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Distribution Pattern, Conservation Status, and Associated Flora of the Genus *Juniperus* in Subalpine Pastures of the Kashmir Himalayas

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Juniperus is an evergreen gymnosperm genus with a broad geographical distribution in the Northern Hemisphere. *Juniperus* constitutes important vegetation associations in the Himalayan highlands that

have significant ecological and socioeconomic importance. This research investigated the distribution pattern, community structure, and ecosystem services provided by *Juniperus*-dominated subalpine vegetation in the upper Neelum Valley, Pakistan. Vegetation attributes and geographical characteristics were systematically recorded at 4 selected sites. Two species of *Juniperus*, *Juniperus communis* L. and *J. excelsa* M. Bieb., were found to have average importance values of 23.4 and 20.02%, respectively. *J. excelsa* showed an average basal area of $0.30 \text{ m}^2 \text{ ha}^{-1}$ and an average stem density of 46.95 ha^{-1} ; *J. communis* had an average basal area of $0.25 \text{ m}^2 \text{ ha}^{-1}$ and an average stem density of 33.21 ha^{-1} . A total of 56 *Juniperus*-

associated plant species from 29 families were recorded, with Asteraceae as the dominant family, followed by Lamiaceae, Polygonaceae, Rosaceae, Caryophyllaceae, and Apiaceae. Predominant associated species included *Thymus linearis*, *Aster falconeri*, *Rosa webbiana*, *Berberis lyceum*, *Anagallis arvensis*, *Rumex nepalensis*, *Poa alpina*, *Bistorta affinis*, and *Iris hookeriana*. The calculated average values were Shannon's diversity, 3.07; Simpson's diversity, 0.94; species richness, 1.11; species evenness, 0.90; and maturity index, 45.90. Hemicryptophytes were the dominant lifeform in the area (57.14%), and microphylls (46.42%) were the dominant leaf type. Overgrazing and fuelwood cutting were identified as serious threats to both *Juniperus* species. Restoration of the degraded juniper stands through collective efforts by government and local communities and regular monitoring is recommended.

Keywords: *Juniperus communis*; *Juniperus excelsa*; regeneration; subalpine; Kashmir.

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Introduction

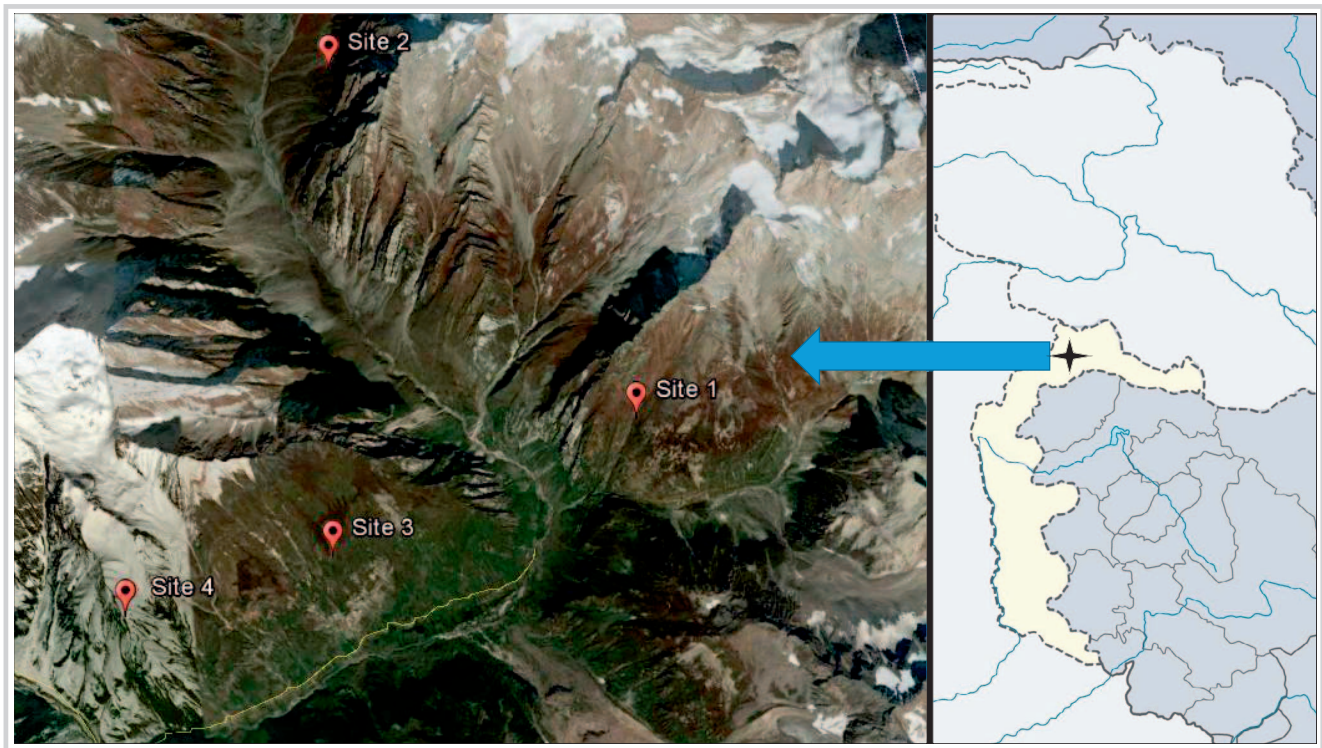
Juniperus is an evergreen gymnosperm genus with broad geographical distribution, occurring in the Arctic, Africa, East Africa, Central Asia, Central America, and South Asia, and it has significant ecological and socioeconomic importance in the Northern Hemisphere (Farjon 1992; Zangiabadi et al 2012; Tavankar 2015). *Juniperus* species constitute an important element of Himalayan highlands vegetation because of their ability to inhabit rocky slopes and poorly developed soils. Juniper stands are able to cope with severe temperatures, heavy snowfall, and strong grazing pressure because of their inherent longevity (Miller et al 2005). *Juniperus* species are distributed across the whole Himalayan region and occur at elevations ranging from 1500 to 4000 masl (Shah et al 2013; Ahmed et al 2015).

The *Juniperus* genus belongs to the Cupressaceae family, which has 67 species. Five *Juniperus* species are

reported in Pakistan (Sarangzai et al 2013), and 4 are reported in India and Nepal (Mao et al 2010). Two species of *Juniperus*, *Juniperus communis* L. and *J. excelsa* M. Bieb., are reported to occur at high elevations in Azad Jammu and Kashmir (Ahmed et al 2015). *J. communis* var. *saxatilis* Pallas, Fl. Ross., commonly known as alpine juniper, has a decumbent shrubby habit and grows on steep slopes between 3080 and 4000 masl. *J. excelsa* is a medium-sized tree growing in the upper ranges of dry temperate and lower subalpine zones between 2310 and 3700 masl (Dickoré and Nüsser 2000; Ali and Qaiser 1993–2007). The *J. excelsa* forests in Baluchistan Province, Pakistan, contain some of the world's oldest (2400 years) and slowest-growing trees and are known as living fossil forests; they are now part of a United Nations Educational, Scientific and Cultural Organization World Heritage site (Sheikh 1985; Sarangzai et al 2012).

Juniperus species play a vital role in maintaining ecological services in the fragile Himalayan highland,

FIGURE 1 Location of the study area and study sites in the western Himalayas. (Source: Google Maps, Image Landsat Copernicus)



including soil fertility, erosion control, humus and biomass production, air purification, and microclimate regulation (García et al 2000; Rawat and Everson 2012). Juniper stands also provide ecosystem services to the local Himalayan communities, including wood for fuel and construction, shelter, ethnomedicinal products, and recreational and ecotourism value (Gonny et al 2006; Ozkan et al 2010; Nüsser and Schmidt 2017). *Juniperus* contributes significantly to the livelihoods of poor and remote mountain populations, who face harsh climatic conditions and lack alternative fuel and energy resources.

The distribution pattern and regeneration status of *Juniperus* in the Himalayan highlands is adversely affected by an increasing human population, fuelwood overextraction, overgrazing, drought, and climate change (Bhattarai et al 2006; Achakzai et al 2013; Gruwez et al 2013). The rapid decline of the species indicates an urgent need for serious conservation efforts at the regional level in the Himalayas (IUCN 2015). Himalayan alpine have received relatively lesser attention compared to the European Alps or North American tundra biomes, indicating a considerable knowledge gap regarding vegetation structure and species conservation status (Nüsser and Dickoré 2002). In light of the ecological and socioeconomic significance of the genus *Juniperus*, the current study was designed to investigate the distribution pattern of *Juniperus* species in the Himalayan highlands of Kashmir and to further analyze the community structure

and vegetation attributes of *Juniperus*-dominated communities. Objectives also included an assessment of the intensity of anthropogenic pressure on *Juniperus* stands and associated flora.

Material and methods

The study area lies in Shoonthar Valley, which is located in the Pir Panjal subrange of the western Himalayas in the Neelum district of Pakistan. This region is administered by Kashmir and ranges from 3000 to 4000 masl at 74°31'E and 34°59'N (Figure 1). The valley is surrounded by high glaciated peaks and steep slopes colonized by *Juniperus* stands. The climate is subalpine to alpine and characterized by extreme cold during winter, with heavy snowfall and freezing temperatures down to -10°C from November to April. Summers are short and cool: the average temperature between June and August is around 10°C . The area receives about 1000 mm of precipitation annually, most of which falls as snow in winter (Dar and Malik 2009; Pak-Met 2015).

Field expeditions were conducted from July to August 2015 at 4 selected sites in Shoonthar Valley (Table 1). Vegetation data were recorded systematically for all sites following standard phytosociological protocols (Panthi et al 2007). Fifteen 5×5 m quadrats were laid at each site, and vegetation density, frequency, and cover were recorded. Primary vegetation data were processed to

TABLE 1 Geographical characteristics of the investigated *Juniperus*-dominated sites.

Site	Elevation (m)	Longitude	Latitude	Aspect	Slope
1	3450	34.98°99'86"	74.52°82'84"	Northeast	60–90°
2	3700	35.03°04'23"	74.51°00'32"	Northwest	60–90°
3	3350	34.97°91'79"	74.51°52'50"	South	30–60°
4	3600	34.97°88'30"	74.49°75'30"	South	60–90°

determine analytical and synthetic phytosociological attributes, including the importance values for *Juniperus*. Indices of diversity were calculated after Simpson (1948) and Shannon and Wiener (1949), and indices of maturity and similarity were calculated after Pichi-Sermolli (1948) and Sørensen (1948), respectively. Species evenness was calculated after Pielou (1975), and species richness was calculated after Menhinick (1964). The physiognomic attributes of the local vegetation, including lifeform and leaf spectra classification, were determined following Raunkier (1956). The geographical coordinates of each site were recorded using the global positioning system. Regeneration and basal area cover were estimated by recording stem and seedling densities at each site. The anthropogenic pressure on *Juniperus* stands was recorded in terms of fuelwood cuttings and overgrazing (visual indicators included cuttings, browsed vegetation, hoof marks, and dung). Data were statistically analyzed by applying multivariate ordination techniques, including cluster analysis and principal component analysis (PCA) (Jongman et al 1995).

Results

Results revealed that the subalpine vegetation of the investigated sites was dominated by 2 species of *Juniperus*, *J. communis* L. and *J. excelsa* M. Bieb., with importance values of 23.42 and 20.01%, respectively. *J. communis* was present at all study sites and had a total average basal area of 0.25 m² ha⁻¹ and a total average stem density of 33.21

ha⁻¹. Maximum growth of *J. communis* was recorded at site 1, where it had a basal area of 0.47 m² ha⁻¹ and a stem density of 54.35 ha⁻¹. *J. excelsa* was present at 3 of the 4 study sites and had a total average basal area of 0.30 m² ha⁻¹ and a total average stem density of 46.95 ha⁻¹. The highest basal area (0.69 m² ha⁻¹) and stem density (91.70 ha⁻¹) were recorded for *J. excelsa* at site 3 (Table 2).

An analysis of the floristic composition of *Juniperus*-associated species showed 56 species belonging to 29 families. Asteraceae (16%) was the most dominant family, followed by Lamiaceae (9%), Polygonaceae (9%), Rosaceae (7%), Caryophyllaceae (5.3%), and Apiaceae (5.3%). Hemicryptophytes were found to be the dominant lifeforms (57.14% of the recorded species), followed by geophytes (17.85%). Microphylls were the dominant leaf spectra (46.42%), followed by leptophylls (17.85%) (Supplemental material, Table S1: <http://dx.doi.org/10.1659/MRD-JOURNAL-D-16-00119.S1>).

Phytosociological investigations revealed 4 communities. The main community was subalpine tangle wood composed of dwarf scrubland and steppe formations. The recorded plant communities showed an average species number of 30.5, with an average Simpson's diversity value of 0.94 and Shannon's diversity value of 3.07. The determined species richness value was 1.1, species evenness was 0.90, and the maturity index was found to be 45.90 (Table 3).

The *J. communis*–*Rosa*–*Allium* community, consisting of 33 species, was located at elevations of 3450 m. *J. communis*

TABLE 2 Structural attributes of *Juniperus*-dominated stands recorded in the study area.

	Site 1	Site 2	Site 3	Site 4	Average
<i>J. excelsa</i>					
Importance value (%)	0.00	24.69	29.58	25.79	20.02
Stem density (ha ⁻¹)	0.00	38.30	91.70	57.90	46.95
Basal area (m ² ha ⁻¹)	0.00	0.24	0.69	0.37	0.30
<i>J. communis</i>					
Importance value (%)	40.37	21.32	15.36	16.64	23.42
Stem density (ha ⁻¹)	54.35	32.69	21.00	24.86	33.21
Basal area (m ² ha ⁻¹)	0.47	0.29	0.11	0.13	0.25

TABLE 3 Phytosociological parameters recorded in the investigated area.

Community name	Elevation (m)	No. of species	Simpson's diversity	Shannon's diversity	Species richness	Species evenness	Maturity index
<i>J. communis</i> – <i>Rosa</i> – <i>Allium</i>	3450	33	0.96	3.22	1.26	0.92	40.00
<i>Aster</i> – <i>J. excelsa</i> – <i>J. communis</i>	3700	40	0.96	3.36	1.19	0.91	45.50
<i>Thymus</i> – <i>J. excelsa</i> – <i>Rosa</i>	3350	30	0.93	2.95	1.24	0.86	37.60
<i>Rumex</i> – <i>J. excelsa</i> – <i>Anagallis</i>	3600	19	0.94	2.73	0.76	0.94	60.52
Average	3250	30.5	0.94	3.07	1.11	0.90	45.90

was the dominant species, followed by *Rosa webbiana*, *Allium wallichii*, *Thymus linearis*, and *Artemisia abrotanum*.

The *Aster*–*J. excelsa*–*J. communis* community, consisting of 40 species, was recorded at an elevation of 3700 m. *Aster falconeri* was the dominant species, followed by *J. excelsa*, *J. communis*, *Berberis lyceum*, and *T. linearis*.

The *Thymus*–*J. excelsa*–*Rosa* community, consisting of 30 species, was recorded at an elevation of 3350 m and was dominated by *T. linearis*, followed by *J. excelsa*, *R. webbiana*, *Verbascum thapsus*, and *J. communis*.

The *Rumex*–*J. excelsa*–*Anagallis* community, consisting of 19 species, was recorded at an elevation of 3600 m dominated by *Rumex nepalensis*, *J. excelsa*, *Anagallis arvensis*, *Poa alpina*, and *Silene vulgaris* (Table S1).

The cluster analysis identified 3 significant correlations in the species data matrix. Elevation, degree of slope steepness, and soil moisture appeared as key factors governing the species assemblages. The largest cluster formed at the x-axis and was composed of 24 species dominated by *J. communis*, *R. webbiana*, *Rhodiola*, *Pedicularis*, *Sibbaldia*, *Aster*, *Astragalus*, *Habeneria*, and *Artemisia*. These species were found in abundance at sites 1 and 2 on steep, dry, and rocky northeast- and northwest-facing slopes ($>60^\circ$). The second cluster represents species mostly recorded at site 4, which is characterized by a moderate southeast-facing slope and relatively higher soil moisture. Composed of 15 species, this cluster is dominated by *J. excelsa*, *Rumex*, *Bistorta*, *Berberis*, *Poa*, *Silene*, *Fragaria*, and *Taraxacum*. The third group, composed of 17 species, was dominated by *Angelica*, *Lindelia*, *Rheum*, *Viola*, *Polygonum*, and *Betula*. This cluster included species from lower elevations and south-facing slopes with better light exposure at site 4 (Figure 2). The PCA verified the species-site correlations identified by cluster analysis. *Aster*, *J. communis*, *J. excelsa*, *Rosa*, *Rumex*, and *Iris* showed strong associations with sites 1 and 2, whereas *Aconitum*, *Thymus*, *Silene*, and *Anagallis* correlated with sites 3 and 4. Species occurring at all sites were clustered in the middle of the PCA in an overlapping manner (Figure 3).

Overgrazing and fuelwood cutting were identified as the major threats to *Juniperus* in the study area. *J. communis* stands exhibited stunted growth and browsed canopy, whereas *J. excelsa* stands showed evidence of cutting for

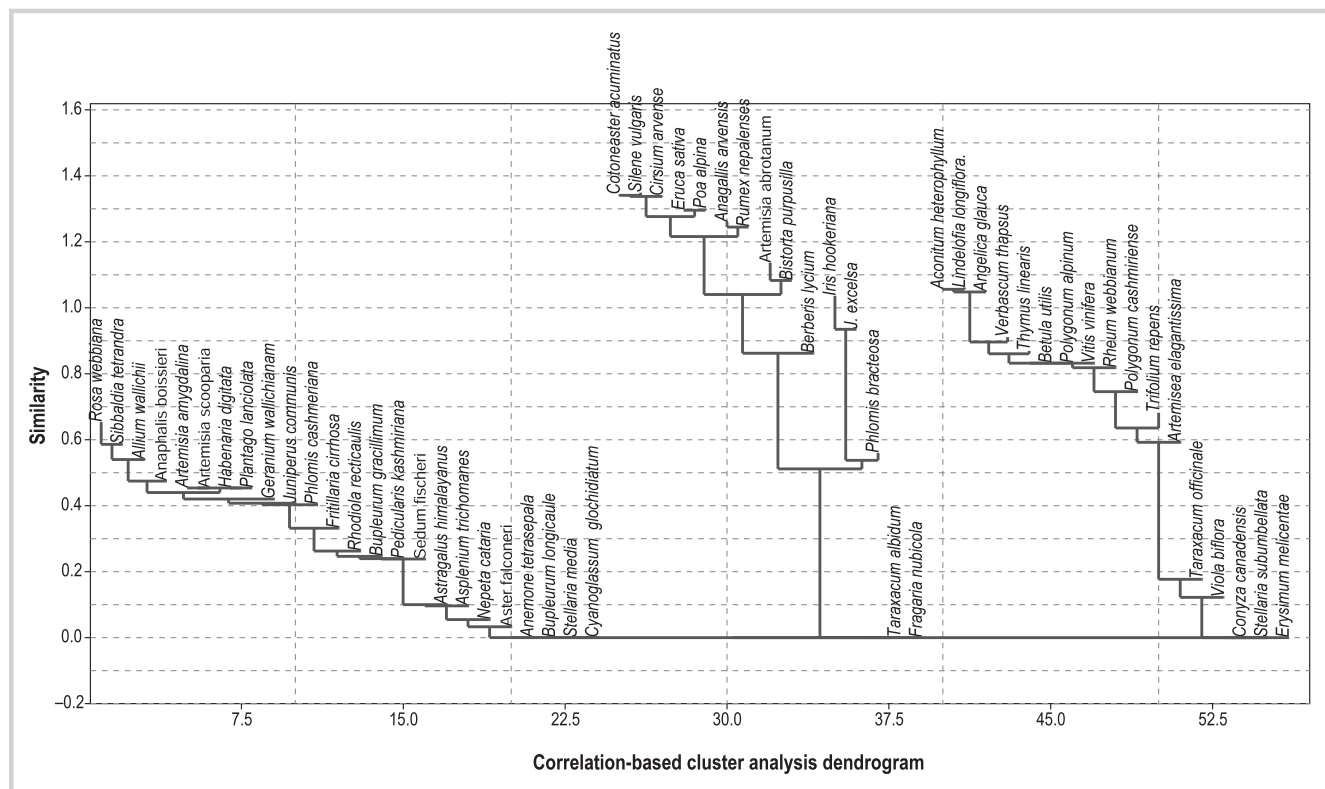
fuelwood and construction. No regeneration was recorded for either species at any of the sites.

Discussion

The current study presents the results of the first investigation focusing on the distribution, structure, and composition of *Juniperus*-dominated vegetation stands in the Himalayan highlands of Kashmir. In this area, *Juniperus* occurs in marginal populations on rugged, rocky slopes and shows no evidence of regeneration because of strong suppression due to overgrazing and overextraction for fuelwood, as well as harsh climatic conditions (Nüsser 2000).

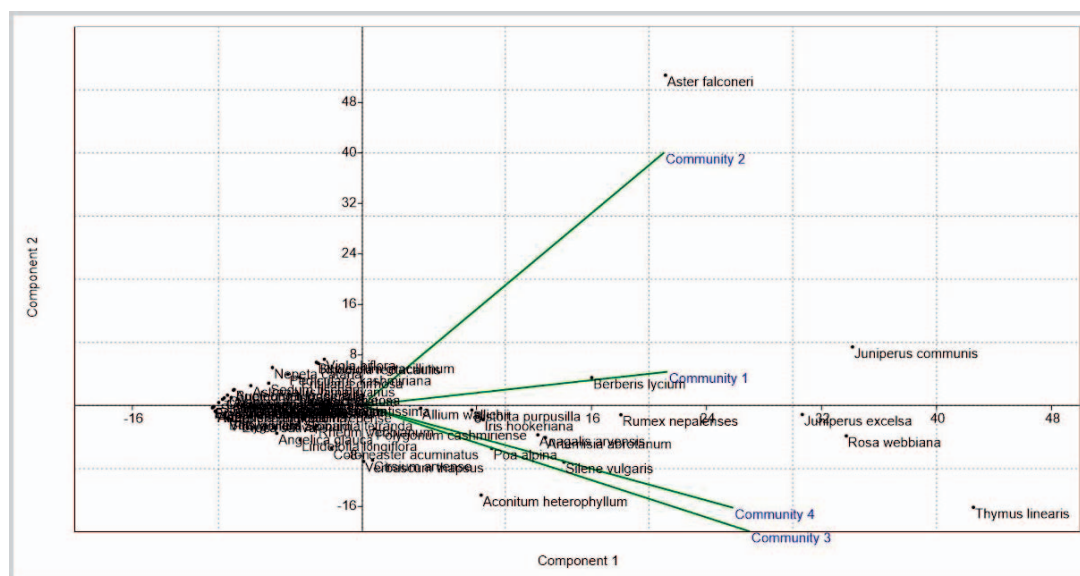
An average Simpson's Diversity Index of 0.94 was recorded in the investigated area, which is lower than the values recorded across the region: 1.53–2.88 in the Western Himalayas (Samant et al 1998), 2.5–3.10 in the Trans-Himalayan region of Nepal (Panthi et al 2007), and 0.91 in Western Himalayan alpine pastures (Shaheen et al 2011). The lower values of diversity and species richness may be attributed to severe anthropogenic pressure and environmental stress (García et al 1998; Körner 2007). Communities were characterized by a high degree of evenness, ie 0.90, which correlates with the low species counts per site as a result of disturbance (Saxena and Singh 1982; Fosaa 2004). The impacts of natural and anthropogenic disturbances were further reflected in the low maturity indices (>60) in 3 of the 4 studied communities. The fourth site, with a maturity index of 60.52, barely qualified as mature (Table 3). Biological spectra analysis showed that local flora was dominated by hemicryptophytic microphyllous vegetation. This particular physiognomy reflects adaptation to the harsh climates of the Himalayan highlands and is supported by the findings of Klimeš and Dickoré (2005) in Ladakh as well as in Malik et al (2007) in the Kashmir Himalayas.

J. communis showed higher abundances and importance values than *J. excelsa* throughout the study area. This is in accordance with the broader geographical distribution of *J. communis* across the Northern Hemisphere because of its inherent longevity and ability to tolerate harsh environmental conditions (Adams 1999; Pirani et al 2011). Soil moisture and slope appeared to be the major

FIGURE 2 Cluster analysis dendrogram of species data based on Ward's method.

microclimatic factors affecting the growth and abundance of *J. excelsa*. In the study area, *J. excelsa* was found to grow best at site 3, which is characterized by higher moisture content and gentler slopes (Table 2). Low slope is reported to facilitate the growth of seedlings, resulting in better recruitment at the local scale (Tavankar 2015).

Juniperus-dominated communities were found to be declining because of an overextraction of wood for fuel and construction purposes (Rawat et al 2009). Overgrazing was recorded as a serious threat, especially because this genus has limited ability to recover from the effects of grazing, which reduces sprouting and seed survival

FIGURE 3 PCA biplot of species and site data.

(Jiménez et al 2003). Most importantly, no evidence of regeneration was found in the study area. Seedling recruitment is hindered by the lack of shade and moisture on steep, sunny, and rocky slopes and compounded by persistent grazing pressure (Couralet et al 2005; Iszkuło and Boratyński 2011). Upward migration of some temperate shrubs (eg *Rosa*, *Cotoneaster*, and *Berberis* species) also contributes to the reduction of natural *Juniperus* habitat because of increased competition (Yadav et al 2006).

In conclusion, *Juniperus* stands in the area are declining because of anthropogenic disturbances and climatic harshness. It is critical to conserve these naturally occurring *Juniperus* stands, which contribute significantly

to the ecological and socioeconomic health of the Himalayan highlands. Pressure on *Juniperus* stands can be reduced by providing local communities with fuel alternatives and efficient building materials—including thermostat sheathing, plywood, foam insulation, and recycled steel—as well as by controlling overgrazing and fuelwood extraction. It is recommended that this diverse and unique vegetation type should be restored through collective efforts involving the government and local communities. This could include establishment of protected areas, afforestation schemes, training and capacity building of departmental personnel and local communities, and regular monitoring.

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Supplemental material

TABLE S1 Floristic composition, physiognomic attributes, and importance values of *Juniperus*-dominated flora.

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