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Original Research

Floral Diversity and Vegetation Dynamics of the Sino-Japanese Vegetation Type in Ashoran Hills, Pakistan

Roohul Amin[1, 2]*, Naveed Akhtar[1], Ajmal Iqbal[2], Abdul Rashid[2], Abdul Salam Khan[2], Muhammad Nauman Khan[1], Alevcan Kaplan[3]°, Majid Iqbal[4], Fethi Ahmet Ozdemir[5], Sarah Abdul Razak[6], Khalid Mashay Al-Anazi[7], Mohammad Abul Farah[7]**

[1]Department of Botany, Islamia College, Peshawar, 25120 Peshawar, Pakistan
[2]Department of Botany, Government Afzal Khan Lala Post-Graduate College, Matta, Swat, Pakistan
[3]Department of Crop and Animal Production, Sason Vocational School, Batman University, Batman 72060, Turkey
[4]Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing, China
[5]Department of Molecular Biology and Genetics, Faculty of Science and Art, Bingol University, 12000 Bingol, Turkey
[6]Institute of Biological Sciences, Faculty of Science, Universiti Malaya, Kuala Lumpur 50603, Malaysia
[7]Department of Zoology, College of Science, King Saud University, Riyadh 11451, Saudi Arabia

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Abstract

Between 2021 and 2023, a botanical survey was conducted in the Hindukush Mountains of Ashoran, Kalam, Swat District, Pakistan. As part of this study, 282 plant species from 206 genera and 73 families were cataloged. The major families include Asteraceae (24 species), Poaceae (22), Rosaceae (17), Fabaceae (14), Lamiaceae (14), Polygonaceae (10), and Ranunculaceae (10). Dicotyledons dominated with 219 species, followed by monocotyledons (39), pteridophytes (13), and gymnosperms (11). Herbaceous plants were the most common (188 species), followed by trees (35), subshrubs (24), and shrubs (23). Perennials were predominant (217 species), with annuals and biennials accounting for 59 and 6 species, respectively. Therophytes were the most common life form (85 species), followed by geophytes (54) and hemicryptophytes (52). Analysis of leaf size revealed that nanophylls dominated (37.23%), followed by microphylls (25.88%), mesophylls (18.79%), and leptophylls (14.89%). Quantitative ecological techniques were used, with quadrats of 1 m^2 for herbs, 5 m for shrubs, and 10 m for trees. Data on the 282 species and environmental parameters were analyzed using Two-way Indicator Species Analysis and Detrended Correspondence Analysis using Juice software version 7.1 and R program version 3.6, identifying five distinct plant communities. The *Cedrus-Polygonum-Quercus* community was located at an altitude of 2062-2112 m (18 territories, 25 species). The *Quercus-Sorberia-Indigofera* community was located at an altitude of 1982-2560 m (17 plant species, 101 species). The *Origanum-*

*e-mail: aminrohul905@gmail.com
**e-mail: kaplanalevcan@gmail.com
°ORCID iD: 0000-0001-6738-7527

Quercus-Seriphedium community was found at an altitude of 2281-2560 m (21 quadrats, 146 species). The *Thymus-Rumex-Poa* community was located at 2596-3115 m (17 quadrats, 127 species). The *Abies-Betula-Picea* community was located at 2405-3009 m (33 quadrats, 170 species). Vegetation was variably disturbed due to deforestation, overgrazing, and agricultural expansion, with some areas heavily impacted by human activities.

Keywords: Floristic composition, Communities, Ashoran Hills, Vegetation, Kalam, Pakistan

Introduction

Environmental fluctuations influence the composition of vegetation and plant species' coexistence in every region. Understanding these variations' ecological significance and hierarchy is crucial for conserving and managing plant resources. Floristic diversity and its biological patterns are dependent on topography and elevation. Plant characteristics such as life form, leaf size, and phenological traits reflect the prevailing ecological and natural conditions [1, 2]. Phytosociology, which deals with plant communities' characteristics, classification, relationships, and distribution, aims to describe species diversity within these communities [3]. Understanding how environmental variables affect the spatial distribution of ecological communities is crucial for predicting vegetation responses to various environmental factors. Ecological theory assumes that a variety of environmental factors shape local species communities and influence different aspects of community structure and composition in various ways [4].

The study of vegetation dynamics is a fundamental aspect of taxonomy that provides essential data for advanced research in plant ecology and conservation [1]. Conducting botanical assessments, which include structural studies of vegetation zones and analyses of floristic composition, is crucial for identifying key elements of plant biodiversity. These assessments contribute to protecting endangered and economically significant species and facilitate the monitoring of protected areas [5]. Pakistan harbors a rich biodiversity spanning across different ecosystems, from coastal regions to high alpine mountains [3]. It is crucial to gain insights into aquatic and terrestrial ecosystems' ecological health, biodiversity, conservation challenges, and management strategies. Ecological traits, such as biological spectra, serve as reference points for assessing current and future phyto-climatic conditions [6]. There are about 300,000 known vascular plant species worldwide [7]. Understanding the floristic composition of a given area is crucial as it provides important information on the diversity and distribution of plant species [8]. This knowledge is key to accurately identifying and systematically conserving plant species. The distribution of plant species provides valuable insights into the environmental factors and ecosystem services within a specific habitat [9]. Plant biodiversity plays a pivotal role in ecosystems, and precise floristic inventories can deepen our understanding of a region's climatic, topographic, and pedological conditions [10]. In addition, these inventories help us to understand the various factors that directly affect forest structure and composition [11]. However, the pressing challenges of urbanization, population growth, human activities, and environmental degradation highlight the importance of ecological and floristic studies [12]. Disturbances are among the most significant factors influencing forest ecosystems, and their effects vary according to the magnitude, frequency, and intensity of these events [13]. Such disturbances can profoundly affect successional patterns, species composition, and diversity, ultimately reshaping forest structure [14].

Extensive floristic inventories and vegetation analyses were carried out in various regions of Pakistan. Notable studies include the comprehensive survey in Torghar district [15] and detailed botanical assessments in Chail valley in Swat [16], Margalla foothills in Islamabad [17], and the Kotli district in Azad Kashmir [1]. Other research works are on the floristic composition of Kalash Valley, Chitral [18], plant diversity in Bin Dara in the Dir district [19], the vegetation dynamics in Utror and Gabral regions of Kalam [20], and the Liakot forests in the Kalam area of the Swat district [21]. Despite these comprehensive studies, the floristic composition and ecological gradients in the Ashoran forest of the Hindu Raj range within the greater Hindu Kush Mountains in Pakistan have not yet been explored. The Ashoran Mountains lie on a fault line and have particular geological features contributing to unique vegetation patterns [21]. The ecological assessment of the vegetation of the Ashoran Mountains in Kalam, Swat, is still unexplored, mainly due to the difficult climatic conditions and poor accessibility. This study conducts a detailed floristic inventory and examines the vegetation dynamics in Ashoran, located in the Hindukush Mountains. It makes a distinctive contribution to our understanding of plant diversity in this region by highlighting the importance of Sino-Japanese characteristics in the local flora. The study uncovers previously unknown patterns of species distribution and ecological interactions in this species-rich but little-studied area through comprehensive and extensive investigations along environmental gradients. The findings provide important insights for conservation efforts and contribute to our understanding of Himalayan biodiversity and its complex biogeographical relationships. The study has the following objectives: 1) to compile a complete floristic list of the flora, 2) to analyze the biological range of the collected plant species, and 3) to investigate the influence of environmental factors on the distribution of vegetation.

Materials and Methods

Study Area

The Ashoran Mountains in Kalam, located in the northernmost part of Swat District, are situated between 34° 11' 27.096" and 35° 55' 50.0376"N latitude and 72° 25' 39.972" to 72° 49' 5.00002"E longitude. This region is characterized by a dry and temperate climate and lies between 1982 m and 3115 m above sea level. As illustrated in Fig. 1, the average maximum temperature in this area is 18.5°C, and the minimum temperature is 3.4°C. The Ashoran Mountains receive an average of 897.7 mm of precipitation annually, and the average annual snowfall is 2834.64 mm. The hottest month is July, with temperatures of up to 26.7°C, while January is the coldest, with temperatures as low as -6.6°C. The amount of precipitation is lowest in September, with an average of 20.6 mm, whereas April has the highest amount of precipitation, with 4056.4 mm.

Data Collection and Analysis

Floristic and ecological assessments were carried out using a phytosociological approach during the reconnaissance trips from 2021 to 2023. Plant species' quantitative and qualitative characteristics were recorded in 106 quadrats, distributed along different altitudinal transects according to standardized protocols [22]. The quadrats had a size of 1 m for herbs, 5 m for shrubs, and 10 m for trees. Various ecological factors such as slope, orientation, and elevation were documented for each sampling unit using a clinometer, a compass, and a GPS system. The plant specimens were collected, pressed, dried, mounted on standard herbarium sheets, and correctly identified from Pakistan's flora [22-24] and compared with herbarium specimens and other literature [25, 26]. The voucher specimens were kept in the herbarium of the Botany Department of Islamia College Peshawar. An alphabetically arranged comprehensive floristic list was prepared, which listed the plant families. Each plant species was classified according to life form, leaf size classes, and biological spectra [27-33]. Data from 106 quadrats were first recorded in Excel software in comma-separated value (CSV) format and then imported into the JUICE program (version 7.0.210), following the recommended methodology [34]. To create realistic species-quadrat associations, the same dataset was organized and processed using a modified version of Two-Way Indicator Species Analysis (TWINSPAN) within the JUICE platform [35]. Five pseudo-species cut levels (0, 2, 5, 10, and 20) were used for the cluster analysis, with Whittaker's beta diversity serving as the TWINSPAN parameter. Subsequently, Detrended Correspondence Analysis (DCA) was performed using the JUICE program in conjunction with the R program (64-bit version 3.5.2) to examine the relationships between species, quadrats, and environmental variables.

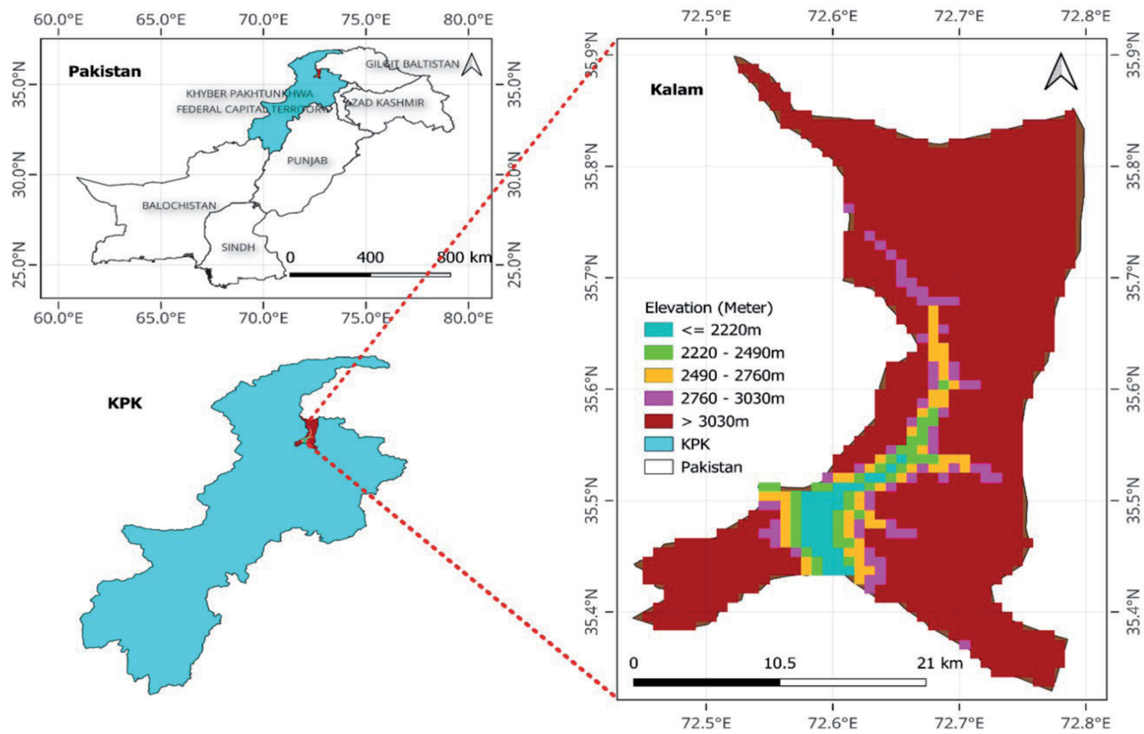

Fig. 1. Study area map.

Results

Floristic Composition

A total of 282 plant species were collected, representing 206 genera and 73 families (Table 1). The dominant family was Asteraceae, which had 24 plant species, followed by Poaceae (22 species), Rosaceae (17 species), Fabaceae, and Lamiaceae (14 species). Polygonaceae and Ranunculaceae had 10 species each (Fig. 2). Dicotyledonous species were the most abundant, with 219 species (78% of the total), followed by monocotyledonous species with 39 (13%), pteridophytes with 13 (4.6%), and gymnosperms with 11 (3.9%). Further details are illustrated in Fig. 3. In terms of habitus, herbs formed the majority with 188 species (66.66%), followed by trees with 35 species (12.4%), subshrubs with 24 species (8.5%), shrubs with 23 species (8.1%) (Fig. 4), climbers with 5 species (1.8%), parasites with 4 species (1.4%), and lianas with 3 species (1.06%).

Life Forms

The predominant life forms were therophytes with 85 species (30%), followed by geophytes with 54 species (19%), hemicryptophytes with 52 species (18%), nanophanerophytes with 21 species (7%), mesophanerophytes with 18 species (6%), microphanerophytes with 17 species (6%), chamaephytes with 14 species (5%), cryptophytes with 12 species (4%), and megaphanerophytes with 9 species (3%) (Fig. 5). The prevalence of therophyte life forms indicates their adaptability to adverse environmental conditions and intense anthropogenic disturbances.

Leaf-Form Spectra

In the area studied, nanophylls were the most common leaf size with 105 plant species (37%), followed by microphylls with 73 species (26%), mesophylls with 53 species (19%), leptophylls with 42 species (15%), macrophylls with 4 species (1.4%), aphylloids with 3 species (1%), and megaphylloids with 2 species (0.7%) (Fig. 6).

Plant Communities

A total of five plant communities were identified using the modified TWINSPAN classification, with Whittaker beta diversity as the classification parameter (Fig. 7).

Cedrus-Polygonum-Quercus (CPQ) Community

The *Cedrus-Polygonum-Quercus* community thrives at altitudes between 2062 m and 2112 m and inhabits the Maidani forest of *Cedrus deodara* (Roxb. ex D.Don) G.Don and at the base of the Ashoran Mountains, characterized by a dense forest of *Quercus dilatata* Royle. This community comprised eighteen stems and twenty-five species, with *Polygonum aviculare* L. dominating the herb layer. The slope in this area was particularly gentle and ranged from 2º to 17º. Aspect varied between 84º and 175º, latitude ranged from 35° 31' 30" to 35° 44' 22.92", and longitude from 72° 36' 52.92" to 72° 49' 4.8". This community had the highest percentage of tree cover at 48.89 percent, followed by 22.78 percent herbaceous cover. The shrub cover was the lowest, with a value of 3.9. Other predominant associated species were *Phleum pratense* L., *Indigofera heterantha* Wall. ex Brandis, *Echinochloa crus-galli* (L.) P. Beauv., *Setaria viridis* (L.) P. Beauv., and *Pinus wallichiana* A.B. Jacks., *Phalaris minor* Retz., *Festuca gigantea* (L.) Vill., *Calamintha umbrosa* (M.Bieb.) Rchb., *Polygonum paronychioides* Small ex Rydb., *Plantago lanceolata* L., *Dianthus orientalis* Adams. Due to its proximity to human settlements, this community has been subject to considerable disturbance in the form of deforestation, overgrazing, and agricultural expansion.

Quercus-Sorberia-Indegofera (QSI) Community

This community thrived at altitudes between 1982 and 2560 m. It comprised 17 sections and harbored 101 species. Slopes in the area ranged from 4º to 55º, with an average slope of 28.38º. The slope ranged from 113º to 263º. The average latitude and longitude were between 34° 54' 33.48" and 35° 55' 49.8" and 72° 25' 21.72" and 72° 41' 30.84", respectively. The average proportion of trees, shrubs, and herbs was coverage of 30, 33, and 18.5, respectively. Predominant species in this community included *Pennisetum flaccidum* Griseb., *Parrotiopsis jacquemontiana* (Decne.) Rehder, *Festuca gigantea* (L.) Vill., *Leptorhabdos parviflora* (Benth.) Benth., *Cedrus deodara* (Roxb. ex D.Don) G.Don, *Origanum vulgare* L., *Lepidium ruderale* L., and others. However, this community is subject to disturbances such as deforestation, overgrazing, and agricultural expansion.

Origanum-Quercus-Seriphedium (OQS) Community

This community lies at an altitude of 2281 to 2756 m and is proof of the resilience of nature. It consists of 21 quadrates and is home to a variety of 146 species. It thrived amidst slopes with gradients from 9° to 66° with aspects from 113° to 273°, offering a panoramic view of the grandeur of nature. Situated at an average latitude and longitude of 34° 11' 26.88" to 36° 0' 0" and 72° 34' 36.84" to 73° 0' 0", it was adorned with majestic species such as *Pinus gerardiana* Wall. ex D.Don, *Indigofera heterantha* Wall. ex Brandis, *Cedrus deodara* (Roxb. ex D.Don) G.Don, *Lonicera hypoleuca* Decne., *Rosa webbiana* Wall. ex Royle, *Prunus jacquemontii* Hook.f., *Jasminum humile* L., *Cotoneaster nummularius* Fisch. & C.A.Mey., *Veronica alpina* L., Garcke Garcke, *Cotoneaster microphyllus* Wall. ex

Table 1. Floristic diversity, habit, life span, life form, and leaf size in the Ashoran Mountains.

A.			Pteridophyta					
S. No	Family	Genera	Botanical Name	Habit	Life Span	Life form	Leaf size	Cultivation status
1	Aspleniaceae	3	*Asplenium septentrionale* (L.) Hoffm.	H	P	Geo	Lep	W
			Asplenium trichomanes L.	H	P	HemC	Lep	W
			Athyrium mackinnoniorum (C. Hope) C.Chr.	H	P	Geo	Lep	W
			Cystopteris dickieana R.Sim	H	P	Geo	Nan	W
2	Polypodiaceae	3	*Dryopteris oreades* Fomin	H	P	Geo	Nan	W
			Dryopteris ramosa (C.Hope) C.Chr.	H	P	Geo	Nan	W
			Dryopteris komarovii Kossinsky	H	P	Geo	Nan	W
			Hypodematium crenatum (Forssk.) Kuhn	H	P	HemC	Lep	W
			Polystichum lonchitis (L.) Roth	H	P	Geo	Nan	W
3	Pteridaceae	2	*Hemionitis nitidula* (Hook.) Christenh.	H	P	Geo	Nan	W
			Adiantum venustum D.Don	H	P	CrP	Nan	W
			Adiantum capillus-veneris L.	H	P	HemC	Nan	W
4	Selaginellaceae	1	*Selaginella sanguinolenta* (L.) Spring	S	P	CrP	Lep	W
B.			Gymnosperms					
5	Cupressaceae	2	*Juniperus excelsa* M.Bieb.	T	P	MicP	Lep	W
			Juniperus communis L.	S	P	NanP	Lep	W
			Cupressus sempervirens L	T	P	MicP	Lep	C
6	Ephedraceae	1	*Ephedra intermedia* Schrenk & C.A.Mey.	S	P	MicP	Ap	W
			Ephedra gerardiana Wall. ex Klotzsch & Garcke	S	P	MicP	Ap	W
7	Pinaceae	4	*Abies pindrow* (Royle ex D.Don) Royle	T	P	MegP	Lep	W
			Cedrus deodara (Roxb. ex D.Don) G.Don	T	P	MegP	Lep	W
			Picea smithiana (Wall.) Boiss.	T	P	MegP	Lep	W
			Pinus gerardiana Wall. ex D.Don	T	P	MegP	Lep	W
			Pinus wallichiana A.B.Jacks.	T	P	MegP	Nan	W
8	Taxaceae	1	*Taxus wallichiana* Zucc.	T	P	MesP	Lep	W
C.			Monocotyledons					
9	Amaryllidaceae	1	*Allium cepa* L.	H	P	Geo	Mes	C
			Allium sativum L.	H	P	Geo	Mes	C
			Allium griffithianum Boiss.	H	P	Geo	Lep	W
			Allium consanguineum Kunth	H	P	Geo	Mic	W
			Allium humile Kunth	H	P	Geo	Nan	W
10	Araceae	1	*Arum jacquemontii* Blume	H	P	Geo	Meg	W

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11	Asparagaceae	1	*Polygonatum verticillatum* (L.) All.	H	P	Geo	Nan	W
12	Asphodelaceae	1	*Eremurus himalaicus* Baker	H	P	Geo	Mes	W
13	Colchicaceae	1	*Colchicum luteum* Baker	H	P	Geo	Nan	W
14	Cyperaceae	2	*Cyperus squarrosus* L.	H	A	Th	Mic	W
			Eleocharis mitracarpa Steud.	H	P	Geo	Lep	W
15	Iridaceae	1	*Iris hookeriana* Foster	H	P	Geo	Mes	W
16	Liliaceae	2	*Lilium polyphyllum* D.Don	H	P	Geo	Mic	W
			Tulipa clusiana Redouté	H	P	Geo	Nan	W
17	Orchidaceae	3	*Cypripedium cordigerum* D.Don	H	P	Geo	Mes	W
			Dactylorhiza hatagirea (D.Don) Soó	H	P	Geo	Mic	W
			Epipactis helleborine (L.) Crantz	H	P	Geo	Lep	W
18	Poaceae	15	*Bromus racemosus* L.	H	A	Th	Mic	W
			Bromus ramosus Huds.	H	P	HemC	Mes	W
			Calamagrostis epigejos (L.) Roth	H	P	Geo	Mic	W
			Calamagrostis filiformis Griseb.	H	P	CrP	Mic	W
			Chrysopogon gryllus (L.) Trin.	H	P	HemC	Nan	W
			Dactylis glomerata L.	H	P	Th	Nan	W
			Echinochloa crus-galli (L.) P.Beauv.	H	A	HemC	Nan	W
			Festuca gigantea f. minor Kuvaev	H	P	HemC	Nan	W
			Pennisetum flaccidum Griseb.	H	P	Geo	Nan	W
			Phalaris minor Retz.	H	A	Th	Nan	W
			Phleum pratense L.	H	P	CrP	Mic	W
			Phleum alpinum L.	H	P	Geo	Mic	W
			Poa alpina L.	H	P	CrP	Mic	W
			Poa annua L.	H	A	Th	Lep	W
			Poa bulbosa L.	H	P	Geo	Lep	W
			Setaria viridis (L.) P.Beauv.	H	A	Th	Nan	W
			Setaria glauca (L.) P.Beauv.	H	A	Th	Nan	W
			Sorghum bicolor (L.) Moench	H	P	Th	Mes	C
			Themeda anathera (Nees ex Steud.) Hack.	H	P	Geo	Nan	W
			Cynodon dactylon (L.) Pers.	H	P	Geo	Nan	W
			Zea mays L.	H	A	Th	Mes	C
			Triticum aestivum L.	H	A	Th	Mic	C
D.			Dicotyledons					
19	Aceraceae	1	*Acer cappadocicum* Gled.	T	P	MesP	Mac	W
20	Amaranthaceae	3	*Amaranthus viridis* L.	H	A	Th	Mic	W
			Chenopodium album L	H	A	Th	Mic	W
			Chenopodium ambrosioides L	H	P	Th	Mes	W
			Spinacia oleracea L	H	A	Th	Mic	C

21	Apiaceae	7	*Bupleurum constancei* Nazir	H	P	Geo	Lep	W
			Bupleurum falcatum L.	H	P	Th	Lep	W
			Chaerophyllum villosum Wall. ex DC.	H	A	HemC	Mic	W
			Chaerophyllum reflexum Lindl.	H	A	HemC	Mic	W
			Pleurospermum stylosum C.B.Clarke	H	P	HemC	Nan	W
			Sium latijugum C.B.Clarke	H	P	HemC	Mes	W
			Daucus carota L.	H	B	Geo	Mes	C
			Foeniculum vulgare Mill.	H	A	Th	Nan	C
			Coriandrum sativum L.	H	A	Th	Lep	C
22	Asteraceae	21	*Achillea millefolium* L.	H	P	HemC	Nan	W
			Anaphalis nepalensis (Spreng.) Hand.-Mazz.	H	P	HemC	Nan	W
			Artemisia scoparia Waldst. & Kit.	H	A	Th	Nan	W
			Artemisia persica Boiss.	S S	P	Th	Mic	W
			Artemisia japonica Thunb.	H	P	Th	Nan	W
			Aster molliusculus (Lindl. ex DC.) C.B.Clarke	H	P	Th	Mic	W
			Cichorium intybus L.	H	P	Th	Nan	W
			Cirsium arvense (L.) Scop.	H	P	Th	Mic	W
			Cirsium falconeri (Hook.f.) Petr.	H	P	HemC	Mes	W
			Galinsoga parviflora Cav.	H	A	Th	Lep	W
			Helianthus annuus L.	H	A	Th	Mes	C
			Lactuca dissecta D.Don	H	A	Th	Nan	W
			Lapsana communis L.	H	A	Th	Mic	W
			Myriactis wallichii Less.	H	A	Th	Mic	W
			Onopordum acanthium L.	H	B	Geo	Mes	W
			Saussurea albescens (DC.) Sch. Bip.	H	P	HemC	Mes	W
			Senecio chrysanthemoides DC.	H	P	HemC	Mic	W
			Seriphidium brevifolium (Wall. ex DC.) Y.Ling & Y.R.Ling	S S	P	HemC	Nan	W
			Solidago virga-aurea Anon.	H	P	HemC	Nan	W
			Tanacetum griffithii (C.B.Clarke) Muradyan	S S	P	Geo	Nan	W
			Taraxacum officinale F.H.Wigg.	H	P	Th	Mic	W
			Tricholepis stewartii C.B.Clarke ex Hook.f.	S S	P	Th	Lep	W
			Xanthium strumarium L.	H	A	Th	Mes	W
			Tagetes minuta L.	H	A	Th	Nan	W
23	Balsaminaceae	1	*Impatiens brachycentra* Kar. & Kir.	H	A	Th	Mic	W
24	Berberidaceae	2	*Berberis jaeschkeana* C.K.Schneid.	S	P	MicP	Nan	W
			Podophyllum hexandrum Royle	H	P	Geo	Mes	W

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25	Betulaceae	2	*Betula utilis* D.Don	T	P	MicP	Mic	W
			Corylus colurna L.	T	P	MesP	Mes	W
26	Boraginaceae	4	*Hackelia uncinata* (Royle ex Benth.) C.E.C.Fisch.	H	P	HemC	Nan	W
			Lindelofia anchusoides (Lindl.) Lehm.	H	P	ChmP	Lep	W
			Lindelofia longiflora (DC.) Baill.	H	P	ChmP	Mes	W
			Myosotis alpestris var. albicans (Riedl) Y.J.Nasir	H	P	HemC	Mic	W
			Myosotis alpestris subsp. asiatica Vestergr.	H	P	HemC	Mic	W
			Onosma dichroantha Boiss.	H	B	Th	Mic	W
27	Brassicaceae	9	*Lepidium ruderale* L.	H	A	Th	Lep	W
			Erysimum melicentae Dunn	S S	B	CrP	Nan	W
			Capsella bursa-pastoris (L.) Medik.;	H	A	Th	Lep	W
			Brassica campestris L.	H	A	Th	Mic	C
			Raphanus sativus L.	H	B	Th	Mac	C
			Nasturtium officinale R. Br.	H	A	Geo	Mic	W
			Brassica rapa L.	H	P	Th	Mes	C
			Rorippa islandica (Oed.) Borb.	H	A	Th	Mic	W
			Sisymbrium brassiciforme C.A.Mey.	H	A	Th	Nan	W
28	Campanulaceae	1	*Campanula tenuissima* Dunn	H	P	HemC	Mes	W
29	Cannabaceae	2	*Cannabis sativa* L.	H	A	Th	Nan	W
			Celtis australis L.	T	P	MesP	Mic	W
30	Caprifoliaceae	3	*Lonicera hypoglauca* Miq.	L	P	NanP	Nan	W
			Lonicera obovata Royle ex Hook.f. & Thomson	S	P	NanP	Mic	W
			Lonicera quinquelocularis Hard.;	S	P	NanP	Lep	W
			Lonicera asperifolia (Decne.) Hook.f. & Thomson	S	P	NanP	Nan	W
			Morina coulteriana Royle	H	P	HemC	Mes	W
			Valeriana jaeschkei C.B.Clarke	H	P	Geo	Nan	W
			Valeriana jatamansi D.Don	H	P	Geo	Nan	W
			Valeriana officinalis L.	H	P	Geo	Nan	W

31	Caryophyllaceae	6	*Arenaria griffithii* Boiss.	S S	P	ChmP	Lep	W
			Arenaria neelgherrensis Wight & Arn.	S S	P	HemC	Lep	W
			Cerastium pusillum Ser.	S S	P	CrP	Nan	W
			Dianthus orientalis Adams	S S	P	Th	Nan	W
			Myosoton aquaticum (L.) Moench	H	P	Th	Mic	W
			Silene conoidea L.	H	A	Th	Mic	W
			Silene gonosperma (Rupr.) Bocquet	H	P	Th	Nan	W
			Silene laxantha Majumdar	H	P	Th	Nan	W
			Stellaria media (L.) Vill.	H	A	Th	Nan	W
32	Convolvulaceae	3	*Convolvulus arvensis* L.	H	P	Th	Mes	W
			Cuscuta reflexa Roxb	Pa	A	Th	Ap	W
			Ipomoea purpurea (L.) Roth.	C	A	Th	Mes	W
33	Crassulaceae	1	*Hylotelephium ewersii* (Ledeb.) H.Ohba	H	P	Geo	Nan	W
34	Cucurbitaceae	1	*Cucumis melo* L.	H	A	Th	Mac	C
			Cucumis sativus L.	H	A	Th	Mac	C
35	Ebenaceae	1	*Diospyros lotus* L.	T	P	MegP	Mic	C
			Diospyros kaki L.f.	T	P	MesP	Mes	C
36	Euphorbiaceae	1	*Euphorbia wallichii* Hook.f.	H	P	Th	Mic	W
37	Fabaceae	12	*Astragalus grahamianus* Benth.	S S	P	MicP	Lep	W
			Astragalus melanostachys Benth. ex Bunge	H	P	MicP	Lep	W
			Indigofera heterantha Wall. ex Brandis	S	P	NanP	Lep	W
			Lathyrus pratensis L.	C	A	Th	Mic	W
			Lathyrus humilis (Ser.) Fisch. ex Spreng.	H	P	Th	Mic	W
			Lespedeza juncea (L.f.) Pers.	S S	P	HemC	Nan	W
			Medicago sativa L.	H	P	Th	Nan	W
			Scaligera orientalis (L.) Raf.	S	P	HemC	Nan	W
			Trifolium pratense L.	H	P	HemC	Nan	W
			Vicia rigidula Royle	C	P	Th	Nan	W
			Phaseolus vulgaris L.	H	A	ChmP	Mes	W
			Robinia pseudo-acacia L	T	P	MesP	Mic	C
			Pisum sativum L.	H	A	Th	Mic	C
			Lotus corniculatus L.	H	A	Th	Mic	W
38	Fagaceae	1	*Quercus dilatata* Royle	T	P	MesP	Nan	W
			Quercus baloot Griff.	T	P	MesP	Nan	W
			Quercus semecarpifolia Sm.	T	P	MesP	Mic	W
			Quercus incana Roxb.	T	P	MesP	Mic	W
39	Gentianaceae	1	*Swertia paniculata* Wall.	H	A	Th	Mic	W

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40	Geraniaceae	1	*Geranium lamberti* Sweet	H	P	Geo	Mic	W
			Geranium wallichianum D.Don ex Sweet	H	P	Geo	Mic	W
41	Grossulariaceae	1	*Ribes orientale* Desf.	S	P	NanP	Mic	W
42	Hamamelidaceae	1	*Parrotiopsis jacquemontiana* (Decne.) Rehder	T	P	NanP	Mes	W
43	Hypericaceae	1	*Hypericum perforatum* L.	H	P	ChmP	Nan	W
44	Juglandaceae	1	*Juglans regia* L.	T	P	MesP	Mes	C
45	Lamiaceae	11	*Calamintha umbrosa* (M.Bieb.) Rchb.	H	P	Th	Nan	W
			Clinopodium vulgare L.	H	P	Th	Nan	W
			Mentha longifolia (L.) L.	H	P	Geo	Mic	W
			Nepeta podostachys Benth.	H	P	HemC	Nan	W
			Nepeta erecta (Royle ex Benth.) Benth.	H	P	HemC	Nan	W
			Nepeta cataria L.	H	P	HemC	Nan	W
			Origanum vulgare L.	H	P	HemC	Nan	W
			Phlomis bracteosa Royle ex Benth.	S S	P	HemC	Mic	W
			Prunella vulgaris L.	H	P	Geo	Mic	W
			Scutellaria edelbergii Rech.f.	S S	P	HemC	Nan	W
			Scutellaria petiolata Hemsl. ex Lace & Prain	S S	P	HemC	Nan	W
			Thymus linearis Benth.	S S	P	ChmP	Nan	W
			Ajuga bracteosa Wall. ex Benth.	H	P	HemC	Mic	W
			Mentha arvensis L.	H	P	Geo	Nan	C
46	Malvaceae	2	*Malva neglecta* Wallr.	H	A	Th	Mic	W
			Abelmoschus esculentus (L.) Moench.	H	A	Th	Mes	C
			Malva sylvestris L.	H	A	Th	Mic	C
47	Moraceae	1	*Morus alba* L.	T	P	MesP	Mic	C
48	Oleaceae	2	*Fraxinus excelsior* L.	T	P	MesP	Nan	W
			Fraxinus xanthoxyloides (G.Don) Wall. ex A.DC.	T	P	MesP	Nan	W
			Jasminum humile L.	S	P	MicP	Nan	W
49	Onagraceae	2	*Epilobium laxum* Royle	H	P	ChmP	Nan	W
			Circaea alpina var. imaicola (Asch. & Magnus) Asch. & Magnus	H	P	HemC	Nan	W
			Epilobium angustifolium L.	H	P	ChmP	Nan	W
			Epilobium latifolium L.	H	P	ChmP	Nan	W
50	Orobanchaceae	2	*Leptorhabdos parviflora* (Benth.) Benth.	H	A	Th	Lep	W
			Pedicularis pectinata Wall. ex Benth.	Pa	P	ChmP	Nan	W
			Pedicularis pyramidata Royle ex Benth.	Pa	P	Th	Nan	W

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51	Oxalidaceae	1	*Oxalis corniculata* L.	H	A	Th	Lep	W
52	Paeoniaceae	1	*Paeonia emodi* Royle	H	P	Geo	Mes	W
53	Plantaginaceae	2	*Plantago lanceolata* L.	H	P	Th	Mic	W
			Plantago major L.	H	P	Th	Mes	W
			Veronica lanosa Royle ex Benth.	H	P	HemC	Nan	W
			Veronica beccabunga L.	S S	P	HemC	Nan	W
			Veronica biloba Schreb. ex L.	H	A	HemC	Lep	W
			Veronica alpina L.	H	P	HemC	Nan	W
54	Plumbaginaceae	1	*Acantholimon lycopodioides* (Girard) Boiss.	S S	P	ChmP	Lep	W
55	Polemoniaceae	1	*Polemonium caeruleum* L.	H	P	Th	Lep	W
56	Polygonaceae	6	*Bistorta amplexicaulis* (D.Don) Greene	H	P	HemC	Mes	W
			Bistorta affinis (D.Don) Greene	S S	P	CrP	Nan	W
			Persicaria maculosa Gray	H	A	Th	Mic	W
			Polygonum aviculare L.	H	A	Th	Nan	W
			Polygonum paronychioides C.A.Mey.	S S	P	Th	Nan	W
			Rheum emodi Wall. ex Meisn.	H	P	HemC	MegP	W
			Rumex dentatus L.	H	A	ChmP	Mes	W
			Rumex hastatus D.Don	S S	P	ChmP	Nan	W
			Rumex nepalensis Spreng.	H	P	HemC	Mes	W
			Oxyria digyna (L.) Hill	H	P	CrP	Nan	W
57	Portulacaceae	1	*Portulaca oleracea* L.	H	A	Th	Nan	W
58	Ranunculaceae	10	*Anemone tetrasepala* Royle	H	P	HemC	Mic	W
			Aconitum violaceum Jacquem. ex Stapf	H	P	Geo	Nan	W
			Actaea spicata L.	H	P	CrP	Mic	W
			Anemone obtusiloba D.Don	H	P	HemC	Nan	W
			Aquilegia pubiflora Wall. ex Royle	H	P	HemC	Mic	W
			Caltha alba Cambess.	H	P	HemC	Nan	W
			Clematis grata Wall.	C	P	MicP	Mic	W
			Delphinium tenuipes Tamura	H	P	HemC	Nan	W
			Ranunculus hirtellus Royle	H	P	CrP	Nan	W
			Thalictrum pedunculatum Edgew.	H	P	HemC	Nan	W

→

59	Rosaceae	10	*Sorbaria tomentosa* (Lindl.) Rehder	S	P	NanP	Mic	W
			Cotoneaster microphyllus Wall. ex Lindl.	S	P	NanP	Nan	W
			Cotoneaster nummularius Fisch. & C.A.Mey.	S	P	NanP	Nan	W
			Fragaria nubicola (Lindl. ex Hook.f.) Lacaita	H	P	Geo	Mic	W
			Potentilla argentea L.	H	P	Geo	Nan	W
			Prunus jacquemontii Hook.f.	S	P	MicP	Nan	W
			Rosa webbiana Wall. ex Royle	S	P	MicP	Nan	W
			Rosa brunonii Lindl.	L	P	NanP	Nan	W
			Rosa canina L.	S	P	MicP	Nan	W
			Rubus ulmifolius Schott	S S	P	NanP	Mes	W
			Rubus hoffmeisterianus Kunth & C.D.Bouché	S	P	NanP	Mic	W
			Prunus amygdalus Batsch	T	P	MesP	Nan	C
			Prunus armeniaca L.;	T	P	MicP	Mes	C
			Crataegus songarica K. Koch.	T	P	MesP	Mes	W
			Malus pumila Mill.	T	P	MesP	Mes	C
			Prunus domestica L.	T	P	MicP	Mes	C
			Prunus persica (L.) Batsch.	T	P	MicP	Mes	C
60	Rubiaceae	4	*Galium asperuloides* Edgew.	H	P	Th	Lep	W
			Galium boreale L.	S S	P	CrP	Lep	W
			Galium acutum Edgew.	H	P	HemC	Lep	W
			Rubia cordifolia L.	C	P	HemC	Mic	W
61	Rutaceae	2	*Dictamnus albus* L.	H	P	NanP	Mes	W
			Skimmia laureola (DC.) Decne.	S	P	NanP	Mic	W
62	Salicaceae	2	*Salix hastata* L.	S	P	NanP	Lep	W
			Populus nigra L.	T	P	MegP	Mes	W
			Salix wilhelmsiana M.Bieb.	S	P	NanP	Lep	W
			Salix tetrasperma Roxb.	T	P	MesP	Mic	W
63	Santalaceae	1	*Viscum album* L.	Pa	P	ChmP	Nan	W
64	Sapindaceae	1	*Aesculus indica* (Wall. ex Cambess.) Hook.	T	P	MegP	Mes	W
65	Saxifragaceae	1	*Bergenia stracheyi* (Hook.f. & Thomson) Engl.	H	P	Geo	Mes	W
66	Scrophulariaceae	2	*Scrophularia scabiosifolia* Benth.	S S	P	Th	Mic	W
			Scrophularia robusta Pennell	H	P	HemC	Nan	W
			Verbascum thapsus L.	H	B	Th	Mes	W
67	Simaroubaceae	1	*Ailanthus altissima* (Mill.) Swingle	T	P	MicP	Mic	C

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68	Solanaceae	4	*Solanum nigrum* L.	H	A	Th	Mic	W
			Solanum nigrum var *vellosum*	H	A	Th	Mes	W
			Solanum tuberosum L.	H	A	Geo	Mes	C
			Hyoscyamus niger L.	H	A	Th	Mes	W
			Lycopersicon esculentum Mill.	H	A	Th	Mic	C
			Capsicum annuum L.	H	A	Th	Mic	C
69	Ulmaceae	1	*Ulmus wallichiana* Planch	T	P	MegP	Mes	W
70	Urticaceae	1	*Urtica dioica* L.	H	P	Geo	Mic	W
71	Viburnaceae	2	*Sambucus wightiana* Wall. ex Wight & Arn.	H	P	Th	Mes	W
			Viburnum grandiflorum Wall. ex DC.	S	P	NanP	Mes	W
			Viburnum cotinifolium D.Don	S	P	NanP	Mes	W
72	Violaceae	1	*Viola canescens* Wall.	H	P	Geo	Nan	W
			Viola biflora L.	H	P	Geo	Nan	W
73	Vitaceae	1	*Vitis vinifera* L.	L	P	NanP	Mes	C

Keys: H: Herb, T: Tree, SS: Sub-shrub, S: Shrub, C: Climber, Pa: Parasite, L: Liana, A: Annual, B: Biennial, P: Perennial, Th: Therophyte, Geo: Geophyte, HemC: Hemicryptophyte, NanP: Nanophyte, MesP: Mesophyte, MicP: Microphyte, ChmP: Chemiphyte, CrP: Cryptophyte, MegP: Megaphyte, Nan: Nanphyll, Mic: Microphyll, Mes: Mesophyll, Lep: Leptophyll, Mac: Macrophyll, Ap: Aphyla, Meg: Megaphyll, W: Wild, C: Cultivated.

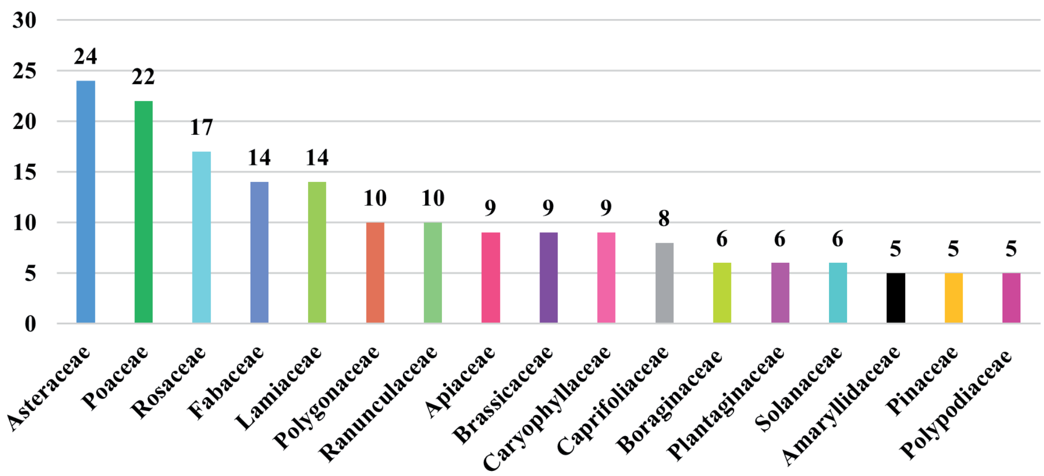

Fig. 2. Dominant families representing the largest number of species.

Lindl., *Sorbaria tomentosa* (Lindl.) Rehder, *Hypericum perforatum* L., and more. The harmonious coexistence of trees, shrubs, and herbs, with an average cover of 32, 24, and 25, respectively, painted a picture of ecological balance. However, overgrazing threatened the delicate equilibrium despite the high location and conservation efforts.

Thymus-Rumex-Poa (TRP) Community

The *Thymus-Rumex-Poa* community thrived in the high alpine regions of the mountain range at an altitude of 2596 m and 3115 m. This community, comprising 17 quadrats and harboring 127 species, had an orientation of 112° to 327° and a slope of 9° to 57°. The geographic coordinates were an average latitude of 35° 31' 30.72" to 35° 37' 58.8" and a longitude of 72° 34' 18.84" to 72° 40' 45.12". Trees, shrubs, and herbs covered the area by an average of 5%, 44%, and 45%, respectively. Notable species included *Rosa webbiana* Wall. ex Royle, *Poa alpina* L., *Phleum alpinum* L., Juniperus communis L., *Bistorta affinis* (D.Don) Greene, *Veronica alpina* L., *Scutellaria petiolata* Hemsl. ex Lace & Prain, *Piptatherum gracile* Mez, *Onosma dichroantha* Boiss., *Ephedra gerardiana* Wall. ex Klotzsch & Garcke Garcke, and *Colchicum luteum* Baker. However, the

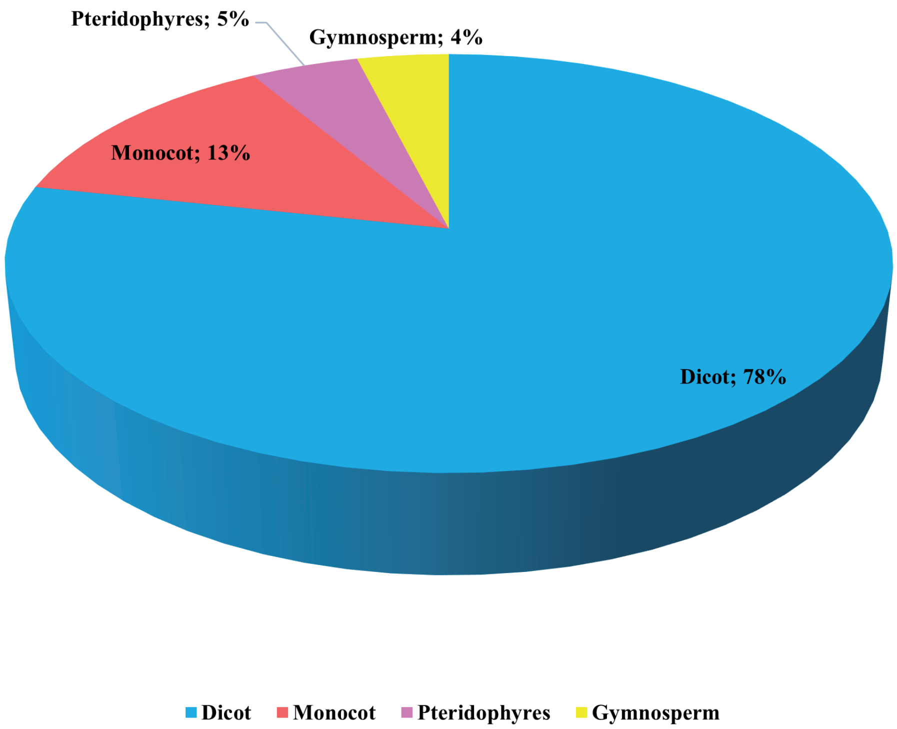

Fig. 3. Percentage of dicots, monocots, pteridophytes, and gymnosperms.

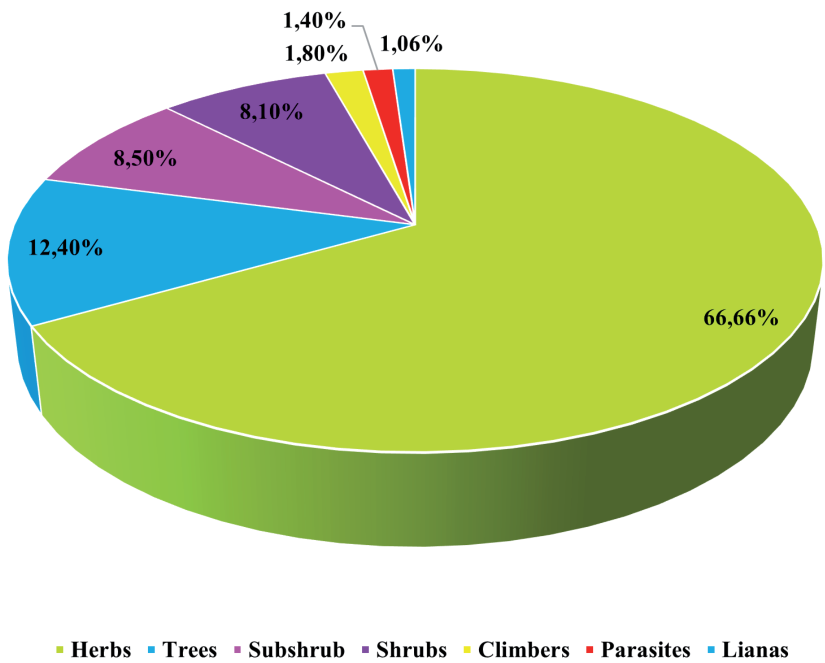

Fig. 4. Percentage of herbs, trees, subshrubs, shrubs, climbers, parasites, and lianas.

community was disturbed by overgrazing and the collection of medicinal plants.

Abies-Betula-Picea (ABP) Community

The *Abies-Betula-Picea* community thrived in subalpine regions with an altitude of 2405 m and 3009 m. With an orientation of 118° to 313° and an inclination of 11° to 68°, the geographical coordinates were between 35° 31' 0.84" and 35° 47' 46.68" and between 72° 40' 21" and 72° 48' 56.88". The area was dominated 28% by trees, 17% by shrubs, and 43% by herbs. This community comprised 33 relicts and harbored 170 species. Notable species included *Bistorta amplexicaulis* (D.Don) Greene, *Lindelofia anchusoides* (Lindl.) Lehm., *Quercus semecarpifolia* Sm., *Euphorbia wallichii*

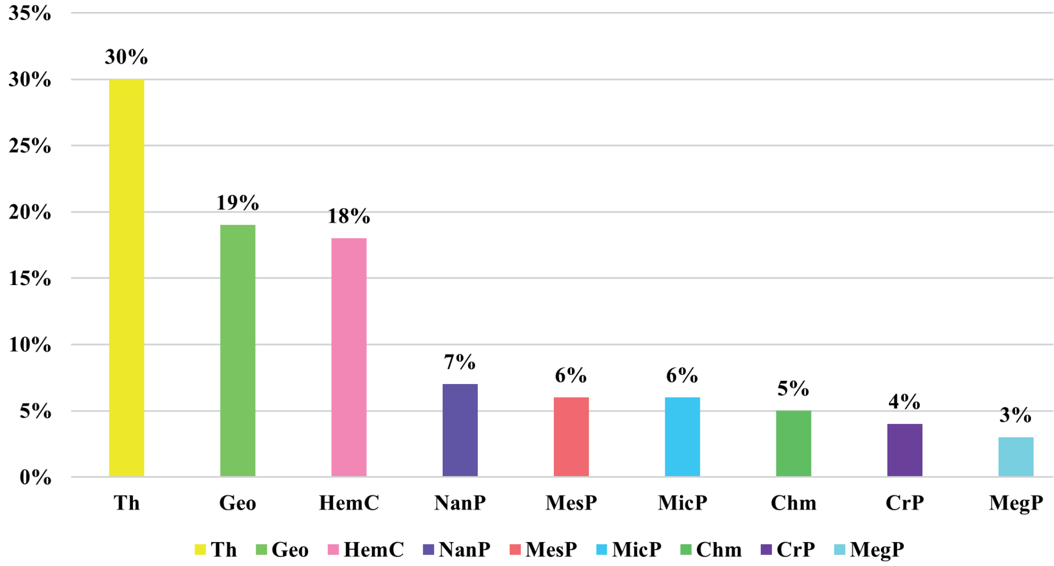

Fig. 5. Percentage of different life forms in the study area.

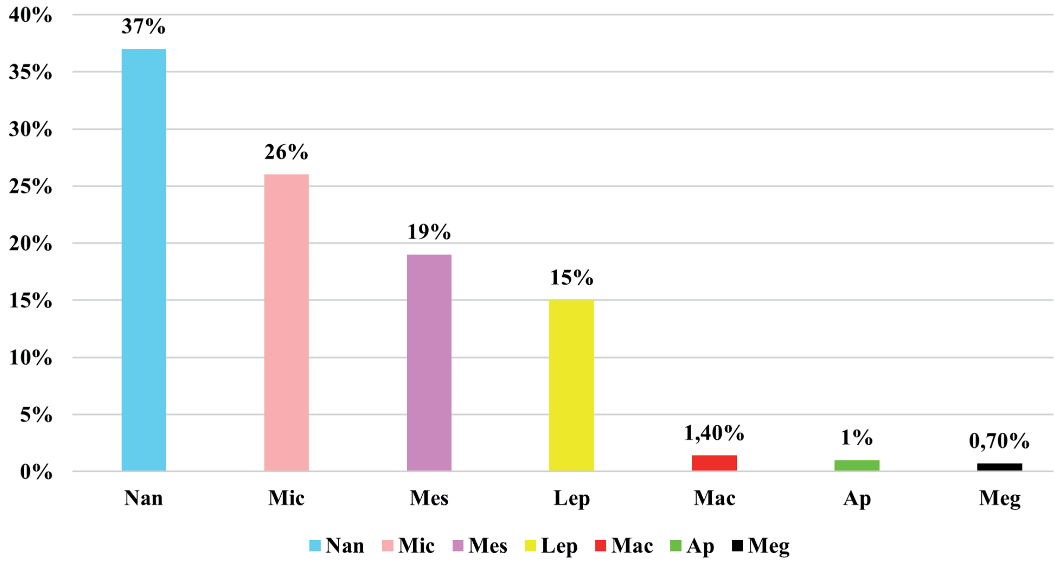

Fig. 6. Percentage of different leaf sizes in the study area.

Hook.f., *Bergenia stracheyi* (Hook.f. & Thomson) Engl., *Rosa webbiana* Wall. ex Royle, *Geranium lamberti* Sweet, *Aquilegia pubiflora* Wall. ex Royle, *Onosma dichroantha* Boiss., and *Rumex hastatus* D.Don. This was the best-preserved community, as it was located on steep slopes and away from human settlements, but it was threatened by overgrazing.

Overall, these communities were disturbed to varying degrees by factors such as deforestation, overgrazing, and agricultural expansion, with some being heavily impacted by humans while others remained relatively well preserved. Figs. 8 and 9 represent the locations of the communities without environmental factors and with environmental factors.

Discussion

The flora of the Ashoran Mountains in Kalam consists of 282 plant species from 73 families, as outlined in Table 1. Most of these species are herbaceous, comprising 66.6% of the total flora. Trees constitute 12.4%, followed by subshrubs with 8.5% and shrubs with 8.1%, as depicted in Fig. 4. Similar findings on the dominance of herbaceous plants have been reported by researchers in other regions of Pakistan, e.g., in the Sarban hills of Abbottabad [36] and in Balakot, Mansehra [37]. In the vast mountainous landscapes, herbaceous plants predominate over woody species [38]. This dominance of herbaceous forms can be attributed to these areas' persistently harsh climatic conditions.

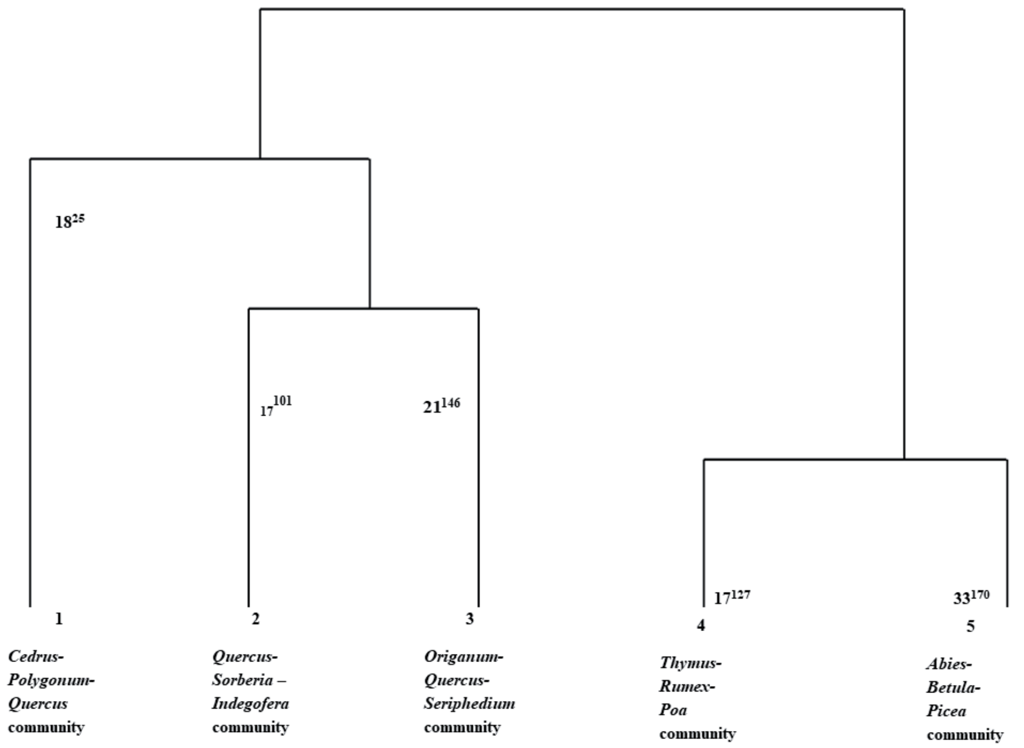

Fig. 7. TWINSPAN (modified after Roleček et al., 2009) classification hierarchy of the five (5) plant associations in the research area (number of relevés are shown as subscripts and number of species are shown as superscripts corresponding with each vegetation unit).

Accurate sampling and analysis are essential for a comprehensive understanding of vegetation and the key factors influencing it in each region. In our study of the Ashoran Mountains, we examined 73 plant families and found that Asteraceae and Poaceae had the highest species richness. These were followed by Rosaceae, Fabaceae, Lamiaceae, and Polygonaceae. These results are consistent with previous studies [6, 39]. Asteraceae, Poaceae, Rosaceae, and Lamiaceae are distributed worldwide and thrive particularly well in temperate forest microhabitats, which emphasizes their broad ecological adaptability. The diverse habitat occurrence of Asteraceae in different habitats is attributed to their high ecological tolerance [40]. Other researchers also observed this pattern in Karak [41] and Malakand [22], where Asteraceae were most abundant in floristic diversity.

Biological spectra, which represent essential botanical characteristics, are often used in vegetation analysis to show how plants adapt to certain climatic conditions. These spectra include various life forms and leaf size categories, which have been extensively documented in Pakistan [40, 42]. In our study in the Ashoran Mountains, a remarkable dominance of therophytes was observed, indicating a significant impact on human activities such as deforestation and grazing. This observation aligns with other ecological studies that state that therophytes often predominate in areas of high disturbance [43]. Our findings are consistent with those of other studies [16, 43], which also reported a similar dominance of therophytes in their study areas.

The resistance of therophytes to extreme ecological conditions, whether at low or high altitudes and in open canopies, probably contributes to their distribution in our study area [44]. The short growing season in this area favors the rapid life cycle of therophytes, allowing them to maximize their growth during the limited favorable periods [45]. With increasing altitude, the harsher climatic conditions restrict the growth of shrubs and trees to lower altitudes and agricultural lands. However, at higher elevations, shrubs such as *Salix species, Juniperus communis, Rosa webbiana,* and *Rosa canina* are able to withstand severe conditions such as snowfall, circadian environmental changes, ice slides, and avalanches.

When examining the leaf size spectra, our study revealed that nanophylls are the most abundant, followed by microphylls. This pattern is consistent with the known ecological distribution of leaf sizes, where microphylls are typically associated with steppe environments, while leptophylls and nanophylls are common in hot desert regions [14]. Plants with larger leaves are generally adapted to warmer, wetter environments, while smaller leaves are more likely to be found in cold, dry climates. Species with large leaves thrive in moist and warm conditions, while the presence of smaller leaves suggests adaptation to drier conditions, lower rainfall, and higher temperatures. Similar observations have been made in other studies [42, 46-49], where nanophilous species were found to occur primarily at lower altitudes with

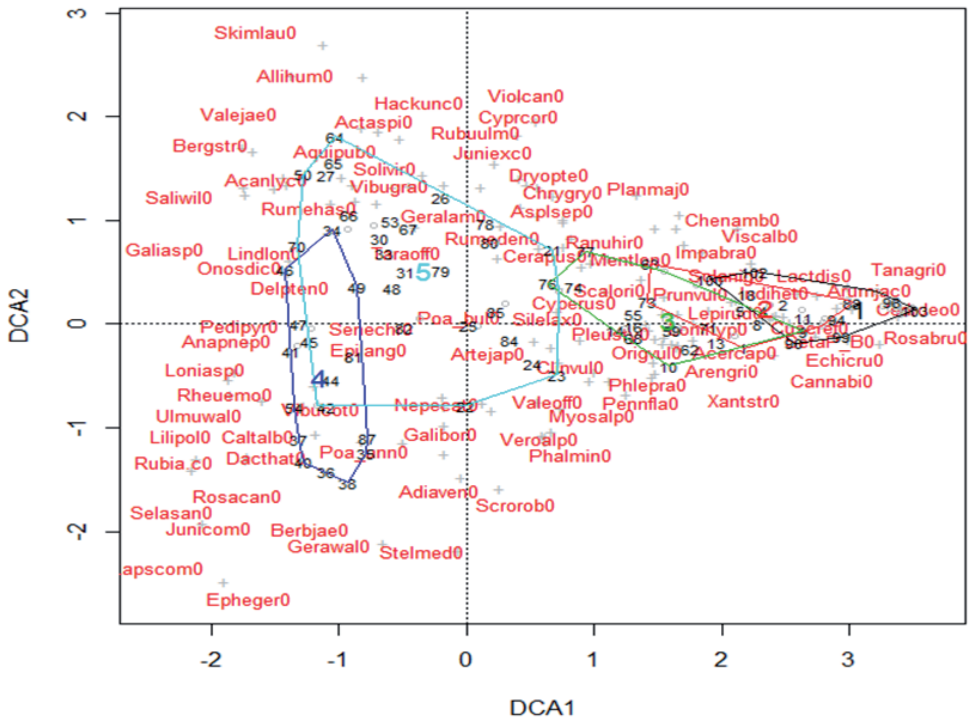

Fig. 8. Ordination diagrams of DCA analysis, showing the species distribution without environmental variables.

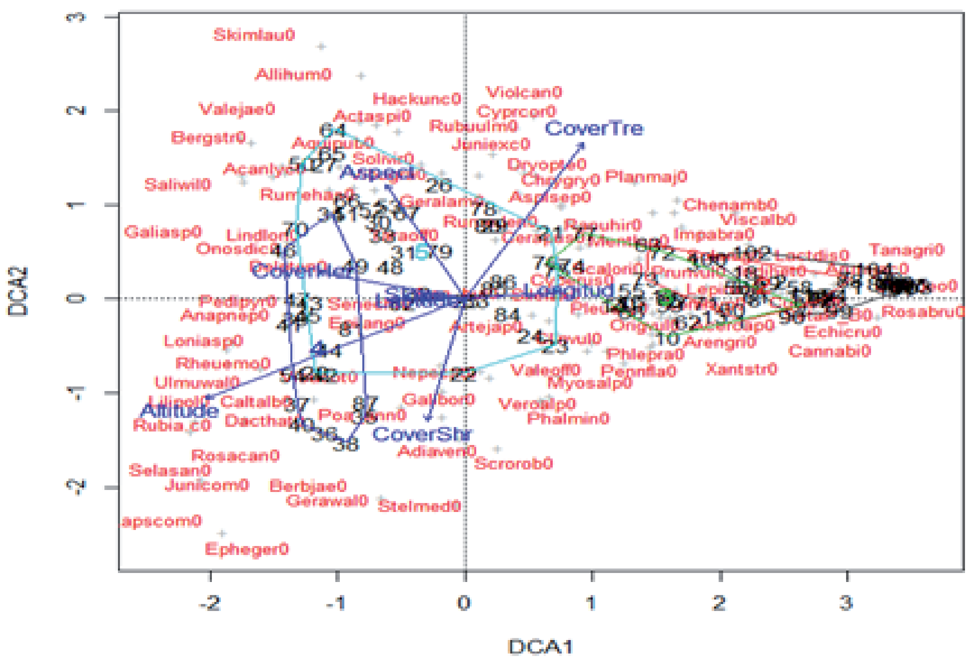

Fig. 9. DCA analysis depicting the species distribution under the impact of different environmental factors operating in the study area.

reduced rainfall, and microphyllous species were more common at higher altitudes. These patterns emphasize the relationship between leaf size and climatic conditions at different altitudes.

In the phytosociological study, five plant communities were identified in the study area using a modified TWINSPAN classification [50, 51]. Canonical Correspondence Analysis (CCA) and Detrended Correspondence Analysis (DCA) are widely used ordination methods in community ecology. These techniques are useful in accurately identifying different ecological units, mapping out ecological gradients, and elucidating the relationships between environmental variables and floristic composition [50, 51].

Conclusions

The Ashoran region in the Hindukush Mountains, with its varied topography and pronounced altitudinal differences, is home to a rich diversity of plant species influenced primarily by Sino-Japanese elements. In this study, 282 plant species were identified, most of which are herbaceous, with the Asteraceae family being particularly well represented. The diverse edapho-climatic conditions support a range of life forms, particularly therophytes and nanophylls. The unique phenology of these species offers insights into their responses to climate change, highlighting the importance of effective forest management and species conservation. However, grazing, deforestation, forest fires, and unplanned development severely threaten the region's biodiversity. Immediate conservation measures are needed to preserve this valuable and diverse ecosystem.

Author Contributions

Conceptualization: R.A., S.A.R., A.R.; Methodology: A.R., N.A., S.A.R.; Supervision: N.A., F.A.O., A.K.; Data Curation: A.I., M.A.F., F.A.O.; Data Analysis: A.I., A.S., M.N.K., M.A.F.; Software: M.N.K., A.S., M.I.; Writing original draft preparation: R.A., A.K., M.I.; Writing-Review and Editing: K.M.A.A., A.K., S.A.R., F.A.O., M.A.F.

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Conflict of Interest

The authors declare no conflict of interest.

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