeneration has important implications for the forest ecosystem health and productivity, as it ensures the sustainability of the forest ecosystem. In moist–temperate forest, the regeneration of assessments is crucial as it maintains biodiversity, provides next generation of trees understories, regulates water flow and protects watersheds, prevents soil erosion, mitigates climate change, moderates' temperature and increases biomass production. A tree recruited in the upperstorey has passed through the understory as a seedling. Forest structure and composition cannot be fully understood without addressing regeneration patterns and forces influencing them (Wangda & Ohsawa, 2006). Successful regeneration depends on the establishment of seedlings and saplings survival, which is determined by the site's environment and human stimuli. Even under high initial seedling densities, disturbances like high–level grazing and tree felling cannot assure successful regeneration (Rooney & Waller, 1998).

The results show that the number of regeneration in moist–temperate forest per plot varied from 781 trees/ha in Swat district to 2,031 trees/ha while the regenerations in moist–temperate forest of Shangla district ranged from 625 trees per hectare to 2,187 trees/ha. Overall, both district's moist–temperate forests had a mean regeneration species composition of 1406 trees/ha. Previously, a study conducted in Sikkim subtropical forests by Sunriyal *et al.*, (1994) reported 1500–2300 seedlings ha–^{1}, in Bhutan, 1750–3100 seedlings ha–^{1} (Moltan *et al.*, 2009), and in moist temperate forests of other western Himalayas, 1977–3416 seedlings ha–^{1} (Pokhriyal *et al.*, 2010). Several factors contributed to the low number of seedlings in the present study, including lack of protection from grazing animals and trampling. As a result of severe and uncontrolled cutting of mother seed trees, seed sources for the next regeneration are disappearing, making the area unsuitable for seed germination and facilitating grass cover development, which retards forest regeneration. As a result of the deforestation, the once lush, green, and densely forested Himalayan mountains have been replaced by steep, dry ridges with dense populations building terrace fields, roads, and houses (Oza, 2003). There is a great deal of intense and heavy tree felling taking place because of the demand for fuel wood and timber. In contrast, excessive and illegal grazing in forest areas is endangering the development of seeds of these trees because there isn't enough grazing space for cattle. The results of the present study indicate that forest management authorities and policy makers need to act immediately to address the deteriorating forest structure and regeneration.

Conclusion

Based on these results, it is concluded that Swat moist–temperate forest is more rich and diverse than Shangla moist–temperate forest. Vegetation in Swat moist–temperate forest thrived with a higher number of tree species than Shangla moist–temperate forest. A higher importance value index, a greater basal area, and prevalent number of trees per hectare were recorded in Swat moist–temperate forest compared with Shangla moist–temperate forest. In spite of this, the importance value index volume differs considerably from species to species and plot to plot. A similar trend was noted in Swat moist–temperate forest mean DBH and average height compared to Shangla moist–temperate forest mean DBH and average height.

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Author's Contribution: Ali, F. designed the research study and collected the data, Khan, P. wrote manuscript, Rajpar, M.N. reviewed and edited the manuscript and Hung, B.M. analyze the data.

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