Brazilian Journal of Biology®

ISSN 1519-6984 (Print)
ISSN 1678-4375 (Online)

Original Article

Phytosociology and ecological framework of forest tree species in the Toormang Valley, Dir Lower, Hindu Kush Range, Pakistan

Fitossociologia e enquadramento ecológico de espécies de árvores florestais no Vale Toormang, Dir Lower, Cordilheira Hindu Kush, Paquistão

Tahir Hameed[a], Izhar Ahmad[a*], Shariat Ullah[b], Vetriselvan Subramaniyan[c], Ijaz Ali[d,e], Hazrat Hussain[f], Muhammad Irfan[g], Hassan A. Hemeg[h], Abdur Rauf[i], Natchana Bhutasang[j] and Ling Shing Wong[k*]

[a]Islamia College, Department of Botany, Peshawar, Khyber-Pakhtunkhwa, Pakistan
[b]University of Malakand, Department of Botany, Khyber-Pakhtunkhwa, Pakistan
[c]Sunway University, School of Medical and Life Sciences, Department of Medical Sciences, Dar ul Ehsan, Malaysia
[d]Centre for Applied Mathematics and Bioinformatics – CAMB, Gulf University for Science and Technology, Kuwait
[e]COMSATS University, Department of Biosciences, Islamabad, Pakistan
[f]COMSATS University, Department of Biotechnology, Islamabad, Abbottabad campus, Pakistan
[g]University of Swabi, Department of Botany, Swabi, Pakistan
[h]Taibah University, College of Applied Medical Sciences, Department of Clinical Laboratory Sciences, Al-Monawara, Saudi Arabia
[i]University of Swabi, Department of Chemistry, Khyber Pakhtunkhwa, Pakistan
[j]Metharath University, Faculty of Health Science, Pathum Thani, Thailand
[k]INTI International University, Faculty of Health and Life Sciences, Nilai, Malaysia

Abstract

The phytosociological survey was conducted during 2018-2020. The research area was classified into five ecological zones based on habitat, physiognomy and species composition. Pc-Ord software was used for cluster analysis and four vegetation communities were established. The *Quercus baloot-Quercus incana* community is situated in Sair at an altitude of 1196 (mean ± SE) m altitude with a 14.1 ± 0 slope angle and contains eleven tree species. The *Pinus wallichiana- Ailanthus altissima* community had a relatively small number of tree species reported in Shakawlie at 1556 (mean ± SE) with a 17.5 ± 0 slope angle. The *Pinus wallichiana- Quercus incana* community is distributed in Wali Kandao and Mangi Kandao at altitudes of 2030.5 (mean ± SE) m and the slope angle was 19.2 ± 1.4. This community possesses a total of twenty-one tree species and is highly diverse. Similarly, the *Populus alba - Platanus orientalis* group was present in Banr Pate, with an altitude of 1613 (mean ± SE) m and a 16.3 slope angle. The principal component analysis (PCA) and non-metric multidimensional scaling (NMS) ordination methods were applied to study the relationships between ecological and soil variables with trees species. The NMS ordination of axis 1 was significantly correlated with Sand% ($p<0.2$), Nitrogen% ($p<0.1$) and Pb (mg/kg) ($r= 0.876751$, $p<0.05$), while the ordination of axis 2 was significantly correlated with Silt% ($p<0.2$), Sand% ($p<0.2$), Organic matter% ($p<0.2$), K (mg/kg) ($r=0.882433$, $p<0.02$), Fe (mg/kg)($r=0.614833$, $p<0.2$), Ca (mg/kg) ($r=0.721712$, $p< 0.2$) and Zn (mg/kg) ($r=0.609545$, $p<0.2$). Similarly, the PCA ordination of axis 1 revealed that it was significantly correlated with phosphorus, calcium and slope angle, while that of axis 2 was significantly correlated with altitude, zinc and manganese.

Keywords: tree species, environmental variables, cluster analysis, PCA & NMS ordination, Toormang Valley, Lower Dir, Pakistan.

Resumo

O levantamento fitossociológico foi realizado durante o período 2018-2020. A área de pesquisa foi classificada em cinco zonas ecológicas com base no habitat, na fisionomia e na composição de espécies. O *software* Pc-Ord foi utilizado para análise de agrupamento e quatro comunidades de vegetação foram estabelecidas. A comunidade *Quercus baloot-Quercus incana* está situada em Sair, a uma altitude de 1.196 m (média ± SE) de altitude, com um ângulo de inclinação de 14,1° ± 0, e contém 11 espécies de árvores. A comunidade *Pinus wallichiana-Ailanthus altissima* teve um número relativamente pequeno de espécies de árvores relatadas em Shakawlie, em 1.556 m (média ± SE) de altitude, com um ângulo de inclinação de 17,5° ± 0. A comunidade de *Pinus wallichiana-Quercus incana* está distribuída em Wali Kandao e Mangi Kandao, em altitude de 2.030,5 m (média ± SE) e ângulo de inclinação de 19,2° ± 1,4. Esta comunidade possui um total de 21 espécies de árvores e é altamente diversificada. Da mesma

*e-mail: Izhar.ahmad@icp.edu.pk; Lingshing.wong@newinti.edu.my
Received: February 4, 2024 – Accepted: April 30, 2024

forma, o grupo *Populus alba-Platanus orientalis* esteve presente em Banr Pate, com altitude de 1.613 m (média ± SE) e ângulo de inclinação de 16,3°. Os métodos de análise de componentes principais (PCA) e ordenação de escala multidimensional não métrica (NMS) foram aplicados para estudar as relações entre variáveis ecológicas e de solo com espécies arbóreas. A ordenação NMS do eixo 1 foi significativamente correlacionada com as porcentagens de Areia (p<0,2), Nitrogênio (p<0,1) e Chumbo (mg/kg) (r=0,876751, p<0,05), enquanto a ordenação do eixo 2 foi significativamente correlacionada com as porcentagens de Silte (p<0,2), Areia (p<0,2), Matéria Orgânica (p<0,2), Potássio (mg/kg) (r=0,882433, p<0,02), Ferro (mg/kg) (r=0,614833, p<0,2), Cálcio (mg/kg) (r=0,721712, p< 0,2) e Zinco (mg/kg) (r=0,609545, p<0,2). Da mesma forma, a ordenação PCA do eixo 1 revelou que estava significativamente correlacionada com fósforo e cálcio, e ângulo de inclinação, enquanto a do eixo 2 estava significativamente correlacionada com zinco e manganês, e altitude.

Palavras-chave: espécies de árvores, variáveis ambientais, análise de cluster, ordenação PCA e NMS, Vale Toormang, Lower Dir, Paquistão.

1. Introduction

Phytosociology is related with plant community composition, structure and distribution (Magray et al., 2022). It is important to use phytosociological methods to study the different kinds of species that live in a certain area (Lovett et al., 2006). Phytosociological research is essential for the maintenance of natural plant communities and biodiversity, as well as for understanding past and future changes (Soni and Namdeo, 2022). Many scientists have shown that the climate and edaphic factors affect the Himalayan and Hindukush regions of Pakistan (Ahmed et al., 2006). The goal of phytosociological studies is to develop a conservation strategy for a wide variety of plant species (Badshah et al., 2016; Hussain et al., 2019).

Forest species supply resin, fuel wood, fodder, and timber to local communities. The increasing demand for forest products and growing populations have put considerable stress on subtropical forest stands, leading to the loss of species and disruption of communities (Timilsina et al., 2007; Gairola et al., 2008). During the course of the last century, over 60% of the forest cover in the Himalayan region's has been eradicated (Todaria et al., 2010). Pakistan is in danger because less than 4% of its land is covered by forests, and 3% of its forests are being cut down every year. Over the last three decades, Pakistan has lost more than a quarter of its forests (Ahmad et al., 2010; Shaheen and Shinwari, 2012).

Plant communities are established by species that share structural and floristic traits at a particular level of ecological tolerance (Magray et al., 2022). The distribution of plant communities is influenced by ecological factors, species competition and human activities (Ilyas et al., 2020). The existence and development of plant communities provide information about the type of plant and the environmental conditions that led to their development (Hussain et al., 2015). The vegetation and plant communities of various habitats are changing gradually or quickly due to human disturbances (Iqbal et al., 2008; Naz et al., 2017). The plant population size and the structure of the vegetation can provide information about the species' ability to tolerate particular ecological characteristics (Sher et al., 2014).The levels of micronutrients and macronutrients in the soil can have a significant impact on plant communities (Hussain et al., 2019). The topography and elevation of mountainous regions have a significant impact on community structure, species richness and species diversity (Khan et al., 2015).

Cluster analysis techniques are used to evaluate ecological groups whereas, ordinations provide specific patterns for plant communities with respect to environmental gradients (Ali et al., 2022a). Research revealed that advanced multivariate statistical analysis was initially limited to use in highly developed countries. However, in recent decades, multivariate statistical analyses have been frequently used to examine vegetation communities and investigate the effects of environmental factors on plant distribution patterns in various parts of the world (Hou et al., 2017). The objective of this study was to analyze the vegetation of the Toormang Valley, Dir Lower, Pakistan, in relation to different environmental and ecological factors. It is predicted that the altitude, slope angle, and aspect of the mountain influence vegetation structure and biodiversity. The literature shows that there is no research on the vegetation of the Toormang Valley. Therefore, the current study is considered necessary for investigating the pattern and features of vegetation in the Toormang Valley, Dir Lower, Pakistan.

2. Materials and Methods

2.1. Study area

The Toormang Valley is located in the lower Dir district of Khyber Pakhtunkhwa, Pakistan. The valley is present in the northwestern corner of Khyber Pakhtunkhwa and is bounded on all sides by the massive Koh-e-Hindukush Range. It is located between 34°54'50" and 34°52'29" N and between 72°01'12" and 72°06'00" E of the Equator. A map showing the various study sites (is shown in Figure 1). Summer is short and pleasant, while winter is harsh. The high mountains receive snow from December to March (Khan et al., 2010).

2.2. Data collection

The data were collected on a regular basis from 2018 to 2020. Based on habitat, species composition, and physiognomy, the valley was divided into five ecological zones. A variety of quantitative methods were applied to study the phytosociology of tree species using a quadrat size of 10m×10 m. At each site, ten quadrats were established for each tree species (Ali and Khan 2022). Ecological parameters such as density, frequency and cover for tree species were calculated (Rahman et al., 2023). A GPS device was used to measure the altitudes and geographical coordinates of each quadrat. The aspect was determined using a magnetic compass, while the slope angle was calculated using a clinometer (Ali et al., 2022b). At each sampling site, soil

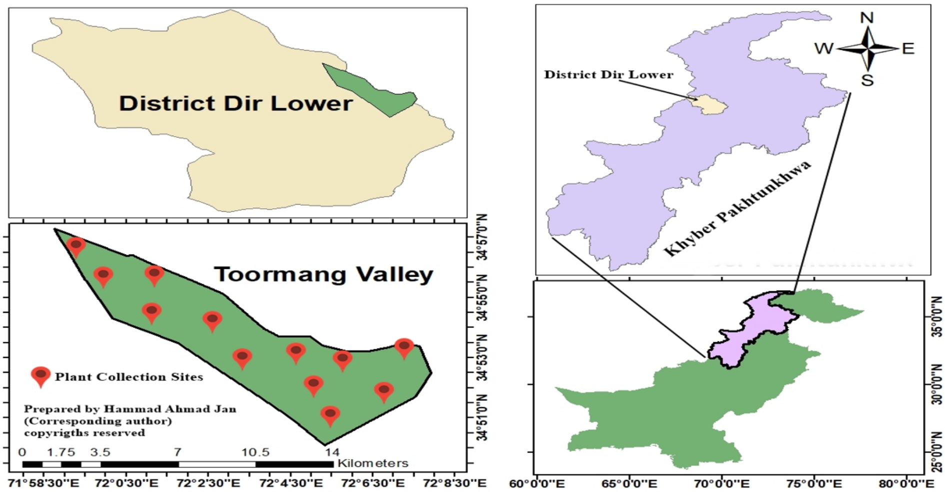

Figure 1. Map of the study area.

was collected from three different regions up to a depth of 15 cm and mixed to form a composite sample (Ali et al., 2017). Soil texture was evaluated using the hydrometer method at the Land Resource Research Institute, NARC, Islamabad (Elfaki et al., 2016). The acid neutralization method was used to assess soil organic matter and lime levels (Amin et al., 2022). The pH of the soil was measured in a 1:5 water-soil solution (Cheng et al., 2019).

2.3. Statistical analysis of the data

PC-Ord (version 5.10) was used for the data analysis. The quantitative data associated with ecological and edaphic variables were subjected to software to reveal core clusters and significant patterns in vegetation structure (McCune and Mefford, 2005). Ward's cluster analysis was used for classification, whereas non-metric multidimensional scaling (NMS) and principal component analysis (PCA) were used for coordination (Gauch and Whittaker, 1981). Then, the IVI data of 28 tree species and 19 parameters were subjected to cluster analysis and ordination at 75%. Furthermore, descriptive statistics were used to calculate the mean and standard error of IVI data collected from different communities of tree species. After that, the soil data from the different study areas were correlated with the various values of the NMS and PCA axes (Gupta et al., 2008).

3. Results

3.1. Ward's cluster analysis of tree species

In the present research, Pc-Ord software (version 5.2) was used to perform cluster analysis on the IVIs of 28 tree species. The resulting data were divided by 75% of the remaining information about the individual species into 4 vegetation groups. The one-way cluster dendrogram and two-way cluster dendrogram of the tree species are shown in (Figures 2 and 3). The *Quercus baloot -Quercus incana* vegetation group was present in the sair at an altitude of 1196 (mean ± SE) m and the slope angle was 14.10°. This group was dominated by *Quercus baloot* (IVI = 15.11 ± 0%) and *Quercus incana* (IVI = 13.53 ± 0%) while *Ailanthus altissima* (IVI =12.53 ± 0%), *Juglans regia* (IVI =11.53 ± 0%) and *Phoenix sylvestris* (IVI =11.14 ± 0%) were the major associates. The total density (426 individuals/ha) and overall basal area (13822 cm^2 cover/ha) were recorded (Table 1). The soil in this vegetation group was sandy loam in texture, calcareous and slightly alkaline in nature, with a pH value of 7.6 ± 0. The organic matter content was low, the nitrogen level was low, the phosphorus was moderate and the potassium content was appropriate (Table 2).

Vegetation group-II was situated in Shakawlie at 1556 (mean ± SE) m altitude with a 17.50 slope angle. This vegetation group is less diverse than other communities. Among them *Pinus wallichiana* (IVI =24.01 ± 0%) and *Ailanthus altissima* (IVI =18.2 ± 0%), were recognized as the leading species, followed by *Quercus dilatata* (IVI =10.18 ± 0%) and *Eriobotrys japonica* (IVI =9.49 ± 0%). The soil in this vegetation group was mostly loamy and calcareous, with a pH of 7.7 ± 0; the nitrogen and organic matter contents were low; the phosphorus content was moderate; and the potassium content was reportedely high compared to that in other communities. In this community, the overall basal area (13842 cm^2 cover/ha) and the highest density per hectare, with 546 individuals, were observed in vegetation group II (Table 1).

Overstory vegetation group III, consists of twenty-one different species and is more diverse than the other communities. This vegetation group is situated in Wali Kandao and Mangi Kandao at an elevation of 2030.5 ± 232.5 (mean ± SE) m and a slope angle of 19.2 ± 1.4°. *Pinus wallichiana* was the dominant species (IVI =20.1 ± 5.33%) followed by *Quercus incana* (IVI=15.42 ± 6.87), *Eucalyptus camaldulensis* (IVI=8.98 ± 6.98) and *Quercus baloot* (IVI=7.44 ± 3.39). The soil was sandy loam in texture with a slightly alkaline pH (7.3 ± 0.1) and was calcareous. Organic matter, nitrogen, and potassium were less abundant, while phosphorus was found in high amounts in the soil

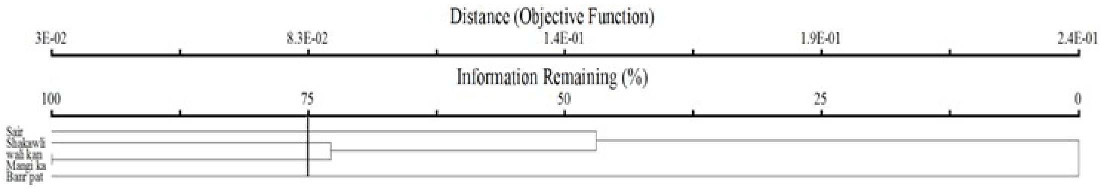

Figure 2. Tree species cluster dendrogram based on IVI.

(Table 2). The density and basal area of the dominant species were (118 ± 0 density/ha and 1520 ± 12.2 cm^2 cover/ha) respectively whereas the overall basal area was greater than that of the other vegetation groups.

Populus alba (IVI =13.54 ± 0%) and *Platanus orientalis* (IVI =13.42 ± 0%) dominated the fourth vegetation group and were found in Banr pate at 1613 (mean ± SE) m altitude and 16.3 ± 0 slope angle. *Acacia modesta* (IVI =10.12 ± 0%) and *Quercus incana* (IVI =9.68 ± 0%) were the major associates with the dominant species. The soil of this community was sandy loam and calcareous, with less organic matter and a pH value of 7.2 ± 0. The nitrogen content was high, the phosphorus content was moderate, and the potassium content was low in the soil (Table 2). This vegetation group was reported as the second most diverse community in terms of the total density (444 individuals/ha) and overall basal area (16815 cm^2 cover/ha), as shown in Table 1.

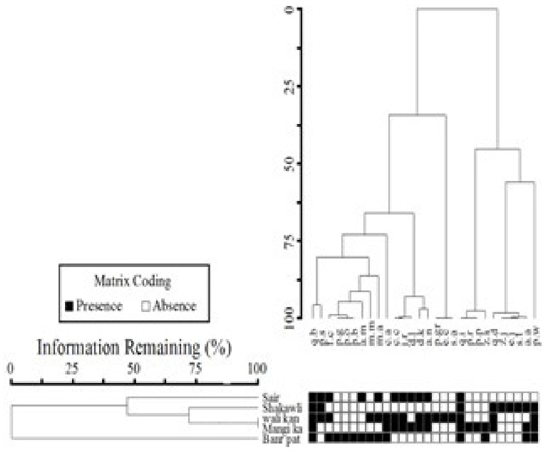

Figure 3. Cluster dendrogram (two-way) of tree species.

3.2. Factors influencing species distribution patterns

The relationships of environmental variables, physiochemical characteristics, and micro and macronutrients with tree species were examined by using NMS and PCA ordination. The results show that different groups of tree species were obtained by using Ward cluster analysis and were also subjected to NMS and PCA ordination.

3.3. NMS ordination of the tree vegetations

Figure 4 shows that in the NMS ordination plot, the *Quercus baloot-Quercus incana* vegetation group located at the bottom of the plot toward axis 1, was generated due to the effects of the high amount of sand (74 ± 0) and low amount of lime (6.75 ± 0). The *Pinus wallichiana-Ailanthus altissima* community on the upper side toward axis 2 developed under the influence of high pH (7.7 ± 0) and low silt concentration (13 ± 0). The *Pinus wallichiana-Quercus incana* located in the left region along axis 2 are characterized by a high clay content (23 ± 2) and a low concentration of organic matter (0.755 ± 0.035). Similarly, the *Populus alba-Platanus orientalis* group on the right side of axis 1 was assembled under the influence of a high nitrogen concentration (0.043 ± 0) and low pH (7.2 ± 0).

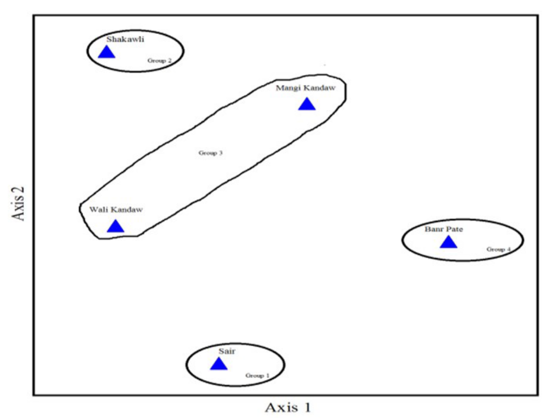

Figure 4. The occurrence of tree species between. Axis 1 and Axis 2 in the NMS ordination graph.

3.4. NMS ordination axis correlation with the soil and environmental variables

The results showed that the NMS ordination of axis 1 was significantly correlated with sand % ($p< 0.2$), nitrogen % ($p< 0.1$) and pb (mg/kg) (r= 0.876751, $p<0.05$), while the NMS ordination of axis 2 was significantly correlated with silt% ($p<0.2$), sand % ($p<0.2$), organic matter % ($p<0.2$), K (mg/kg) (r=0.882433, $p<0.02$), Fe (mg/kg)(r=0.614833, $p<0.2$), Ca (r=0.721712, $p<0.2$) (mg/kg) and Zn (r=0.609545, $p<0.2$) (mg/kg) (Table 3; Figure 4). The correlations of NMS ordination axes 1 and 2 with the remaining parameters were determined non-significant. Current research has revealed that the primary parameters affecting the distribution of tree species are altitude, organic matter, nitrogen, phosphorus, calcium, magnesium and lead.

Table 1. Overstory vegetation Ward's cluster analysis and IVI values, density/ha and cover/ha in different vegetation groups.

S.N	Species	GROUP 1			GROUP 2			GROUP 3			GROUP 4		
		Mean ± SE			Mean ± SE			Mean ± SE			Mean ± SE		
		IVI	Density/ ha	Cover/ha	IVI	Density/ ha	Cover/ha	IVI	Density/ ha	Cover/ha	IVI	Density/ ha	Cover/ha
1	*Quercus baloot* Griff.	15.11 ± 0	90 ± 0	1620 ± 0	6.49 ± 0	18 ± 0	1298 ± 0	7.44 ± 3.39	16 ± 6	1180 ± 1180	6.06 ± 0	16 ± 0	1100 ± 0
2	*Quercus incana* Bartram.	13.53 ± 0	12 ± 0	520 ± 0	8.22 ± 0	28 ± 0	590 ± 0	15.42 ± 6.87	62 ± 10	1340.2 ± 1.4	9.68 ± 0	84 ± 0	580 ± 0
3	*Ailanthus altissima (*Mill.)Swingle.	12.53 ± 0	4 ± 0	3380 ± 0	18.2 ± 0	20 ± 0	1360 ± 0	3.61 ± 3.65	4 ± 2	1130.3 ± 510.2	0 ± 0	0 ± 0	0 ± 0
4	*Platanus orientalis*	5.24 ± 0	16 ± 0	702 ± 0	0 ± 0	0 ± 0	0 ± 0	1.98 ± 1.56	2 ± 2	370 ± 370	13.42 ± 0	96 ± 0	1705 ± 0
5	*Phoenix sylvestris* (L.) Roxb.	11.14 ± 0	98 ± 0	1860 ± 0	0 ± 0	0 ± 0	0 ± 0	1.15 ± 1.15	2 ± 2	110 ± 110	8.06 ± 0	8 ± 0	1400 ± 0
6	*Acacia modesta* Wall.	9.87 ± 0	80 ± 0	580 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	10.12 ± 0	4 ± 0	3330 ± 0
7	*Celtis caucasica* Willd.	6.62 ± 0	92 ± 0	1702 ± 0	0 ± 0	0 ± 0	0 ± 0	6.27 ± 1.47	14 ± 4	2500.2 ± 280	0 ± 0	0 ± 0	0 ± 0
8	*Diospyros lotus* L.	4.57 ± 0	8 ± 0	560 ± 0	0 ± 0	0 ± 0	0 ± 0	4.05 ± 1.36	6 ± 2	1406.3 ± 550	0 ± 0	0 ± 0	0 ± 0
9	*Juglans regia*	11.53 ± 0	4 ± 0	1120 ± 0	0 ± 0	0 ± 0	0 ± 0	5.27 ± 1.47	10 ± 4	1800.2 ± 426.2	0 ± 0	0 ± 0	0 ± 0
10	*Diospyros kaki* L.f.	3.57 ± 0	4 ± 0	488 ± 0	0 ± 0	0 ± 0	0 ± 0	2.5 ± 0.12	6 ± 0	1950.2 ± 210	0 ± 0	0 ± 0	0 ± 0
11	*Acacia nilotica* (L.) Delile.	6.24 ± 0	18 ± 0	1290 ± 0	0 ± 0	0 ± 0	0 ± 0	1.34 ± 1.34	2 ± 2	130 ± 130	0 ± 0	0 ± 0	0 ± 0
12	*Quercus dilatata* Royle.	0 ± 0	0 ± 0	0 ± 0	10.18 ± 0	4 ± 0	3360 ± 0	2.24 ± 0.55	2 ± 0	790 ± 790	0 ± 0	0 ± 0	0 ± 0
13	*Ziziphus jujuba* Mill.	0 ± 0	0 ± 0	0 ± 0	7.61 ± 0	12 ± 0	1726 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
14	*Eriobotrys japonica* (Thunb.) Lindl.	0 ± 0	0 ± 0	0 ± 0	9.49 ± 0	80 ± 0	540 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
15	*Salix tetrasperma* Roxb.	0 ± 0	0 ± 0	0 ± 0	8.81 ± 0	32 ± 0	1470 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
16	*Melia azedarach* L.	0 ± 0	0 ± 0	0 ± 0	6.99 ± 0	160 ± 0	1708 ± 0	2.02 ± 2.02	2 ± 0	430 ± 430	4.16 ± 0	4 ± 0	1306 ± 0
17	*Pinus wallichiana.* Jacks.	0 ± 0	0 ± 0	0 ± 0	24.01 ± 0	192 ± 0	1790 ± 0	20.1 ± 5.33	118 ± 14	1520 ± 12.2	3.78 ± 0	4 ± 0	1160 ± 0
18	*Morus macroura* Miq.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	2.56 ± 1.56	2 ± 2	540 ± 540	7.16 ± 0	12 ± 0	1700 ± 0
19	*Ficus carica* L	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	9.25 ± 0	80 ± 0	566 ± 0
20	*Populus alba*	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	13.54 ± 0	92 ± 0	1696 ± 0
21	*Ziziphus sativa* Gaertn.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	4.05 ± 4.05	6 ± 6	1415.2 ± 590	4.23 ± 0	8 ± 0	580 ± 0
22	*Pyrus baccata* L.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	8.15 ± 0	28 ± 0	1410 ± 0
23	*Celtis australis* L.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	1.72 ± 1.02	2 ± 2	330 ± 330	2.38 ± 0	8 ± 0	282 ± 0
24	*Punica granatum* L	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	2.3 ± 2.37	2 ± 4	140 ± 140	0 ± 0	0 ± 0	0 ± 0
25	*Eucalyptus camaldulensis* Dehnh.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	8.98 ± 6.98	20 ± 10	1750 ± 65.3	0 ± 0	0 ± 0	0 ± 0
26	*Salix alba* L.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	2.2 ± 2.37	14 ± 14	565 ± 565	0 ± 0	0 ± 0	0 ± 0
27	*Pinus roxburghii* Sarg.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	3.02 ± 2.02	2 ± 2	735 ± 735	0 ± 0	0 ± 0	0 ± 0
28	*Pyrus* pashia D. Don.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	1.69 ± 1.69	0 ± 0	320 ± 320 ±	0 ± 0	0 ± 0	0 ± 0
	Total		426	13822		546	13842		294	20451		444	16815

Key: (SE) standard error = the standard error is the approximate standard deviation of a statistical sample population.

Table 2. Soil nutrients and topographic and edaphic factors related to Overstory species.

Parameters	GROUP 1			GROUP 2			GROUP 3			GROUP 4		
	Mean	±	SE	Mean	±	SE	Mean	±	SE	Mean	±	SE
Altitude	1196	±	0	1556	±	0	2030.5	±	232.5	1613	±	0
Slope	14.1	±	0	17.5	±	0	19.2	±	2.2	16.3	±	0
Clay %	18	±	0	13	±	0	23	±	2	23	±	0
Silt %	8	±	0	42	±	0	14	±	2	4	±	0
Sand %	74	±	0	45	±	0	63	±	4	73	±	0
PH	7.6	±	0	7.7	±	0	7.3	±	0.1	7.2	±	0
Lime	6.75	±	0	7	±	0	6.625	±	0.375	7.5	±	0
O.M%	0.79	±	0	0.93	±	0	0.755	±	0.035	0.86	±	0
N %	0.039	±	0	0.04	±	0	0.0378	±	0.0012	0.043	±	0
P (mg/kg)	6.2	±	0	5.4	±	0	25.55	±	18.15	6.5	±	0
K (mg/kg)	70	±	0	110	±	0	95	±	5	85	±	0
Fe (mg/kg)	0.893	±	0	1.14	±	0	1.05	±	0.171	1.33	±	0
Zn (mg/kg)	0.272	±	0	0.911	±	0	0.513	±	0.375	0.288	±	0
Ca(mg/kg)	0.88	±	0	0.3166	±	0	0.239	±	0.006	0.327	±	0
Cu (mg/kg)	0.222	±	0	0.344	±	0	0.388	±	0.176	0.4312	±	0
Mn(mg/kg)	3.232	±	0	2.345	±	0	3.5865	±	1.6005	4.786	±	0
Pb(mg/kg)	1.23	±	0	1.12	±	0	1.06	±	0.08	1.9	±	0
Mg (mg/kg)	2.243	±	0	2.987	±	0	2.839	±	0.707	3.786	±	0

Key: (O.M) organic matter. Soil organic matter is the portion of soil composed of plant or animal material at different phases of decomposition.

Table 3. Correlation between NMS ordination axes 1 and 2 with soil and environmental variables.

Parameters	Axis 1		Axis 2	
	Multiple R	Probability level	Multiple R	Probability level
Altitude	0.582739	Non significant	0.309706	Non significant
Slope	0.345	Non significant	0.412765	Non significant
Clay %	0.115103	Non significant	0.357328	Non significant
Silt %	0.572639	Non significant	0.693407	p<0.2
Sand %	0.670957	p<0.2	0.727211	p<0.2
PH	0.170988	Non significant	0.04095	Non significant
Lime	0.607827	Non significant	0.406289	Non significant
O.M %	0.226227	Non significant	0.654887	p<0.2
N %	0.745442	p<0.1	0.291178	Non significant
P (mg/kg)	0.434446	Non significant	0.16645	Non significant
K (mg/kg)	0.109396	Non significant	0.882433	p<0.02
Fe (mg/kg)	0.287441	Non significant	0.614833	p<0.2
Zn (mg/kg)	0.483008	Non significant	0.609545	p<0.2
Ca(mg/kg)	0.493294	Non significant	0.721712	p<0.2
Cu (mg/kg)	0.054042	Non significant	0.414328	Non significant
Mn(mg/kg)	0.374698	Non significant	0.043376	Non significant
Pb(mg/kg)	0.876751	p<0.05	0.108986	Non significant
Mg (mg/kg)	0.275011	Non significant	0.394547	Non significant

3.5. PCA ordination of tree vegetation

PCA ordination was used to study the associations of tree vegetation with edaphic, topographic, soil micro and macronutrients. Ward's cluster analysis revealed four groups of tree species, which were superimposed on PCA ordination axes 1, 2; 1, 3 and axes 2, 3. According to the results, PCA ordination and Ward's cluster analysis are separate methodologies that are used for the same objectives. In the PCA ordination, community 1 is present on the left side of axis 2, while community 2 is on the right of axis 1. Group 3 is present at the left of axis 2, and group 4 is present on the upper side towards axis 2. The PCA ordination axes 1,2; 2,3 and 1,3 are shown in (Figures 5, 6 and 7) respectively.

3.6. Association of the PCA ordination axis with topographic, edaphic and soil nutrients

The PCA ordination of axis 1 revealed that it was significantly correlated with slope ($p< 0.20$), clay percentage ($r=0.754$, $p< 0.10$), P concentration ($R=0.785$, $p< 0.10$) (mg/kg) and Ca concentration ($r=0.687$, $p< 0.20$)(mg/kg). PCA ordination axis 2 showed a significant correlation with altitude ($p< 0.10$), K ($r= 0.803$, $p< 0.10$), Zn ($r= 0.637$, $p< 0.20$) and Mn (0.893, $p< 0.02$), while PCA ordination axis 3 showed no significant correlation (Table 4).

4. Discussion

The climate of the lower Dir is moist and cold (Irfan et al., 2018). However, the differences in plant communities at various altitudes are due to significant changes in physiographic, edaphic, and climatic conditions (Ahmed, 1986). The nutrients in the soil, soil moisture, and amount of rainfall all have a significant impact on the establishment of forest communities, as do other environmental factors (Timilsina et al., 2007).The *Quercus baloot-Quercus incana* community was established in Sair at an altitude of 1196 m above sea level with a 14.1 slope angle. The dominant tree species were *Quercus baloot* and *Quercus incana*. The woody species that are associated with this species are *Ailanthus altissima, Juglans regia, Phoenix sylvestris, Acacia modesta,* and *Celtis caucasica.* These findings are consistent with those of Rahman et al. (2022), who investigated Quercus-dominated forests in the Swat district. The *Quercus baloot* was also reported by Khan et al. (2010) from District Chitral. Khan (2012) reported the *Quercus baloot-Quercus dilitata* community from Dir Upper. Ali (2016) described an *Abies pindrow-Quercus incana* community from Chail Valley district swat. In Quercus-dominated communities, the degree of verifiability is mostly determined by the aspect and altitude of the landscape (Coop and Givnish, 2007).

The *Pinus wallichiana- Ailanthus altissima* community was found in Shakawlie at 1556 m altitude with a 17.5 slope angle. This community is less diverse than other tree communities. These results are in agreement with those of Zaman and Badshah (2020), who also reported that due to the extensive use of wood in the area, tree species were quite scarce. The presence of insufficient trees and rather thick plants in the vicinity of the lower sections demonstrated the disturbed nature of the ecosystem, which is under enormous biotic pressure. The expansion of the population and the construction of new residential units are the main causes of species extinction in this area. The lower number of tree species could be attributed to the increased demand for fuel, timber wood, infrequent

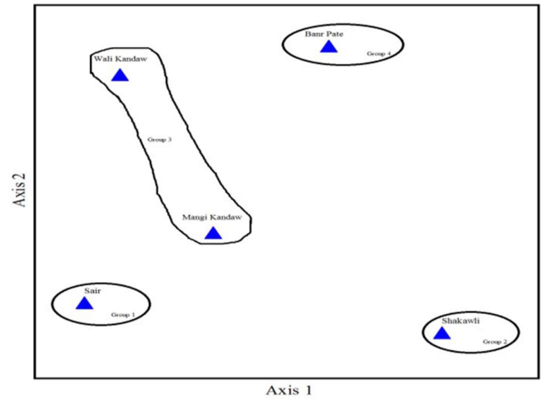

Figure 5. PCA ordination (axis 1 and axis 2) of tree species.

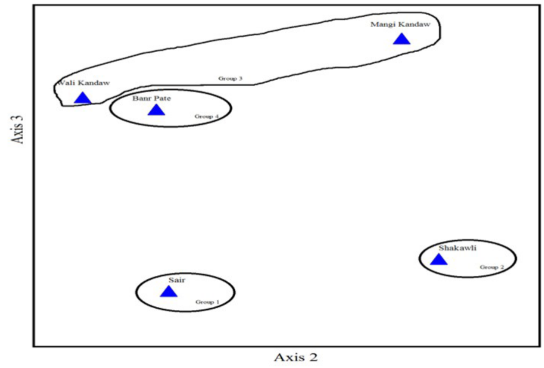

Figure 6. PCA ordination (axis 2 and axis 3) of tree sspecies.

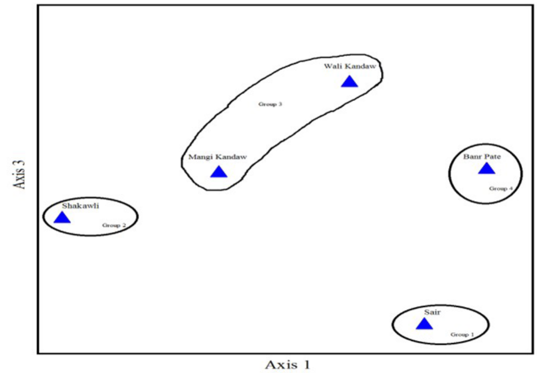

Figure 7. PCA ordination (axes 1 and 3) of tree species.

Table 4. Correlation of PCA ordination axis 1 and 2 with soil and environmental factors.

Parameters	axis 1		axis 2		axis 3	
	Multiple R	Probab. Level	Multiple R	Probab. Level	Multiple R	Probab. Level
Altitude	0.453	Non significant	0.745	P < 0.10	0.132	Non significant
Slope	0.576	P < 0.20	0.043	Non significant	0.243	Non significant
Clay %	0.754	P < 0.10	0.543	Non significant	0.465	Non significant
Silt %	0.532	Non significant	0.365	Non significant	0.165	Non significant
Sand %	0.453	Non significant	0.253	Non significant	0.376	Non significant
pH	0.432	Non significant	0.352	Non significant	0.254	Non significant
Lime	0.564	Non significant	0.601	Non significant	0.436	Non significant
O.M %	0.235	Non significant	0.412	Non significant	0.0243	Non significant
N %	0.376	Non significant	0.054	Non significant	0.534	Non significant
P mg/kg	0.785	P < 0.10	0.476	Non-significant	0.297	Non significant
K mg/kg	0.326	Non significant	0.803	P < 0.10	0.184	Non significant
Fe mg/kg	0.0436	Non significant	0.576	Non significant	0.0476	Non significant
Zn mg/kg	0.234	Non significant	0.637	P < 0.20	0.574	Non significant
Ca mg/kg	0.687	P < 0.20	0.587	Non significant	0.376	Non significant
Cu mg/kg	0.476	Non significant	0.351	Non significant	0.265	Non significant
Mn mg/kg	0.597	Non significant	0.893	P < 0.02	0.042	Non significant
Pb mg/kg	0.472	Non significant	0.574	Non significant	0.265	Non significant
Mg mg/kg	0.564	Non significant	0.0453	Non significant	0.065	Non significant

fires, and the clearing of the forest for porches to be built on top. A decrease in forest area indicates a variety of environmental and economic problems (Ullah, 2013; Sharifullah et al.,2020). *Pinus wallichiana*w was the most common species with 24.01% IVI, followed by *Ailanthus altissima, Quercus dilatata* and *Eriobotrys japonica*. *Pinus wallichiana* was also reported by Ilyas et al. (2015) as the dominant species with *Quercus incana* from Swat. Ahmed et al. (2006) and Akbar (2013) reported similar observations in their investigations, which supports the current findings. Khan et al. (2012) also investigated *Pinus wallichiana* as a dominating species in the dry temperate zone of Chitral. Some species present in this community were also documented in a *Quercus baloot*-dominated community (Khan et al., 2012).

Populus alba and *Platanus orientalis* communities were found in Banr Pate. This community consisted of thirteen different species. The *Pinus wallichiana- Quercus incana* community was reported from Wali Kandao and Mangi Kandao at an altitude of 2030.5 m; this community has a total of twenty-one different species and is more diverse than other communities. On the basis of IVI, the leading species in this community was *Pinus wallichiana,* followed by *Quercus incana* and *Eucalyptus camaldulensis.* These findings are consistent with those of Jackson (2005), who investigated woodlands dominated by *Pinus wallichiana,* while Rahman et al. (2017) reported *Pinus wallichiana*-dominated communities in the district of Swat. The *Picea smithiana-Pinus wallichiana* community was also reported by Wahab et al. (2010) from Dir. *Pinus wallichiana* has previously been reported in both pure communities and in combination with other species, demonstrating its wide ecological range (Ahmad et al., 2010; Khan et al., 2013). In these forests, the climate is of the moist temperate type, which indicates that the temperature is low and the amount of rainfall is abundant. Therefore, the plant communities that have been reported might be the remains of a temperate forest that once covered the land (Hussain et al., 1992; Malik, 2005).

The plant communities in any zone are based on the types of plants and the environmental conditions in which they grow and flourish (Malik, 1986). Climatic, physiographic and soil variables cause considerable shifts in plant communities (Ahmed, 1986). In the present study, NMS and PCA ordination were used to investigate the associations between vegetation and edaphic, topographic and soil macro and micronutrients. Similar NMS and PCA techniques were used by Rahman et al. (2016); who identified four *Isodon rugosus*-dominated communities in Khwazakhela using cluster analysis and NMS ordination.

Tavili et al. (2009) investigated environmental vegetation relationships in the rangelands of Southern Khorasan and applied cluster analysis as well as CCA ordination. Khan (2012) reported three communities of *Quercus baloot* from the Upper Dir district using cluster analysis and DCA coordination. Haq et al. (2015) used CCA and DCA ordination and recorded four communities from Nandiar Khuwar, while Irshad et al. (2016) also reported four plant communities through cluster analysis and NMS ordination. et al., (2010) applied CCA ordination to investigate the vegetation of the Middle Kunlun Mountains in China. Khan et al. (2017) reported the DCA and CCA ordination of tree vegetation from the Tandiana forest in the Western Himalayas (Pakistan). A similar approach was taken by Akbar (2013) who explored tree vegetation via cluster analysis and principal component analysis (PCA). Therefore, my results are in line with those of the above authors.

In the present study, the correlation between NMS ordination axes 1, 2 and the others studied parameters were not significant. The main factors affecting tree species distribution are altitude, nitrogen, soil organic matter, calcium, and lead concentrations. Rahman et al. (2022) agreed with our findings, claiming that most climatic factors have little or no effect on vegetation patterns. Rahman et al. (2016) reported that CCA ordination axes were significantly correlated with soil pH, organic matter, phosphorus, and potassium concentrations in the soil, while the NMS ordination axes showed a significant correlation with several environmental and edaphic parameters, as reported by Oswalt et al. (2006). According to the results, PCA ordination and Ward's cluster analysis are separate methodologies that are used for the same objectives. Akbar et al. (2011) studied the tree vegetation data of Gilgit Baltistan through PCA ordination, while DCA ordination was used by Ilyas et al. (2015) for investigating the Kabal Valley vegetation of Swat district. Ahmed et al. (2011) showed a significant correlation between ordination axes and a variety of environmental factors such as altitude, soil pH, organic matter, magnesium, and nitrogen concentration. Akbar et al. (2011) showed a strong correlation of PCA ordination axes with magnesium, iron, nitrogen, manganese, and zinc concentrations in soil related to tree vegetation. In the present study, the majority of the analyzed parameters were not significantly correlated with the PCA ordination. This may be due to strong climatic changes that affected natural processes as documented by Khan et al. (2013), Wahab (2011) and Gui et al. (2010).

In the present study, the density/ha and cover/ha of the tree species differed among the various sampling sites in the study area. It was found that different tree species had low density/ha and cover/ha. The lower contribution of such tree species may be attributed to the rising demand for firewood and other uses, as reported by Ullah (2013). The highest density/ha of trees was found in community group 2, followed by community group 3 and community 1. Some important tree species that show the highest density/ha in different communities are *Pinus wallichiana*, *Melia azedarach*, *Phoenix sylvestris*, *Celtis caucasica*, *Quercus baloot*, *Quercus incana*, *Acacia modesta*, *Eriobotrys japonica* and *Salix tetrasperma*.

The mean cover/ha of the tree species in the different communities ranged from 110-3380 cm^2 basal area/h. The highest cover/ha was shown by *Ailanthus altissima*, followed by *Quercus dilatata*, *Celtis caucasica*, *Diospyros kaki*, *Phoenix sylvestris*, *Quercus baloot*, *Eucalyptus camaldulensis*, and *Pinus wallichiana*. Our results are in line with recorded values of 83-5947 cm^2 basal area/h from *isodon rugosus* dominated communities at Khwazakhela swat (Rahman et al., 2016).

5. Conclusion

The vegetation of Toormang valley, Hindukush ranges were analyzed with the help of PC-Ord. The cluster analysis classified the vegetation into four different vegetation groups, namely, *Quercus baloot-Quercus incana*, *Pinus wallichiana-Ailanthus altissima*, *Pinus wallichiana-Quercus incana* and *Populus alba-Platanus orientalis*. These vegetation groups faced different environmental (altitude, slope, aspect) and edhapic (texture, organic matter, nutrients etc) conditions. Both the environmental and edaphic variables were important in determining the composition, structure, and vegetation distribution in the research area.

Acknowledgements

The present work is a part of Ph. D research project of Tahir Hameed. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors are thankful to the local inhabitants of the Toormang Valley for their cooperation during data collection.

References

AHMAD, S.S., WAHID, A. and AKBAR, K.F., 2010. Multivariate classification and data analysis of vegetation along Motorway (M-2).Pakistan. *Pakistan Journal of Botany*, vol. 42, no. 2, pp. 1173-1185.

AHMED, M., 1986. Vegetation of some foothill of Himalayan range in Pakistan. *Pakistan Journal of Botany*, vol. 18, pp. 261-269.

AHMED, M., HUSAIN, T., SADRUDDIN, S., HUSSAIN, S.S. and SIDDIQUI, M.F., 2006. Phytosociology and structure of Himalayan forests from different climatic zones of Pakistan. *Pakistan Journal of Botany*, vol. 38, no. 2, pp. 361-383.

AHMED, M., SHAUKAT, S.S. and SIDDIQUI, M.F., 2011. A multivariate analysis of the vegetation of *Cedrusdeodara* forests in Hindukush and Himalayan ranges of Pakistan: evaluating the structure and dynamics. *Turkish Journal of Botany*, vol. 35, pp. 419-438. http://doi.org/10.3906/bot-1009-57.

AKBAR, M., 2013. *Forest vegetation and dendrochronology of Gilgit, Astore and Skardu districts of Northern areas (Galgit-Baltistan), Pakistan.* Karachi: Federal Urdu University of Arts, Sciences and Technology, 395 p. PhD Thesis in Philosophy.

AKBAR, M., AHMED, M., HUSSAIN, A., ZAFAR, M.U. and KHAN, M., 2011. Quantitative forests description from Skardu, Gilgit and Astore districts of Gilgit-Baltistan, Pakistan. *FUUAST Journal of Biology*, vol. 1, no. 2, pp. 149-160.

ALI, A., 2016. *Ecological evaluation of plant resources and vegetation structure of Chail valley, district Swat, Pakistan.* Peshawar: Department of Botany, University of Peshawar. PhD Thesis.

ALI, F. and KHAN, N., 2022. Do environmental variables and overstory communities affect the spatial pattern of understory vegetation? Lessons from *Monotheca buxifolia* (Falc.) A. DC. forests in Pakistan. *Acta Botanica Brasílica*, vol. 36, e2021abb0210. http://doi.org/10.1590/0102-33062021abb0210.

ALI, F., KHAN, N., ALI, K. and KHAN, I., 2017. Influence of environmental variables on the distribution of woody species in Muslim graveyards of Malakand Division, Hindukush Range Mountains of Pakistan. *Pakistan Journal of Botany*, vol. 49, no. 6, pp. 2357-2366.

ALI, F., KHAN, N., ABD-ALLAH, E.F. and AHMAD, A., 2022a. Species diversity, growing stock variables and carbon mitigation potential in the phytocoenosis of *Monotheca buxifolia* forests along altitudinal gradient across Pakistan. *Applied Sciences*, vol. 12, no. 3, pp. 1292. http://doi.org/10.3390/app12031292.

ALI, F., KHAN, N., ALI, K., KHAN, M.E.H. and JONES, D.A., 2022b. Vegetation pattern and regeneration dynamics of the progressively declining *Monotheca buxifolia* Forests in Pakistan: implications for conservation. *Sustainability*, vol. 14, no. 10, pp. 6111. http://doi.org/10.3390/su14106111.

AMIN, M., GURMANI, A.R., ALI, F., KHAN, S.M., FARID, A., SHAKUR, M. and KHAN, W., 2022. Investigation of multi-pesticide residues in *Prunus persica* L. (Peach) cultivars of district Swat using gas chromatography-mass spectroscopy. *Polish Journal of Environmental Studies*, vol. 31, no. 2, pp. 1535-1542. http://doi.org/10.15244/pjoes/141808.

BADSHAH, L., HUSSAIN, F. and SHER, Z., 2016. Floristic inventory, ecological characteristics and biological spectrum of plants of Parachinar, Kurrum agency, Pakistan. *Pakistan Journal of Botany*, vol. 48, no. 4, pp. 1547-1558.

CHENG, L., ZHANG, Y. and SUN, H., 2019. Vegetation cover change and relative contributions of associated driving factors in the ecological conservation and development zone of Beijing, China. *Polish Journal of Environmental Studies*, vol. 29, no. 1, pp. 53-65. http://doi.org/10.15244/pjoes/102368.

COOP, J.C. and GIVNISH, T.J., 2007. Spatial and temporal patterns of recent forest encroachment in montane grasslands of the Valles Caldera, New Mexico, USA. *Journal of Biogeography*, vol. 34, no. 5, pp. 914-927. http://doi.org/10.1111/j.1365-2699.2006.01660.x.

ELFAKI, J.T., GAFER, M.A., SULIEMAN, M.M. and ALI, M.E., 2016. Hydrometer method against pipette method for estimating soil particle size distribution in some soil types selected from Central Sudan. *International Journal of Engineering Research and Advanced Technology*, vol. 2, no. 2, pp. 25-41.

GAIROLA, S., RAWAL, R.S. and TODARIA, N.P., 2008. Forest vegetation patterns along an altitudinal gradient in sub-alpine zone of West Himalaya, India. *African Journal of Plant Science*, vol. 2, no. 6, pp. 42-48.

GAUCH, H.G. and WHITTAKER, R.H., 1981. Hierarchical classification of community data. *Journal of Ecology*, vol. 69, no. 2, pp. 537-557. http://doi.org/10.2307/2259682.

GUI, D., LEI, J., ZENG, F. and RUNGE, M., 2010. Ordination as a tool to characterize soil particle size distribution, applied to an elevation gradient at the north slope of the Middle Kunlun Mountains. *Geoderma*, vol. 158, no. 3-4, pp. 352-358. http://doi.org/10.1016/j.geoderma.2010.06.002.

GUPTA, A., JOSHI, S.P. and MANHAS, R.K., 2008. Multivariate analysis of diversity and composition of weeds communities of wheat fields in Doon valley India. *Tropical Ecology*, vol. 49, no. 2, pp. 103-112.

HAQ, F.U., AHMAD, H. and IQBAL, Z., 2015. Vegetation composition and ecological gradients of subtropical-moist temperate ecotonal forests of NandiarKhuwar catchment, Pakistan. *Bangladesh Journal of Botany*, vol. 44, no. 2, pp. 267-276. http://doi.org/10.3329/bjb.v44i2.38516.

HOU, D., O'CONNOR, D., NATHANAIL, P., TIAN, L. and MA, Y., 2017. Integrated GIS and multivariate statistical analysis for regional scale assessment of heavy metal soil contamination: A critical review. *Environmental Pollution*, vol. 231, no. Pt 1, pp. 1188-1200. http://doi.org/10.1016/j.envpol.2017.07.021. PMid:28939126.

HUSSAIN, F., SHAH, A., ILLAHI, I. and REHMAN, R., 1992. Phytosociology of the vanishing subtropical vegetation of Swat with special reference to Docut hills: spring aspect. *Sarhad Journal of Agriculture*, vol. 8, pp. 185-191.

HUSSAIN, F., SHAH, S.M., BADSHAH, L. and DURRANI, M.J., 2015. Diversity and ecological characteristics of flora of Mastujvally, district Chitral, Hindukush Range, Pakistan. *Pakistan Journal of Botany*, vol. 47, no. 2, pp. 495-510.

HUSSAIN, M., KHAN, S.M., ABDALLAH, E.F., HAQ, Z.U., ALSHAHRANI, T.S., ALQARAWI, A.A., RAHMAN, I.U., IQBAL, M., ABDULLAH and AHMAD, H., 2019. Assessment of Plant Communities and identification of indicator species of an ecotonal forest zone at Durand line, District Kurram, Pakistan. *Applied Ecology and Environmental Research*, vol. 17, no. 3, pp. 6375-6396. http://doi.org/10.15666/aeer/1703_63756396.

ILYAS, M., QURESHI, R., AKHTAR, N., MUNIR, M. and HAQ, Z.U., 2015. Vegetation analysis of Kabalvally, district Swat, Pakistan using multivariate approach. *Pakistan Journal of Botany*, vol. 4, no. 7, pp. 77-86.

ILYAS, M., QURESHI, R., ZIAUL-HAQ, I.U., MUNIR, M.U., MUNAZIR, M.E. and MAQSSOD, M., 2020. Ecological evaluation of existing plant resources of Manrai Hills, Swat, Pakistan using multivariate analysis. *Pakistan Journal of Botany*, vol. 52, no. 5, pp. 1727-1736. http://doi.org/10.30848/PJB2020-5(43). PMid:31861734.

IQBAL, M.Z., SHAH, S.Z. and SHAFIQ, M., 2008. Ecological surveys of certain plant communities around urban areas of Karachi. *Journal of Applied Science & Environmental Management*, vol. 12, no. 3, pp. 51-60.

IRFAN, M., KHAN, I., ALI, A., KHAN, R., ALI, A. and JAN, G., 2018. Ethnomedicinal Uses of the Plants of Tehsil Laalqilla, District Lower Dir, Khyber Pakhtunkhwa, Pakistan. *Journal of Applied Environmental and Biological Sciences*, vol. 8, no. 6, pp. 61-66.

IRSHAD, M., KHAN, N., ALI, K. and MUHAMMAD, Z., 2016. The influence of environmental variables on Punicagranatum assemblages in subtropical dry temperate woodland in the district of Dir Lower, Khyber Pakhtunkhwa, Pakistan. *Turkish Journal of Botany*, vol. 40, pp. 610-622. http://doi.org/10.3906/bot-1602-32.

JACKSON, M.L., 2005. *Soil chemical analysis: advanced course.* Wisconsin: UW-Madison Libraries Parallel Press.

KHAN, N., 2012. A community analysis of Quercusbaloot forest district Dir Upper, Pakistan. *African Journal of Plant Science*, vol. 6, no. 1, pp. 21-31. http://doi.org/10.5897/AJPS11.231.

KHAN, N., AHMED, M., WAHAB, M. and NAZIM, K., 2010. Size class structure and regeneration potential of *Monothecabuxifolia* District Dir Lower Pakistan. *International Journal of Biotechnology*, vol. 7, pp. 187-196.

KHAN, N., MOINUDDIN, A., SIDDIQUI, S.F., SADIA, B. and IRSHAD, A., 2012. A Phytosociological study of forest and non-forest vegetation of district Chitral, Hindukush range of Pakistan. *FUUAST Journal of Biology*, vol. 2, no. 1, pp. 91-101.

KHAN, N., SHAUKAT, S.S., AHMED, M. and SIDDIQUI, M.F., 2013. Vegetation-environment relationships in the forests of Chitral district Hindukush range of Pakistan. *Journal of Forestry Research*, vol. 24, no. 2, pp. 205-216. http://doi.org/10.1007/s11676-013-0346-9.

KHAN, W., KHAN, S.M. and AHMAD, H., 2015. Altitudinal variation in plant species richness and diversity at Thandiani sub forests division, Abbottabad, Pakistan. *Journal of Biodiversity and Environmental Sciences*, vol. 7, no. 1, pp. 46-53.

KHAN, W., KHAN, S.M., AHMAD, H., SHAKEEL, A. and PAGE, S., 2017. Ecological gradient analyses of plant associations in the Thandiani forests of the Western Himalayas, Pakistan. *Turkish Journal of Botany*, vol. 41, pp. 253-264. http://doi.org/10.3906/bot-1602-22.

LOVETT, J.C., MARSHALL, A.R. and CARR, J., 2006. Changes in tropical forest vegetation along an altitudinal gradient in the Udzungwa Mountains National Park, Tanzania. *African Journal of Ecology*, vol. 44, no. 4, pp. 478-490. http://doi.org/10.1111/j.1365-2028.2006.00660.x.

MAGRAY, J.A., WANI, B.A., ISLAM, T., GANIE, A.H. and NAWCHOO, I.A., 2022. Phyto-ecological analysis of *Phytolacca acinosa* Roxb. assemblages in Kashmir Himalaya, India. *Frontiers in Forest and Global Change*, vol. 5, pp. 976902. http://doi.org/10.3389/ffgc.2022.976902.

MALIK, Z.H., 1986. *Phytosociological study on the vegetation of Kotli Hills, Azad Kashmir.* Peshawar: University of Peshawar, 245 p. M.Phil. Thesis.

MALIK, Z.H., 2005. *Comparative study of the vegetation of Ganga Chotti and Bedori Hill Dist. Bagh Azad Jammu and Kashmir.* Peshawar: University of Peshawar. PhD Thesis.

MCCUNE, B. and MEFFORD, M.J., 2005. *Multivariate ananlysis of ecological data, Version 5.0.* 5th ed. Gleneden Beach: MjM Software Design. http://doi.org/10.1890/0012-9623(2005)86[201:MAOEDU]2.0.CO;2

NAZ, F., AHMED, M. and SIDDIQUI, M.F., 2017. Quantitative description of rapidly changing vegetation around Karachi. *Fuuast Journal of Biology*, vol. 7, no. 1, pp. 89-104.

OSWALT, S.N., BRANDIES, T.J. and DIMICK, B.P., 2006. Phytosociology of vascular plants on an international biosphere reserve: Virgin Islands National Park, St. John, US Virgin Islands. *Caribbean Journal of Science*, vol. 42, no. 1, pp. 53-66.

RAHMAN, A., KHAN, N., BRAUNING, A., ULLAH, R. and RAHMAN, I., 2022. Effects of environmental and spatial gradients on Quercus-dominated Mountain Forest communities in the Hindu-Kush ranges of Pakistan. *Saudi Journal of Biological Sciences*, vol. 29, no. 4, pp. 2867-2877. http://doi.org/10.1016/j.sjbs.2022.01.013. PMid:35531177.

RAHMAN, A., KHAN, N., ULLAH, R. and ALI, K., 2023. Stand structure and dynamics of the naturally managed oak-dominated forests and their relation to environmental variables in Swat Hindu Kush Range of Pakistan. *Sustainability*, vol. 15, no. 5, pp. 4002. http://doi.org/10.3390/su15054002.

RAHMAN, I.U., KHAN, N. and ALI, K., 2017. Classification and ordination of understory vegetation using multivariate techniques in the *Pinuswallichiana* forests of Swat valley, northern Pakistan. *Naturwissenschaften*, vol. 104, no. 3-4, pp. 24. http://doi.org/10.1007/s00114-017-1431-2. PMid:28271176.

RAHMAN, K., KHAN, A., NISAR, M., HAMEED, T., KHAN, M.S., JAN, A.U., ULLAH, S., AHMAD, A., IQBAL, A. and KHAN, I.A., 2016. Phytosociological study on *Isodonrugosus* dominated communities in Khwazakhela district Swat, Khyber Pakhtunkhwa, Pakistan. *International Journal of Biosciences*, vol. 9, no. 6, pp. 292-302. http://doi.org/10.12692/ijb/9.6.292-302.

SHAHEEN, H. and SHINWARI, Z.K., 2012. Phytodiversity and endemic richness of Karambar Lake vegetation from Chitral, Hindukush-Himalayas. *Pakistan Journal of Botany*, vol. 44, no. 1, pp. 15-20.

SHARIFULLAH, A., HAZRAT, A.H., KHAN, K., SHER, S., ALI, M., AZIZ, A., RAHMAN, A.H., KHAN, K., AHMAD and ADNAN, M., 2020. Phytosociological structure of Skyland forests at Wari, Dir Upper, Khyber Pakhtunkhwa, Pakistan. *Bioscience Research*, vol. 17, no. 2, pp. 815-826.

SHER, Z., FARRUKH, H. and BADSHAH, L., 2014. Biodiversity and ecological characterization of the flora of Gadoon Rangeland, District Swabi, Khyber Pukhtunkhwa, Pakistan. *Iranian Journal of Botany*, vol. 20, no. 1, pp. 96-108. http://doi.org/10.22092/IJB.2014.6160.

SONI, A. and NAMDEO, K.P., 2022. Plant biodiversity and phytosociological studies on tree species diversity of ratanpur forest bilaspur district (c.g.) India. *Journal of Medicinal Plants Studies*, vol. 10, no. 2, pp. 139-142.

TAVILI, A., ROSTAMPOUR, M., CHAHOUKI, M.A.Z. and FARZADMEHR, J., 2009. CCA application for vegetation-environment relationships evaluation in arid environments (Southern Khorasan rangelands). *Desert*, vol. 14, pp. 101-111.

TIMILSINA, N., ROSS, M.S. and HEINEN, J.T., 2007. A community analysis of sal (*Shorearobusta*) forests in the western Terai of Nepal. *Forest Ecology and Management*, vol. 241, no. 1-3, pp. 223-234. http://doi.org/10.1016/j.foreco.2007.01.012.

TODARIA, N.P., POKHRIYAL, P., UNIYAL, V. and CHAUHAN, D.S., 2010. Regeneration status of tree species in forest of Phakot and PathriRao watersheds in Garhwal Himalaya. *Current Science*, vol. 98, no. 2, pp. 171-175.

ULLAH, S., 2013. *An ecological assessment of Justiciaadhatoda L. in Malakand Division.* Pakistan: Department of Botany, University of Malakand. M.Phil. Thesis.

WAHAB, M., 2011. *Pupulation dynamics and dendrochronological potential of Pine tree species from district Dir.* Karachi: Federal Urdu University of Arts, Sciences and Technology. PhD. Thesis.

WAHAB, M., AHMED, M., KHAN, N. and SARANGZAI, A.M., 2010. A phytosociological study of pine forests from district Dir, Pakistan. *International Journal of Biology and Biotechnology*, vol. 7, no. 3, pp. 219-226.

ZAMAN, A. and BADSHAH, L., 2020. Vegetation dynamics along an elevational gradient in Terich Valley, Chitral Hindu kush range, northern Pakistan. *Applied Ecology and Environmental Research*, vol. 18, no. 5, pp. 6099-6119. http://doi.org/10.15666/aeer/1805_60996119.