Vegetation Classification and Distribution Patterns in Sheikh Badin National Park, Khyber Pakhtunkhwa, Pakistan

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Abstract

The structure, composition, and distribution of plant communities are significantly influenced by both environmental and edaphic factors. The present study was aimed to highlight the effect of various environmental and soil physicochemical factors on the vegetation structure of Sheikh Badin National Park, Pakistan. A total of 29 woody tree species were recorded during sampling of phytosiological data. The reported native and exotic tree species were mostly belongs to mega-phanerophytic (72.4 %) life form. Similarly, both microphyll and nanophyll were the dominant leaf size class having a contribution of 55.17 % to the total. Ward's agglomerative cluster analysis classify the reported plant species of Sheikh Badin National Park into four distinct vegetation types mainly dominated by *Acacia modesta*, *Acacia nilotica*, *Olea ferruginea*, *Capparis decidua*, *Eucalyptus lanceolatus*. Different topographic and edaphic variables significantly affect the vegetation in the studies area. Moreover, diversity indices, species richness and evenness also vary in resulted plant communities which were significantly correlated with elevation, silt, sand, and slope angle. Therefore elevation, soil content, and slope angle were the key factors persuading forest communities and species diversity. Presence of both natural (Drought, climate change) and anthropogenic (cutting, burning, grazing etc.) exposed the sensitivity of these protected areas, which has been compromised. Thus, we recommend an

urgent management plan to conserve these national assets for long term use and to favor regeneration of native plants for allowing the renewal.

Keywords: Forest composition, diversity, Sheikh Badin National Park, Pakistan.

Introduction

National park is a specified area usually declared and owned by national or provincial government reserve for specific purposes like protection and maintenance of landscapes, flora, fauna, recreation, education, and natural sceneries for the present and future generations (Rashid et al., 2020). Due to practical implementation of different polices, both floristic and faunistic lives are comparatively more conserved in the protected areas including national parks, game reserves, wildlife sanctuaries etc. (Huntley et al., 2019). Ecosystem dynamics in protected areas are mainly determined by biological resources, specifically natural vegetation (Ali et al., 2022a). Environmental conditions, spatial heterogeneity, and disturbances all play significant roles in plant community composition, species persistence, and plant richness (Ali and Khan, 2022).

Plant ecology mainly helps in understanding the multidimensional relationships (quantitative, qualitative, and synthetic etc.) of plant communities with environmental variables (Hussain et al., 2019). Mountainous regions are significant for conserving nature and natural vegetation, which is very important for third world countries like Pakistan having limited protected areas (Ali et al., 2023). Therefore, these natural forests are especially important for providing ecological services to people (Muenchow et al., 2013). In the mountainous regions, vegetation community structure, composition and species diversity are determined by various complex factors (Khan et al., 2022). One important factor is altitude, which strongly influences the structure of the vegetation due to close link with precipitation, elevation, nutrients availability, and wind direction (Ali et al., 2022b).

A total of 21 National Parks spreads on 29,589 Km^2 has been identified in Pakistan which covers approximately 3 % of the total area. Of which, only six national parks including Sheikh Badin National Park (SBNP), are located in Khyber Pakhtunkhwa province (Ahmad et al. 2021). SBNP first declared as reserve forest in 1952, game sanctuary in 1972 and declared as a National Park in 1993 by the provincial wildlife department. SBNP spread over an area of 15,515 Hectare

(38336) acres with an altitude of 1400m above sea level and is the only destination of south region to attract tourists (Ullah et al., 2022). The Park area comes under forest type of sub-tropical thorn forest with abundant growth of scrub forests. The Park has 107 plant species belonging to 90 different genera's and 49 families, 26 trees, 20 shrubs, 53 herbs and 8 grass species. Moreover, Sheikh Badin is the only reasonably extensive chunk of the mountain range for safety of animals in the area. Suleiman Markhor and Urial locally migrate within these hill ranges at different seasons (Ahmad et al., 2021; Ali et al., 2017). Other Wildlife includes Wolf, Jackal, Jungle Cat, Chukor, Black Partridge, see-see partridge, and Rock pigeon (Ullah et al., 2015).

In Pakistan few ecological studies have been conducted on national parks, e.g. Chitral Gol National park (Asmat et al., 2021), Deosai National parl (Melis et al., 2020); Ayubia National park (Ahmad, 2012) etc. However, very less attention was paid to describe the vegetation composition and structure in relation to soil physiochemical properties (Ullah et al., 2022). Keeping in view all the points, the current study was assigned in such a way to describe the vegetation composition, structure and diversity of SBNP. It is also one of the objective to explain prevailing environmental factors concerning vegetation composition.

Material and methods

Study area

Vegetation composition, structure in relation to environmental and edaphic factors were analysed in Sheikh Badin National Park, Pakistan (Figure 1). SBNP has diverse climate contributing to the formation of micro ecosystems characterized by various life forms of plants including both indigenous and exotic plant species (Attaullah et al., 2016). The park is situated near National Highway Authorities (N55) and spinning between 32°16'N to 32°38'N latitude, and 70°54'E to 71°21'E longitude with elevation ranging from 300 m to 1350 m asl (Ullah et al., 2022). SBNP is surrounded by Dera Ghazi Khan in east, while its eastern portion touches with river Indus. In the north, it is bounded by Lakki Marwat, and in the southwest South Waziristan is located (Attaullah et al., 2016). Water shortage is one of the most important factor in the studied area which provides difficulties to plants and local communities. The locals depend on the stagnant rainwater stored in ponds constructed in the British era (Figure 2). The locals and animals use this impure water for several months, which is extremely unhygienic.

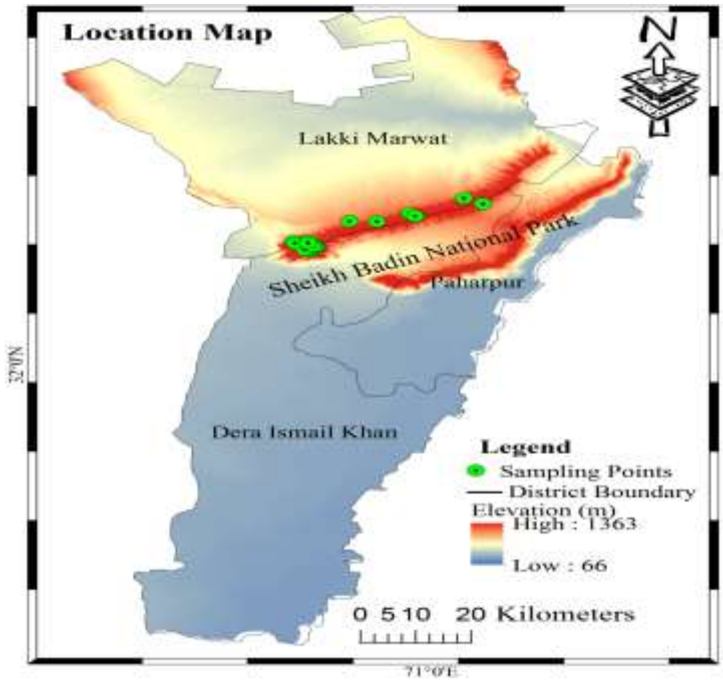

Figure 1. Map of the study area showing the sampling sites in Sheikh Badin National Park

Figure 2. Water storage system established in 1885 since functional in SBNP

Sampling Design and Data collection

After a general survey, 29 least disturbed sites spreads on area of ≥ 2 hectares and showing no recent sign of disturbances were selected for sampling (Ali et al., 2022a). Due to natural and anthropogenic disturbances, vegetation in SBNP has subjected to certain degree of disturbances, we recorded the presence or absences of terraces, agricultural practices, cutting in the overstory and clearing of shrubs in the understory vegetation stratum (Ali et al., 2017). Phytosociological data was collected by establishing 25 quadrates of 10 × 10 m^2 at each sampling site. Within the quadrate, various ecological parameters like, height and diameter at breast height (DBH) of individual tree species were recorded following the procedure of Ali et al., (2019). Likewise, specimens of the understory and canopy vegetation were collected and identified with the help of taxonomists following Flora of Pakistan. Soil samples were collected from all sampled plots, packed in polythene bags and transported to the Agriculture Research Centre Tarnab Peshawar various analysis.

Data Analysis

Brief description such as family name, local name, life-forms and leaf spectra of individual tree type were recorded and analyzed using the literature. The phytosociological characteristics and absolute values were summarized. The floristic array comprised of 29 stands × 29 plant species and an array of environmental and soil physicochemical properties was prepared and then subjected to PC-ORD for classification by choosing Ward's agglomerative techniques (Khan et al., 2015). Soil pH was calculated in the field by a dynamic pH meter (model P9565-IAE) and proportion of coarse particles (gravel, silt, clay and sand) was determined by sieve analysis and hydrometer procedure (Ali et al., 2017). Different soil parameters like organic matter, nitrogen (N), potassium (K), phosphorus (p), water holding capacity (WHC), electrical conductivity (EC), total dissolve solutes (TDS) and soil bulk density (BD) were assessed (Khan et al., 2015).

Results

Floristic composition of SBNP

A total of 29 trees species recorded in different sampling sites in SBNP. Of these 29 tree species, Megaphanerophyte was the leading life form having 21 species, while Phanrophyte and Nanophanerophytes contributes 4 tree species each to the total. Similarly, among leaf size classes, Microphyll and Nanophyll were dominant having 8 species each followed by Leptophyll (5 species), Mesophyll (4 species), and Magaphyll (2 species). Based on Importance value index (IVI), we classify the reported 29 plant species into 4 distinct vegetation types (Figure 3). Vegetation type-I was composed of 12 plant species reported from 5 sites and co-dominated by *Capparis decidua* (IVI= 28.88 ± 1.06) and *Acacia nilotica* (IVI= 12.15 ± 4.3). The sites of this vegetation types was located on lower elevations i.e. 539.8 ± 102.07 m asl (Table 1). *Ziziphus jujuba, Acacia modesta*, *Dalbergia sissoo* were the other subordinate species of this group with mean important value index ranging from 6.16 to 8.45. *Eucalyptus lanceolatus, Mellia* *azedarach, Salvadora oleoides, and Techomela undulata* were sparsely distributed with IVI ranging from 1.94 to 2.84%, while the remaining were rare species having average IVI ranging from 0.58 to 1.30.

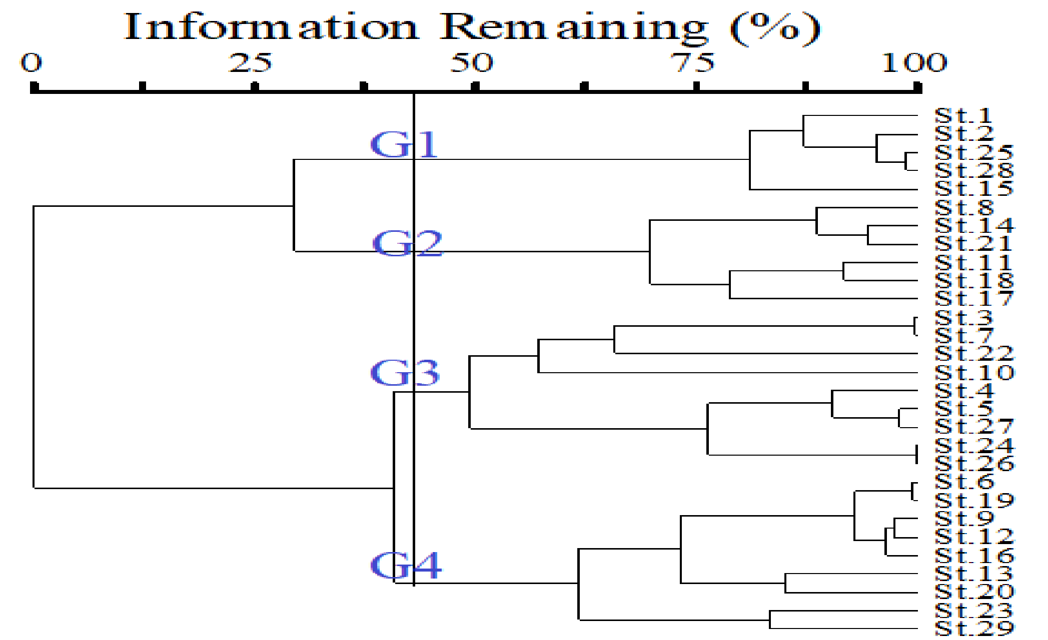

Figure 3. Cluster dendrogram of 29 plots and 29 tree species in the SBNPark, Pakistan.

Acacia nilotica (IVI= 19.8 ± 2.14) and *Eucalyptus lanceolatus* (IVI=15.97 ± 1.54) collectively dominated the vegetation types-II, which have reported 19 plant species from stands. The sampling sites of this vegetation type was located comparatively on steep slopes (38.33±4.41) and high elevation (494.67±58.38). Among the other associates, *Acacia modesta*, *Ailanthus altissima*, *Dalbergia sissoo*, *Morus alba*, *Phoenix dactylifera*, *Prosopis cineraria* etc. were more common. Similarly vegetation type-III was consisting of 16 tree species from 9 stands and dominated by *Acacia modesta* (IVI= 42.1±3.19). The stands of this group are located on higher elevation (853.56 ± 104.38) in comparison to the above two discussed vegetation types. The fourth vegetation types was consisted of 26 plant species from tree stratum and was co-dominated by *Olea ferruginea* (IVI= 26.33±4.04) and *Acacia modesta* (IVI = 19.16 ± 4.54). High elevation (870.89±113.93) and steep slopes are the main features of the vegetation type. Major contributing tree species of the group were *Dalbergia sissoo*, *Ziziphus jujuba*, *Acacia* *nilotica*, *Capparis decidua*, *Eucalyptus lanceolatus*, *Monothica buxifolia*, *Morus nigra* and *Techomella undulata*.

Table 1. Mean Importance values of tree species for the groups resulted from Ward's agglomerative cluster analysis

S.no	Trees	Life form	Leaf size	Group I	Group II	Group III	Group IV
1	*Acacia modesta*	MP	Le	7.50±4.5	6.82±4.42	42.1±3.19	19.16±4.54
2	*Acacia nilotica*	MP	Le	12.15±4.3	19.8±2.14	1.74±1.15	2.8±2.8
3	*Albizia lebbeck*	MP	Le	1.12±0.72	0±0	0±0	0.6±0.6
4	*Alianthus altissima*	MP	Mic	0±0	5±3.45	0±0	0±0
5	*Capparis decidua*	NP	AP	28.88±1.06	1.16±1.16	7.56±2.66	4.34±2.2
6	*Cordia myxa*	MP	Mes	0±0	2.86±1.87	0.45±0.45	1.23±0.91
7	*Dalbergia sissoo*	MP	Nan	6.16±3.88	5.95±2.31	2.88±2.30	9.76±2.43
8	*Eucalyptus lanceolatus*	MP	Mic	2.32±2.32	15.97±1.5	1.84±1.45	3.27±1.66
9	*Ficus carica*	MP	Mac	0±0	2.66±1.35	0±0	0.59±0.38
10	*Ficus palmata*	MP	Mes	0±0	0±0	0.89±0.71	0.14±0.14
11	*Grewia optiva*	MP	Mic	0±0	0±0	0±0	0.75±0.75
12	*Gymnosporia royleana*	NP	Mic	1.84±0.27	0.27±0.27	0±0	0.27±0.27
13	*Melia azedarach*	MP	Mic	2.23±2.23	2.77±1.77	2.35±1.57	5.13±1.71
14	*Monothica buxifolia*	MP	Mic	0±0	0.92±0.92	1.58±1.04	3.03±1.71
15	*Morus alba*	MP	Mes	0±0	5.66±2.71	0.27±0.27	0.62±0.62
16	*Morus nigra*	MP	Mes	0±0	0.85±0.85	0±0	2.06±0.84
17	*Nannorrhops ritchiana*	MP	Meg	1.3±1.3	0±0	0±0	0.21±0.21
18	*Olea ferruginea*	MP	Mic	0±0	2.14±1.49	24.10±6.3	26.33±4.04
19	*Phoenix dactylifera*	MP	Meg	0.62±0.62	4.23±2.68	0.23±0.23	1.22±1.67
20	*Pistichia vera*	PH	Nan	0±0	0±0	0±0	0.27±0.27
21	*Pistacia chinensis*	PH	Nan	0±0	0±0	0±0	0.29±0.29
22	*Prosopis cineraria*	NP	Le	0.58±0.58	6.14±3.98	0±0	0±0
23	*Punica granatum*	PH	Nan	0±0	0±0	0±0	0.6±0.6
24	*Salix tetrasperma*	MP	Mic	0±0	2.84±2.84	1.16±1.16	0±0
25	*Salvadora oleoides*	NP	Nan	2.84±2.84	6.12±4.15	4.50±3.18	1.6±1.15
26	*Tamarix aphylla*	MP	Le	0±0	0.95±0.95	3.59±3.59	0±0
27	*Techomella undulate*	PH	Nan	1.94±1.94	3.45±1.34	4.1±2.21	7.87±1.45
28	*Ziziphus jujube*	MP	Nan	8.45±4.66	6.48±2.82	1.79±0.89	7.7±2.98
29	*Zizyphus mauritiana*	MP	Nan	0±0	0±0	0±0	0.48±0.48

MP = Megaphanerophyte, PH = Phanrophyte; NP = Nanophanerophyte, Ap = Aphyllous, Mac = Macrophyll, Mes = Mesophyll, Mic = Microphyll, Nan =Nanophyll, Le = Leptophyll, Meg =Magaphyll;

Figure 3. The most populated stand of the SBNP

Diversity Indices

We also assesses different diversity indices, species richness and species evenness for the resulted four vegetation types and results are given in table 2. Vegetation type-I and III were recorded with Simpson index followed by group-IV, while Group-II was recorded on lower peak. Similar trend was reported for Shannon and maturity indices. In contrast, the value for species richness was recorded maximum for vegetation type-II (Table 2). While species evenness ranges from 0.87 for group-II to 1.04 for group-III. Table 3 shows strong correlation between available water and Shannon diversity (P < 0.01).

Table 2. Average Simpson, Shannon diversity, Maturity index, Evenness, and richness values of the resulted four vegetation types.

Groups	Simpson diversity	Shannon diversity	Maturity index	Evenness	Richness
Group I	**0.10±0.01**	2.7±0.29	25.18±2.01	0.93±0.13	1.27±0.11
Group II	0.07±0.01	2.63±0.06	22.62±2.19	0.87±0.02	**2.51±0.11**
Group III	**0.10±0.01**	**2.78±0.21**	**25.48±0.81**	**1.04±0.08**	1.25±0.04
Group IV	0.09±0.009	2.7±0.08	22.92±1.16	0.92±0.02	2.40±0.06

Table 3. Correlation coefficients of species diversity values with environmental variables.

Diversity values	Elevation	Slop angle	Aspect	Available Water	pH	Organic Matter	clay
Shannon-Wiener index	-0.537	0.739**	0.069	0.847***	0.042	0.452	0.393
Species Evenness	-0.005	0.2065	0.069	0.428	0.098	0.040	-0.411
Species Richness	0.865***	0.0292	-0.001	0.645**	0.168	0.613	-0.125

*P < 0.1, ***P < 0.05, ***P < 0.01

Environmental characteristics of the resulted vegetation types

Most of the stands of the vegetation type-I were facing south and north-west. Sand particle contents (57.08 ± 6.81) and Phosphorus contents (11±2.47) in the soil of this group were maximum (Table 4). The stands of vegetation type-II were located on lower elevation ranges. Clay and silt particles were dominated the soil texture of this community type. Similarly lime contents and pH were also among the top edaphic variables in comparison to the soil of the other vegetation types. In contrast, Phosphorus contents and soil porosity were ranked on the lower side for the soil of vegetation type-II. *Acacia modesta* dominated sties were positioned on high elevation ranges which severely affect the availability of water due gravitational forces.

Table 3. Descriptive statistic of the environmental variables in the five tree communities of graveyards.

Environmental variables	Group I Mean± SE	Group II Mean± SE	Group III Mean± SE	Group IV Mean± SE
Elevation	539.8±102.07	494.7±58.38	853.56±104.38	669.89±113.93
Slop	37±4.063	38.33±4.41	36.44±3.5	32.77±3.55
Aspect	4.2±1.02	5.5±1.06	3.33±0.76	3.33±0.37
Clay%	16.4±2.16	18.97±1.12	15.69±1.46	18.13±1.19
Silt%	27.6±8.23	31.27±3.12	26.84±3.50	29.29±4.08
Sand	57.08±6.81	49.8±3.79	56.75±5.11	52.58±4.65
Class	2.6±0.4	3±0.45	3.22±0.40	2.77±0.32
pH	7.92±0.05	8.033±0.09	7.78±0.11	8±0.07
Organic matter	1.37±0.32	1.07±0.27	1.79±0.35	0.83±0.22
Lime	20.7±4.22	25.5±6.60	19.83±3.27	23.72±4.67
Nitrogen	0.07±0.02	0.05±0.01	0.09±0.02	0.04±0.01
P(mg/kg)	11±2.47	8.11±0.60	8.15±0.64	8.33±0.79
K(mg/kg)	119.2±12.47	122±11.34	126.89±16.34	106.22±15.38
Wilting point	0.116±0.009	0.122±0.004	0.11±0.006	0.12±0.004
Field capacity	0.23±0.01	0.24±0.009	0.22±0.01	0.24±0.009
Bulk density	1.47±0.02	1.44±0.02	1.48±0.02	1.45±0.01
Porosity	0.45±0.007	0.46±0.006	0.44±0.009	0.45±0.006
Saturation Point	1.27±0.24	0.91±0.11	1.61±1.42	1.06±0.14
Available water	0.112±0.0012	0.12±0.006	0.11±0.007	0.12±0.007

Discussion

Establishing protected areas is one of the most effective strategies for conservation of both flora and fauna (Chape et al. 2005). However, the effectiveness of protected areas in achieving the key objectives has been growing due to continuous interference from natural and anthropogenic disturbances (Geldmann et al., 2019). Protected area provides a platform for research activities, tourism spot and play a huge role in improving the economy and living conditions of the local community. Sheikh Badin National Park, located in Dera Ismail Khan District, has been considered one of Pakistan's bio-diverse and degraded protected areas (Ullah et al., 2022; Khan et al., 2020). In current study we classified the reported 29 tree species into four distinct vegetation types mainly dominated by *Acacia modesta*, *Acacia nilotica*, *Olea ferruginea*, *Capparis decidua* and *Eucalyptus lanceolatus*. The presence of these dominant tree species in the current studied area was also reported by Ullah et al., (2016); and Ali et al., (2022a). Presence of disturbances both from natural sources (climate change and drought), and anthropogenic activities (cutting, grazing etc.) were frequently observed in the Sheikh Badin National Park. The finding of such disturbances was also reported by Khan et al., (2015) while working on vegetation composition of Muslim graveyards.

The current results showed that vegetation type I and II appeared on low elevation (494 to 539 m asl) where habitats were warm and facing severe water shortage. The other vegetation groups occurred between an elevation ranged of 670 m to 853 m where environmental conditions were comparatively cooler. In the above elevational range, several broadleaved and deciduous tree species were present but *Olea ferruginea*, *Acacia* species like *A. modesta*, *A. nilotica* and *Ziziphus* species occurred in all the microhabitats as leading species, reflecting the wide-ranging distribution in the studied area. These results are in conformity to Molnar et al. (2017), stated that several plants regularly appeared particularly with stable populations of *O. ferruginea*, threatened by human activities in the Muslim graveyards (Ahmed, 2011). Several other species like *Punica granatum*, *Ficus carica*, *Grewia optiva*, *Pistichia vera*, etc. occurs in weak association with dominant species but none of them occurred as co-dominant species. Several species listed in Table 2 show their narrow distribution because of their occurrence and minor contribution in all the sample plots and resulted vegetation types. The frequent distribution of some ecologically and economically important tree species are also reported by several workers in the studied area (Ullah et al., 2022; Hussain et al., 2019; Ullah et al., 2016).

With regard to the physiographic variations, vegetation in the Sheikh Badin National Park were on steep (32-38°) slope and facing towards south and west directions. It has been reported that water conditions (precipitation) on northern aspect are better than southern aspect which leads to the formation of broad-leaved evergreen and deciduous broad-leaved forests as also reported in the present study. Topography, vegetation communities, and soil characteristics are interlinked (Khan et al., 2022). Our results show spatial variability in elevation and soil characteristics across the Sheikh Badin National Park. As a result of this special variability, environmental and edaphic factors significantly affect tree species distribution among the four established woody plant communities. The differences in soil characteristics across our study area can be linked to the parent material. This is reflected by higher clay, silt, pH, Lime, welting point, and available water content in vegetation type-II. Our results also point out that the phosphorus content of the soil was limited in soil of Sheikh Badin national Park due to its absorption in to mineral surfaces under low saturated hydraulic conductivity (Nobile et al., 2020).

On the other hand, the available Nitrogen in the soil did not show any marked difference among the communities. Similarly, organic matter was also not an important factor, which means that these factors not affect the vegetation in the studied area. In contrast, elevation, slope angle, silt, and sand were the only marginal environmental factors that showed significant differences and affected the establishment of communities. During the study, variation in elevation among plots was relatively limited. Elevation was the key factor in establishing our communities due to its co-variation (Zebire et al., 2019), which affects the sites and strongly influences species composition (Clilverd et al., 2013).

Species diversity and richness were strongly correlated with elevation, slope angle, and available water content. Therefore, elevation, slope angle, and available water content were the key factors in manipulating species diversity in SBNP. Many researchers have also revealed that elevation is one of the important factors affecting species distribution and diversity in mountainous regions (Ali et al., 2022a; Khan et al., 2022). Based on elevation, intermediate elevations are usually observed for species with high diversity values (Khan et al., 2015). The forest vegetation structure in the present study revealed different forest microzones within the Sheikh Badin National Park. These microzones were secondary natural forests restored from damaged dry-temperate deciduous forests and degraded lands. Therefore, vegetation showed the effects of slope angle, elevation, and landform on forest structure, composition, and diversity. These activities must be regulated, i.e., the number of tourists should be regulated in summer, according to the capacity and facilities of the park.

Conclusion

In conclusion, four diverse woody tree vegetation types were identified and elevation along with soil physiochemical properties were found to be remarkably correlated with vegetation distribution pattern and must be considered while designing the management strategies. This study will helps in better understanding of the mechanisms driving vegetation distribution in other protected area. However, we recommend further study at both local and regional scales to disentangle the vegetation-environment relationships, and other biotic and abiotic factors must be considered for better understanding in the national parks.

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Conflicts of Interest; "The authors declare no conflict of interest."

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