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Research Article

Distribution Pattern of Tree Species and Richness along an Altitude Gradient in the Sub-Alpine Temperate Zone of Hindu Kush Mountainous Forests, Pakistan

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Abstract: Lal-Koo Mountains Forest (LMF) is the most extensive vegetation type in the largest Hindukush Mountainous ranges of Pakistan, however highly overlooked compared to the Himalayan and Karakorum ranges. Here, we studied the conifer tree species regeneration, diversity, basal area, density, and species richness of the Lal-Koo Mountains Forest (LMF) along the altitude gradient. We used the quadrate (10 m × 10 m) sampling method for vegetation analysis at 54 different locations between 1970-3120 m elevations. We found a total of 115 species belonging to 58 families. We find the maximum value of Shannon's -Winner index 3.603 at 2115 m and Simpson's Diversity Index at 0.91 at 2290 m along an altitude gradient in lower elevation ranges. The current finding revealed that observed tree species richness shows a unimodal pattern with a peak at 2400 m in the mid–elevational range followed by a basal area peaked at 2300 m across the elevation gradient. We concluded that the high growth ratio of regenerates is due to open areas (free canopy space) likely available due to severe deforestation at low altitudes. In Lalkoo, tree density did not follow a regular trend, although the highest values were obtained around 2400 m and 2600 m along altitude. Our results also indicate that there is a narrow elevational range at high altitudes (near the timberline) measured from 2750 m – 3120 m, of the gradient. Furthermore, we discovered broader altitude ranges in the midst (relating well with the theory behind the mid-domain effect) in the range of 2345 m – 2750 m, but the lower altitude range assessed from 1970 - 2345 m does not reveal precise data for the reported species richness, which is a deviation from Stevens elevational Rapaport rule.

Keywords: Lalkoo Forest, Hindukush Mountains, Pakistan, Regeneration, Elevation gradient, Species richness, Diversity, domain effect.

1. INTRODUCTION

Altitude is a combination of multi-environmental variables that interact with other factors like topography, aspect, soil texture, nutrients, and inclination of slope that couple forest composition [1-2]. The idea about Altitudinal variation that exists among tree species was also assessed multiple times in forest ecosystems in relation to topographic and soil variables [3], observed from floristic composition, species richness [4] and evenness, resilience, and total plant production [1]. Moreover, habitat variability is an essential component in determining biodiversity along the altitudinal gradient [5]. Mutually dependent interactions, such as the latitudinal inclination of

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diversification, latitudinal variations of species abundance, and links across diversity and productivity, are interrelated across spatial patterns due to geographic restrictions and the impacts of territory. Recently latitudinal patterns of species richness have also been the focus of biological research that affects the distribution of individual species [6-7].

However, little research sought to evaluate the function of identification of the mid-domain effect (MDE) in determining species abundance and uniformity peaks at mid-level heights in a range region [8]. According to this research, MDE is affected by the species including the prevalence of relative range widths and median, the availability, placement, and constraining the ability of border restrictions, and the sampling place [9].

The mid-domain effect (MDE) has been proposed as a null explanation for diversification contours and motif perception [8]. Colwell and Lees [8], greatly launched the concept, stating that "given a domain with geometric limitations, the overlaps of species ranges grow towards the center of the domain if they are put haphazardly, giving a uni-model sequence of species abundance along the slope." In typically, the MDE is better for species with a large range compared for those with a small range. The notion of MDE piqued the interest of scholars who wanted to apply it to other analyses.

Using various measurements of vegetation analysis like tree's Diameter at Breast Height (DBH), Forest Denseness, soil analysis, aspects, and temperature are considered as important variables, significantly affecting vegetation patterns. However, factors like subtropical precipitation patterns are observed, showing a tendency in rise along an elevation gradient of 3500- 4000 meters and then decrease at various elevation ranges in lower altitudes influenced by topography in the mountainous forests [7]. Similarly, high altitude changes in the composition of soil and drastic decrease in soil temperature greatly affect tree's Diameter at Breast Height (DBH) as well. The percentage of sand documented [10] decreased by 1 % for 152.47 feet within altitudes of 6400 and 9600 feet, whereas the percentage of silt declined by 1 % per 188.23 feet within the identical levels. Magnesium (Mg) amd Potassium (K) concentration in soil rise with elevation by almost 1 mg/kg every 63.82 feet and 1 mg/kg every 30.92 feet, respectively. These features imply that numerous aspects associated with the altitudinal gradient, such as soil type and ambient temperature, can be investigated [11], availability of soil nutrients and depth of soil concerning both B and A/O horizons influences flora in a geographical area [12]. Aside from these considerations, it has been proposed that species abundance is directly influenced by elevations as well as climatic conditions, therefore species variability of various life forms generally diminishes with rising height, and extremely tiny life forms persist at extreme elevations [13].

Lalkoo Mountains forest (LMF) is the most extensive vegetation type in the largest Hindu Kush Mountainous (HKM) ranges of Pakistan. Ecologically these mountains (HKM) are moist temperate forest zones, that are con-jointly located with great mountainous ranges of the Himalayas and Karakoram [3]. Both the Himalayan and Karakorum Mountain ranges are studied enormously, under research focusing on ecology, however, the Hindu Kush Mountains (HKM) ranges are highly ignored and overlooked [14-16]. The Lalkoo mountainous forest is floristically diverse and one of the world's biodiversity hotspots [17]. In addition, these mountains are distributed within a very small geographical extent making, between an elevation gradient of 1800 and 4400 m with great economic importance for timber usage and crown coverage [14, 18]. Like other moist temperate forests, Lalkoo presents a high richness of tree species like *Abies* (Fir), *Picea* (Spruce), *Quercus* (Oak), and *Pinus* (Blue pine). All these characteristics make this study, ideal for an altitudinal pattern of tree species. We studied species richness patterns along the altitudinal gradient which is an advanced tool for analysis of biodiversity for both floral [18] as well faunal communities [19-21].

The main objective of the current work is to analyze the effects of environmental indicators on plant species and diversity patterns along an altitudinal gradient in Lalkoo mountainous forests, Pakistan. Besides, our primary objective, we were also interested to focus on conservation and devise management guidelines to conserve the biodiversity of these mountainous forests. Lastly, we discussed some baselines for future management [22-23].

2. MATERIALS AND METHODS

The study was conducted in the Lalkoo mountainous forest (LMF) Swat District of Hindukush, Pakistan which stretch across the Himalayas and Karakorum Mountain ranges. Geographically Lalkoo area lies within the coordinates of 35°08′ 27.62″ N and 72°23′09.12″E with an altitudinal range from about 1581 m a.s.l. and reaches the highest peak of alpine pastures of 3849 m a.s.l. However, the present observations were assessed between 1970 and 3120 m.a.s.l. The famous visiting spot Gabin Jaba (locally means honey marshes) with an elevation of 2581m a.s.l., is also located in the research area. The annual temperature of the investigated area was recorded at 13.96 °C to 22.25 °C. The amount of relative humidity is maximum in July, August, and September having 73.55 %, 80 %, and 69 % respectively. The mean annual rainfall recorded in Lalkoo is 1777 mm. Maximum rainfall observed in July and August with a mean total rainfall of 228.9 mm and 220.9 mm while minimum rainfall occurred in November and December which is recorded at 42.4 mm and 78.4 mm (data source PMD; http://www.pmd.gov.pk).

We studied tree various species along an elevation gradient. The research region is categorized as moist temperate woodland and contains alpine, sub-alpine, and grassland zones. The basal area was calculated as (GBH)2/4pi, where pi 14 = 3.14. We also estimated the species' dominance. The basal area was measured as DBH ≥10 cm and 1.3 m above the ground, while regeneration (Seeding and Sapling) was measured at DBH <10 cm, and height >30 cm. All the trees inside the plot were counted, and their girths were determined using a measuring tap-adopting the method [24]. Slope, elevation, and aspect for each plot are recorded as well. Slope and aspect were measured by compass; elevation was measured by the altimeter.

2.1 Field survey

From June 2016 to December 2019, fieldwork was carried out. We picked six separate locations, referred to as Site-A, Site-B, Site-C, Site-D, Site-E, and Site-F (Figure 1), along the height on various hill-slopes from 54 sampled plots (quadrats) ranging in altitude from 1970 m to 3095 m (Table 1). Each hill-slopes was sorted into nine elevation zones/sections, and plots SIQ-I, SIQ-II, SIQ-III, SIQ-IV, SIQ-V, SIQ-VI, SIQ-VII, SIQ-VIII, and SIQ-IX were used to analyze them. The distance between two neighboring plots was preserved at least 115 m, and sampling plots were considered spatially isolated. The following are the predominant biological aspects of these Lalkoo mountainous forests (LMF) Swat District locations.

2.1.1 Site-A

This site starts near Shaheed Bela Khawar (SBK) located at 35° 08′ 45.95″ N and: 72° 23′ 17.47″ E (SIQ-I) and reaches to the peak of Barjo Sar (BS) located at 35° 09′ 25.30″ N and: 72° 25′ 19.59″ E(SIQ-IX) with 270° (W), 225° (W-S), 315° (W-N). The elevation range from bottom to top is 2125 m to 3045 m.

2.1.2 Site-B

This site starts near the entrance to Koz Lolkoo (KLK) is dominated by *Pinus wallichiana*. It is located on 35° 09′ 23.65″ N and 72° 23′ 21.37″ E, with elevation from 2200 m a.s.l., to 3120 m a.s.l., Famous small peak's local names are Bar Sange Sar, Tango Sar, and Oonani Sar. This site ends with Splo Sar (SPS) with a slope from 180° to 270° (S-W) along nine sampled plots.

2.1.3 Site-C

This site starts in the lower elevation range an area called Dunkacha (DK) and ends with the highest range Julba Sar (JS), which is affected by deforestation. The altitude of the area varies from 2000 m a.s.l., situated (35° 08′ 11.846″ N, 72° 23′ 28.34″ E) near to Bar Kale Lalkoo (BKL, DK) and reaches to forest Peaks of Julba sar (35° 09′ 04.34″ N, 72° 24′ 45.48″ E) with altitude 2920 m a.s.l., This site has slope ranging from 270 (W), 225 (W-S), and 45 (N-E) from SIQ-I to SIQ-IX. Famous site peak's local names are Gadro Dowl, Bata, and Char.

2.1.4 Site-D

This site has an extensive area with different undulating slopes and diverse vegetation types of trees like *Taxus wallichina* and *Aesculus indica* that are scattered in the thick vegetation of *Abies pindrow* and *Picea smithiana*. This site starts from Kar Khawar (KK) in the lower altitude of 2175 m (35° 09′ 16.75″ N, 72° 20′ 59.96″ E) and continuous with the peaks of high altitude at 3095 m of Kapar Sar (KS). This situated between 35° 09′ 16.75″ N and 35° 09′ 39.83″ E). This site is almost East facing with aspect 90, while the only plots SIQ-II, SIQ-III, and SIQ-VI are 135 E-S facing.

2.1.5 Site-E

This area has some cultivated land at lower altitudes, starting with the lower altitude of 1970 m, Dunkacha (DK: N 35° 08.489, E 72° 22.989), and reaches to sub-alpine zone dominated by *Quercus* spp. in the highest peaks called Landai Sar (LS: 35° 09′ 16.81″ N, 72° 21′ 06 .09″ E) with an altitude of 2890 m. All the aspects recorded at this site are East facing while SIQ-II and SIQ-IV are East-West with all the surveyed area.

2.1.6 Site-F

This site starts from elevation with an elevation of 2000 m in the area of Lower Lalkoo (LL), located at 35° 08′ 44.44″ N and 72° 23′ 28.38″ E, and reaches high altitudes of 2920 m in peaks of Shalkho Sar (SS) located at 35° 09′ 12.32″ N and 72° 24′ 45.50″ E. The aspects W (270), W-N (315), and W-S (225) were unique to this site.

2.2 Data Analysis

We used general linear models (Using SPSS) and Microsoft Excel 2010 to examine the relationships of regeneration, species tree density basal area, and richness with elevation. To determine inter-correlations among predictor variables, we used Pearson correlations, which can cause collinearity effects, and fitted values were compared with standardized residuals for each significant predictor. Using Shannon's and Simpson's diversity indexes, we calculated plant biodiversity. The Shannon's index (H') was calculated as (H' = ΣPi*ln Pi), whereby, Pi is the significance value of a species as a proportion of all individuals. Simpson's Diversity Index was calculated using the formula C = ΣPi2, where C is Simpson's diversity and Pi is described previously [25].

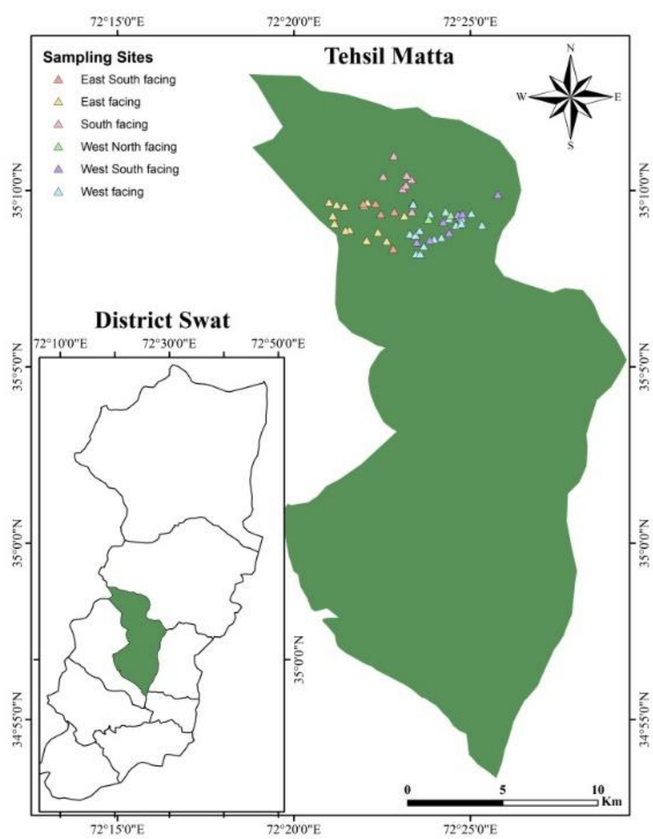

Fig. 1. Geographical locations of study sites

Table 1. Geographical details of study sites

Sites Name	Latitude	Longitude	Elevation range	Slope range
Site-A	35° 08'45.95"	72° 23' 17.47"	2125-3045 m	225°-315°
Site-B	35 09 23.65	72 23 21.37	2200-3120 m	180°-270°
Site-C	35 08 11.84	72 23 28.34	2000-2920 m	45°-270°
Site-D	35 09 16.75	72 20 59.96	2175-3095 m	90°-135°
Site-E	35 08.489	72 22.989	1970-2890 m	176°-265°
Site-F	35 08 44.44	72 24 45.50	2000-2920 m	225°-315°

We selected Quadratic regression using GLM models (better fit) for comparison of selected variables. We compared real species richness to null model predictions to determine the role of the mid-domain effect [26], in which domain bounds can also be characterized by soft and hard borders [27]. The mid-domain effect (MDE) concept of Colwell and Lees, [27] provides a straightforward and supplementary insight on species abundance gradients, that is effectively presented in a review of the literature. According to the Mid-domain effect (MDE) theory, the arbitrary allocation of species geographic ranges of varied sizes inside an area (or domain) constrained by hard bounds results in a peak in species diversity in the center of the domain [27]. We evaluated each species' range and reported it as the disparity between the lowest elevation of 1970 m and the greatest elevation of 3120 m along the species diversity gradient [27]. Throughout sampling, range size is frequently overlooked. Range sizes were also utilized to assess the robustness of the null model to ranging midpoints [28] with 95 % prediction curves relying on 1000 simulations at every 115 m elevational domain without substitution by empirical range sizes. Model fitness (GLM) was determined by regressing empirical species abundance against the average of modeled richness. We assumed that the sampling effort was equivalent at all locations (9 quadrats/site) and that as the number of people grows, so does the richness of the studied species. When contrasted to altitude, most of our data-set variations exhibit a hump-shaped association (see scattered plots) [28].

3. RESULTS

According to the current study, the largest peak of Shannon's-Wiener Index of diversity (H') was recorded between 2.043 (at 2315 m) to 4.334 (at 2575 m), indicating more species in an ecosystem, hence H' values of more than 2 have been recognized as a medium to high diverse (Table 2). Thus, the Lalkoo mountainous forest (LMF) has a high species variety, particularly at mid-height.

While the lowest value of the Shannon index was recorded at 0 .923 (2920 m) at Site-F(SIQ-IX). We recorded the highest value 1.74 of the Simpson index (D') at the elevation range of 2345 m, Site-C (SIQ-VI). However, the second maximum value across the total elevation gradient was recorded as D'=1.63(2690 m) and D'=1.61(2460 m) while the lowest value D'=0.2 was recorded consecutively in two sampling plots at Site-F (SIQ-VIII and IX) near the timberline at an altitude of 2805 m, and 2920 m, respectively. A such similar pattern of tree species in timberline area was reported by Rawal *et al*. [29]. We found characteristics decline in species density, basal area, and regeneration towards the end of high elevation across the altitudinal gradient. Regression between basal area and elevation reveals a strong quadratic association ($r2=0.012$, $P<0.05$) as well as a hump-shaped relation with a peak around 2400 m. Nevertheless, regeneration has a very low r2 value ($r2=0.004$, $F=0.281$, $df=52$, $p=0.053$; slope=-0.000, intercept = 6.237) and a uniformly distributed motif (Fig. 2) close to the ecotone layer, but due to excess deforestation at lower altitudes, the capacity of regeneration is greatest due to more available space and light availability.

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We found characteristics decline in species density, basal area, and regeneration towards the end of high elevation across the altitudinal gradient. Regression drawn between basal area and the elevation shows a significant quadratic relation (r2=0.012, P<0.05) and shows a hump-shaped relationship with a peak at around 2400 m. However, regeneration shows a very low r2 value (r2=0.004, F=0.281, df=52, p=0.053; slope=- 0.000, intercept=6.237) and has with uniform distribution pattern (Figure 2) near ecotone layer however due to excess deforestation at the lower altitudes the capacity of regeneration is maximum due to more available space and light availability.

The tree's density shows a significant correlation with elevation (r2=9.00, p < 0.05, t=1.99: two-sample t-test). Maximum variation of trees density was observed at mid-elevation (2300-2600 m) in the mixed dominant zone of *Pinus wallichiana, Abies pindrow*, and *Picea smithana*) between 2300-2600 m. The response of species richness to elevation was modeled employing general linear modeling [31]. Species richness was negatively correlated with elevation showing quadratic model (r2=0.227, p>0.05, t=1.99, Intercept = 15.0938, Slope= -0.0039, F=19.11, t=6.55) that followed a hump-shaped maximum richness at 2400 m elevation.

Our analysis revealed that out of total species richness (710) the maximum species richness 18 % was analyzed for *Pinus wallichiana* (121) followed by 17 % by *Abies pindrow* (121), 11 % Picea smithiana (81) and 7 % for *Quercus dilatata*. The tree's density shows a significant correlation with elevation (r2=9.00, p<0.05, t=1.99: two-sample t-test). Maximum variation of trees density was

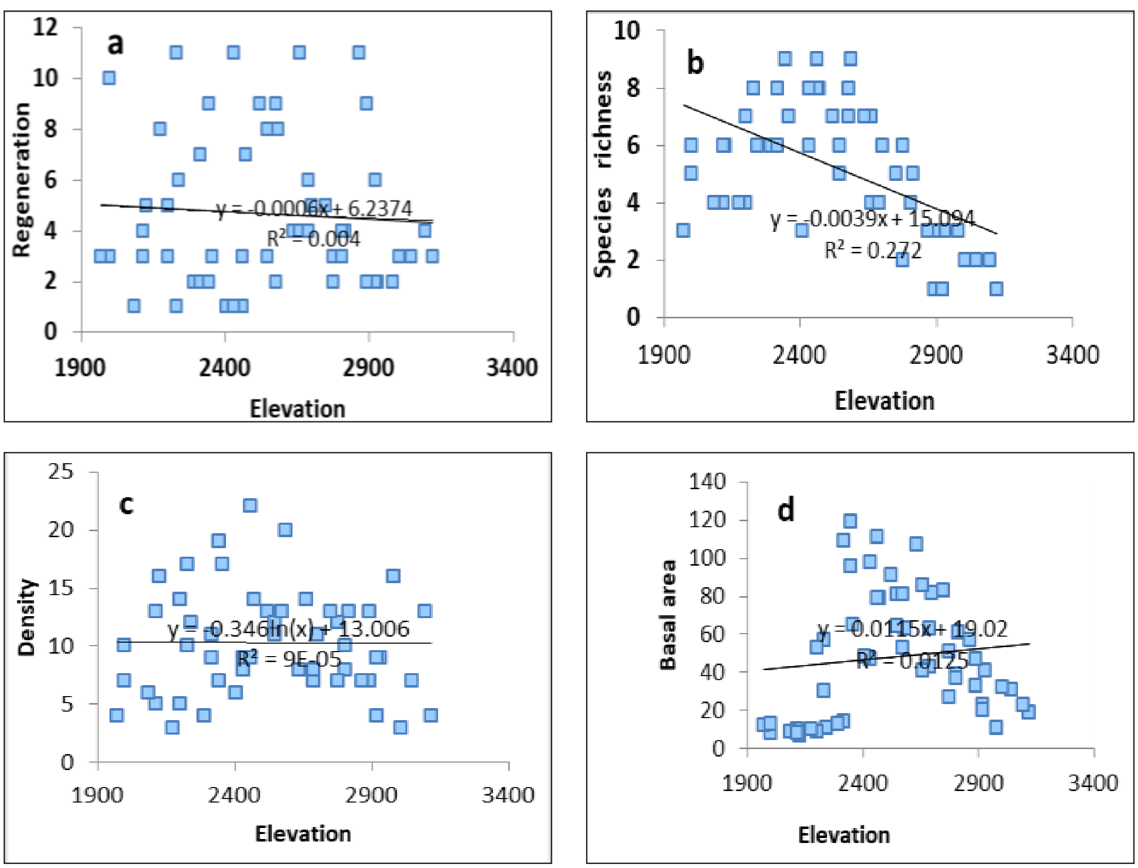

Fig. 2. Observed species richness and diversity parameters (a), Regeneration (b), Species richness (c), Density (d), Basal area of trees along an elevation gradient of Lalkoo, Hindukush Mountainous Range.

observed at mid-elevation (2300-2600 m) in the mixed dominant zone of *Pinus wallichiana, Abies pindrow* and *Picea smithana*) between 2300-2600 m. The response of species richness to elevation was modeled employing general linear modeling [31]. Species richness were negatively correlated with elevation showing a quadratic model (r2=0.227, p>0.05, t=1.99, Intercept= 15.0938, Slope= -0.0039, F=19.11, t=6.55) that followed a hump-shaped maximum richness at 2400 m elevation. Our analysis revealed that out of total species richness (710) the maximum species richness of 18 % was analyzed for *Pinus wallichiana* (121) followed 17 % by *Abies pindrow* (121), 11 % *Picea smithiana* (81), and 7 % for *Quercus dilatata* as shown in Figure 3.

Our results revealed that the maximum species richness in the range of 2200 to 2700 m, (having overlapping boundaries) shows mid-elevation peaks especially in species richness which is due to the increasing overlap of species ranges towards the center of the domain as the extent of elevation is bounded by highest and lowest elevations conforming mid-domain effect (MDE).

4. DISCUSSION

When GLM models for altitude and topography were compared independently, it was discovered that height is a stronger determinant of species richness then surface topography for all species and virtually all species groupings. Additionally, our findings reveal that species diversification, as measured by Shannon's index (H') and Simpson's index (D'), varies significantly in response to fluctuations in the altitudinal inclination in abundance (number of species) and constancy in the sampling sites.

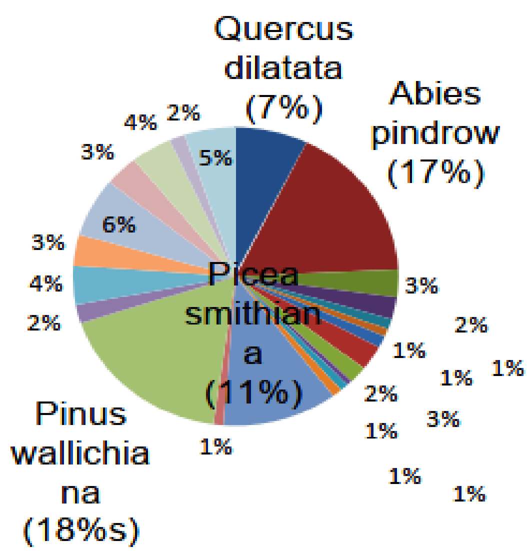

Fig. 3. Range size distribution of dominant trees observed along an elevation gradient in Lalkoo Swat.

Table 2. Results of simple linear regression of basal area, tree density, species richness, and regeneration with elevation gradient in Lalkoo forest.

	Intercept	Slope	D.f	*F*	*P*	R^2	*t* statistics
Trees basal area	19.02	0.0110	52	0.35	0.001	0.012	0.81
Tree's density	11.45	-0.0004	52	1.1E-05	0.05	9.001	1.99
Species richness	15.09	-0.0039	52	19.11	2.71	0.722	6.55
Regeneration	6.24	-0.0061	52	0.28	0.053	0.004	1.89

High values of Shannon's diversity were recorded H'=3.603 at Site-F (SIQ-II) with elevation 2115 m, H'= 3.591 at Site-F (SIQ-I) with elevation 2000 m, and H'= 3.860 at Site-F (SIQ-VII) with elevation 2690 m. The larger value of H' (>2) the greater will be species diversity of the ecosystem [32]. The high value of Simpson's index, D'=0.91 were analyzed in the elevation range of 2290 m, at Site-D (SIQ-II) and the lowest range of Simpson's index D'=0.3 were recorded at Site-F (SIQ-IX) in the lower elevation 2920m. Greater the value of Simpson's index (0 >1) represents no diversity. Our results obtained revealed the high biodiversity of trees in Lalkoo mountainous forest (LMF) Swat District of (the Hindukush range mountains). To ensure prolonged biodiversity, aspects of vegetation must be kept at many natural sizes, from genetic and species divisions to habitats and landforms [33].

We found significant correlation between saplings (DBH<10 cm, height>30 cm) and elevation ($r2=0.005$, $p>0.05$, $t=1.948$, Intercept=6.237, Slope=-0.0006, F= 0.2960). Across the elevation gradient higher sapling density (8-11) was observed in the lower elevation range of 2175 m a.s.l., to 2430 m a.s.l., which is due to factors like open area available to sapling due to severe deforestation and open canopy compared with a dense canopy that is probably due to light requirement of the seedlings. It is also revealed that seedlings are light-demanding require direct solar radiation and tolerate spring frost. Shrestha *et al*. [34] found that the seedlings grow best in a sunny position. However, Scott *et al*. [35] also reported that they best grow in shade. While frequently lower values of sapling density (<2 to >5) were recorded in the higher altitudinal gradient between 2660 to 3045 m. But frequent data available regarding sapling growth also revealed that besides temperature other environmental variables like slope, aspect, altitude, soil moisture are regarded as a significant predictor for sapling abundance. So, from our research analysis, it is obvious that sapling density decreased with altitude [35-37].

We also discovered that the area of altitudinal bands in Lalkoo increases steeply (from 2125 m) with increasing altitude and then decreases (to 2775 m), following a hump-shaped sequence of life-forms in the mid altitudes ranging with a peak about 2400 m. Species richness, as measured by the Shannon index, exhibited a hump-shaped dispersion to height [38-39]. Hump-shaped dispersion is typical in the Himalayas and other moist temperate forests [40-41].

The present investigation revealed that the highest species richness appears at intermediate altitudes and decreases monotonically with increasing elevation ranges [38]. On several occasions in the Himalayas and moist temperate forests like Lalkoo, a uni-modal dispersion sequence of vegetation types of abundance such as bryophytes, ferns, epiphytes, and species high prevalence of numerous animal communities were ascertained, indicating that this is the broad On Sense On elevational trend vigorously encountered in the research area [42].

At a broader level, the mid-elevation peak in plant diversity is influenced by a variety of factors such as soil factors, temperature, humidity, and the mid-domain effect (MDE), all of which are regarded as major indicators of the mid-elevation peak in plant species richness distribution patterns [43-45]. The mid-elevation peak in species richness was determined by randomly placing elevation slopes selected from a specified range size distribution in a geographic location with strict limits [43, 46]. It is further stated that while considering the function of the mid-domain effect, the organisms that occupy the same boundaries (hard and soft) must be examined jointly. Tree species richness diversity pattern in Lalkoo significantly deviated from MDE null model. Although the Lalkoo mountainous forest has ecological and floristic continuity with the greatest Hindukush mountainous ranges most of our study sites in the lower elevation ranges exhibit not climatologically or geographically hard boundaries so the deviation might be caused by the limitation to the applicability of MDE (modeled by mid-domain) within the observed area. It is also significantly highlighted that the degree of departure of the MDE peak from the empirical distribution implies that other factors such as climatic variables and evolutionary history factors play a significant role in interpreting the reported species abundance patterns. Despite the existence of numerous eco-physiological restrictions to vegetation types of growth beyond the timberline at higher elevations, the impact of these hurdles on tree species spreading is thought to be minor [47-49].

The present investigation revealed that MDE gives explanatory detail about tree species richness distribution patterns along elevation gradients [50-51]. According to the most recent MDE research, species borders that coincide along an altitudinal inclination promote increasing confluence of species ranges toward the center of a restricted geographical region [46, 52]. As a result, MDE forecasts a hump-shaped abundance of spatial variability in a mountainous environment like Lalkoo, with the highest diversity at mid-elevation ranges [26]. However, numerous studies have demonstrated that, in addition to MDE, the elevation trend of species richness can be influenced by area, size, climatic condition, and evolutionary history [51-53], which may provide better perspectives on the biodiversity distribution together across elevation gradients [54]. The total mean basal area 2538.33 (t-Test: Paired Two Sample for Means) was found between <7 ± >119 for trees with greater than 4 cm diameter at breath height. The tree basal area shows the highest peak at mid-elevation (at 2400 m) however maximum increase was observed from the 2315 m to 2775 m elevation range. The overall minimum basal area was found at 2125 m a.s.l., Site-A(SIQ-I) So this has been revealed that the lower value of basal area at lower altitudinal ranges is due to human interference like deforestation that affected most of the forest area in the lower altitudinal range near Lalkoo villages.

Human intervention is the primary source of an imbalanced environment; some estimations claim that between one-third and one-half of the earth's topography has been seriously altered by anthropogenic activities [54-55]. Due to the frigid climate patterns at higher altitudes, most tree species have a restricted elevation range size, resulting in a decrease in the basal area at higher elevations. Some tree species have a narrow elevation range along elevation slopes in mountainous forests [18].

5. CONCLUSION

The present study revealed that Lalkoo mountainous forest (LMF) Swat reserves has a reasonably good tree species pattern along an altitudinal gradient. Visual observations of the forest area in its lower altitudes towards higher altitudes show four distinct vegetation overlapping zones that is Blue–Pine zone dominated by Pinus wallichiana for which maximum tree species diversity was observed between 2125 to 2520 m a.s.l., . Fir – Spruce zone is dominated by Picea smithiana and Abies pindrow that shows maximum diversity between 2635 to 2750 meter, Spruce –Oak zone is dominated by Abies pindrow, Quercus semicarpifolia, Taxus wallichina and Picea smithiana in some sites that shows maximum diversity between 2865 to 2920 m a.s.l., and also Alpine–Sub-alpine flora that include mostly scrubby vegetation formed by Juniferous communis that is observed above 3300 m.

The regeneration potential of the sapling is found maximum of 10,11/Unit sample in the lower elevation range2000 m a.s.l., and 2230 m a.s.l., which is due to the high availability of free canopy space due to heavy deforestation near Lalkoo villages. The elevation pattern of species richness followed a uni-model (hump-shaped) pattern peak was at 2400 m a.s.l., Tree density was not uniform along the elevation gradient however high species density were found at around 2600 m a.s.l., Maximum basal area was observed in the mid-elevation range of 2500 m show a peak of quadratic pattern. At mid-elevation range across the elevation, gradient found maximum tree species diversity [56] which corresponds to theory of the mid-domain effect. The study suggests that the distribution pattern of tree species is greatly regulated by altitude and climatic factors [56], however factors like past historical factors that are not evaluated in the present investigation also play important role in Hindukush mountainous range forest Lalkoo Swat.

6. DECLARATION

I declare that: (i) the results are original; (ii) the same material is neither published nor under consideration elsewhere; (iii) approval of all authors has been obtained, and (iv) in case the article is accepted for publication, its copyright will be assigned to Pakistan Academy of Sciences. Authors must obtain permission to reproduce, where needed, copyrighted material from other sources and ensure that no copyrights are infringed upon.

7. CONFLICT OF INTEREST

The authors declare no conflict of interest.

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