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ECOLOGICAL ATTRIBUTES AND CONSERVATION STATUS OF THREATENED MEDICINAL PLANTS IN THE PAK-AFGHAN BORDER, BAJAUR, PAKISTAN

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Abstract

For the first time, systematic conservation planning attempts to evaluate the status of endangered medicinal plants that require immediate conservation. Ecological characteristics and threat factors of the selected medicinal plants were identified in the field survey and by interviewing the inhabitants of the area. Anon., 2010, criteria and categories were used for the assessment of the area of occupancy and extent of occurrence of the species. The evaluated species were exposed to eight distinct types of threats, putting them at risk. Six of these species- *Arisaema flavum, Bergenia ciliata, Myrtus communis, Solanum surattense, Teucrium stocksianum* and *Vitis jacquemontii* fulfill the requirements for the category of endangered threat, while three of these species-*Alnus nitid, Caralluma tuberculata* and *Eremurus himalaicus*-meet the criteria for critically endangered species The phytogeographical exploration reveals that *Alnus nitida, Eremurus himalaicus, Arisaema flavum* and *Vitis jacquemontii* belonged to Sino-Japanese and Western Himalayan regions while *Caralluma tuberculata* and *Teucrium stocksianum* to the Irano-Turanian and Sino-Japanese elements. Local communities utilized these species as medicine to treat a range of ailments. These nine species are threatened in the wild and consequential in-situ conservation measures are needed to ensure long-term survival. Using this study as a prototype for local conservation programs with medicinal plants will improve future conservation efforts.

Key words: Conservation; Ethnomedicinal uses; Threat assessment; Area of occupancy; Extent of occurrence

Introduction

Biodiversity is an essential source of livelihood due to the wide range of ecological services it offers (Brockerhoff *et al*., 2017). These ecological services are the result of efficient management of natural resources (Pukkala, 2016). However, many species in the ecosystem are rapidly becoming extinct due to the world's population expansion, urbanization, invasive species, habitat fragmentation, and increased reliance on limited natural resources (Pimm & Raven, 2017). The rate of plant extinction is thousands of times faster than the rate of plant diversification (De Vos *et al*., 2015). Approximately, 137 species of plants and wild animals are disappearing due to anthropogenic activity and no new species replaced them. In the next fifty years, a half-million to a million plant species will go extinct, if the current pace continues (Hilton-Taylor, 2000). This rate is 1000-10,000 times faster than what should be expected (Soelberg & Jäger, 2016). The total number of species found in Pakistan's mountainous and woodland regions is declining by 1.5% annually due to anthropogenic pressures such as deforestation and commercial usage (Shinwari & Qaiser, 2011; Ullah *et al*., 2023).

Most plants in a region can be utilized as herbal remedies for safeguarding the health of residents. Developing and developed countries use plant-based medications to treat several ailments (Smith-Hall *et al*., 2012). Medicinal plants are the most prevalent source of novel pharmaceuticals in the world. Nearly 80% of the population in developing countries utilize herbal remedies as their primary source of healthcare, while more than 25% of prescribed drugs are made from wild plant species (Hamilton, 2004). Threats to the diversity of medicinal plant species in a specific location include habitat fragmentation, overharvesting, agricultural enforcement, intrusion by invasive species, disease assault, overgrazing, consumption of plants as fuelwood and unsustainable exploitation (Chen *et al*., 2016; Abdela & Sultan, 2018).

The IUCN and WWF reported that about 50,000 to 80,000 angiosperms plants are globally used as medicine with 15,000 species potentially facing extinction as a result of habitat degradation and overharvesting. The flora of Pakistan is comprised of 6000 plant species, with over 2000 species known for their medicinal properties (Ullah, 2017). The increasing human population and unsustainable use of medicinal plants have caused a reduction of about 20% in wild plant resources (Chen *et al*., 2016). Sustainable utilization of resources such as medicinal plants promotes public health initiatives and can aid in the eradication of poverty (Epstein *et al*., 2003). Implementing the strategies of in-situ and ex-situ conservation would create possibilities for the protection of the biodiversity of a given region (Gepts, 2006). For systematic conservation efforts, multiple sets of conservation guidelines have been established, particularly ex-situ and in-situ conservation strategies, and the development of species inventory systems and their management (Hamilton, 2004; Heywood, 2015). It increases opportunities for maintaining diversity and establishes a link between sustainable use of resources

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and ecologically friendly processes (Forest *et al*., 2007). The categories and criteria of the IUCN Red List are restricted to the wild plant species that fall within a taxon with a natural ecological range. Around the globe, researchers are working to discover the endangered species; but unfortunately, little investigation has been done, and very little information exists about the threatened flora of Pakistan (Alam & Ali, 2010; Haq, 2011; Khan & Hussain, 2013; Malik *et al*., 2015). This study aims to document the various challenges faced by the region's threatened medicinal plants and to develop strategies for their identification and conservation.

Material and Methods

Study area: The tribal district of Bajaur has recently merged with Khyber Pakhtunkhwa province of Pakistan. It is a hilly terrain located between 34° 30 and 34° 58° N latitude and 71° 11 to 71° 48° E longitude. The Hindu Kush range has some high mountains north and northwest of Bajaur. Its total area is 1290 square kilometers. The Afghan provinces of Kunar and Bajaur are shared by a 52-kilometer border. The Pashat Valley is situated near this border, having the highest peak, known as "Latai Sar," and is the site for cross-border trade and transit (Fig. 1). Summer is pleasant, but winters are bitterly cold because of the copious snowfall. The average temperature in the area ranges from 5° to 10°C; however, it lowers to 0°C in December and January. The annual rainfall is about 500 mm, of which only 375 mm falls in July and August.

Ecological characteristics: The ecological characteristics such as life for and leaf size spectra of the species were recorded using the standard methods (Raunkiaer, 1934; Hussain *et al*., 2015; Haq & Badshah 2021a; Ali *et al*., 2022; Manan *et al*., 2023; Haq *et al*., 2023b).

Ethnomedicinal profiling: Information about the therapeutic benefits of the plants was gathered from the local inhabitants through semi-structured questionnaires. The quantitative metrics of Use Value (UV) and Relative Frequency of Citation (RFC) for each species were calculated according to the given formulae in the available literature.

Use value (UV): The species' use value was calculated using a formula specified in the published literature (Savikin *et al*., 2013; Haq *et al*., 2022).

$$\text{Use value (UV)} = \sum U/n$$

where "U" represents the total number of reports submitted by users for a specific species and "n" represents the total number of informants interviewed for a particular plant species.

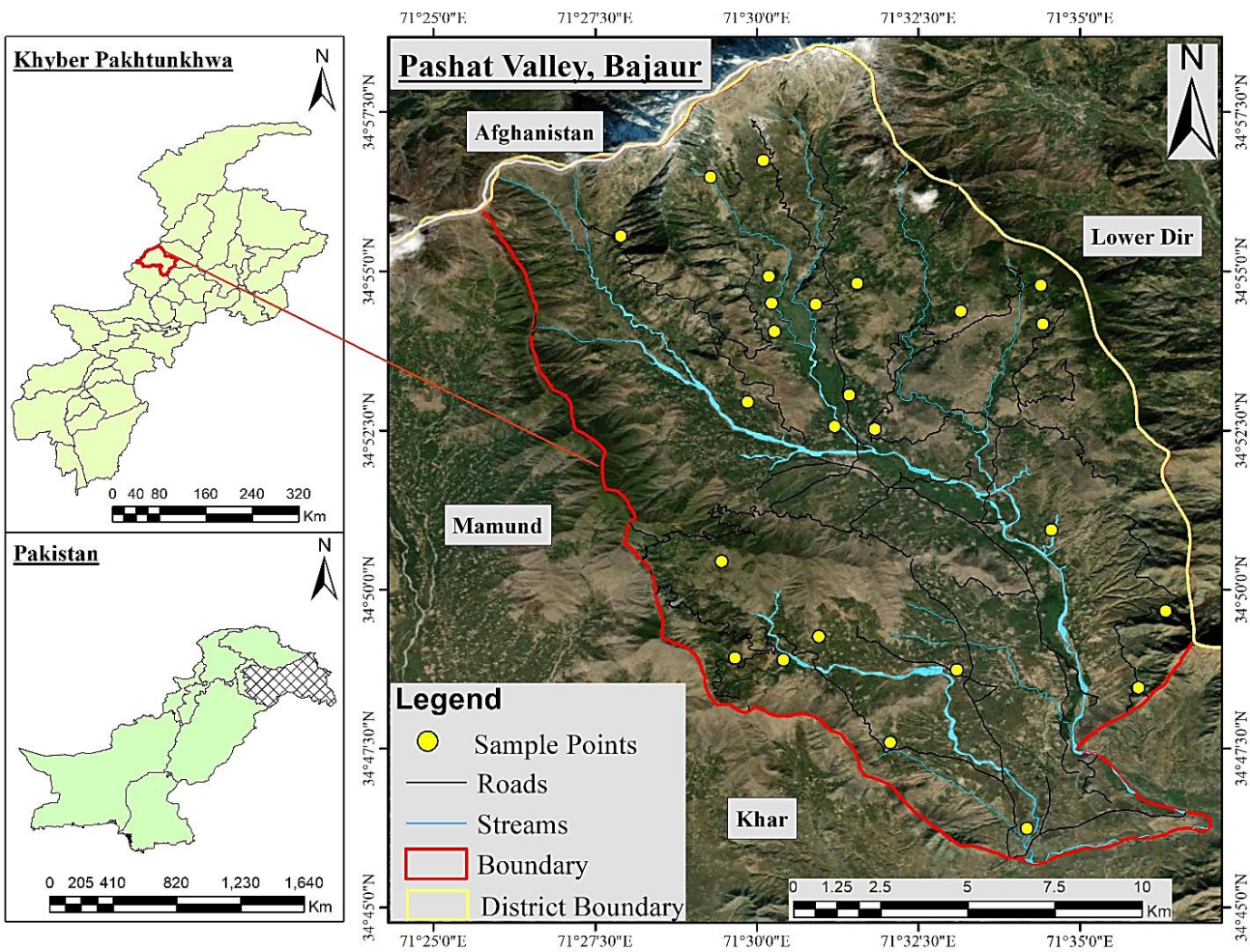


Fig. 1. Map of the area.

Table 1. Ecological characteristics and medicinal uses of the threatened plant species.

Species	Family	Habit	Life form	Leaf size	Phenology	Uses	UV	RFC
Alnus nitida Endl.	Betulaceae	T	Megp	Mes	Aug-Sep	The leaves and fruit extract are used as analgesics and for the treatment of inflammatory infections	0.08	0.05
Arisaema flavum (Forssk.) Schott	Arecaceae	H	Geo	Mes	May-Jul	The rhizome paste is used to treat scorpion stings and snake bites	0.08	0.1
Bergenia ciliata Sternb.	Saxifragaceae	H	Geo	Mes	Mar-Apr	A decoction of the leaves and roots is used to treat both asthma and urinary infections	0.08	0.4
Caralluma tuberculata N.E. Brown.	Asclepiadaceae	H	Th	Nan	Mar-Apr	To treat constipation, abdominal pain and diabetes, whole plants are cooked and eaten	0.13	0.09
Eremurus himalaicus Baker	Asphodelaceae	H	Geo	Nan	Mar-Apr	The decoction of the entire plant can be used to treat stomach ulcers, abdominal pain, and constipation	0.13	0.17
Myrtus communis L.	Myrtaceae	S	Np	Mic	Apr-May	The leaf extract is used to treat cholera, dysentery, dyspepsia, gastrointestinal disorders, and healing of a wound	0.21	0.21
Solanum surattense Burm.f.	Solanaceae	H	Th	Mic	Apr-Aug	Obesity and cholesterol reduction can be achieved by drinking a decoction of fruits	0.08	0.16
Teucrium stocksianum Boiss	Lamiaceae	H	Hem	Mic	May-Jun	The decoction of the entire plant is used to relieve labour pains, and jaundice, and as a blood purifier	0.13	0.13
Vitis jacquemontii Parker.	Vitaceae	L	Np	Mes	Apr-May	Extracts from fruits and leaves can be used to treat cholera and urinary infections	0.08	0.06

Key: A- Annual, P- Perennial, Hb- Herb, Sb- Shrub, L- Liana, Geo- Geopphyte, Hem- Hemicryptophyte, Micp- Microphanerophyte, Th-Therophyte, Np- Nanophanerophyte, Mic- Microphyll, Mes-Mesophyll, N- Nanophyll

Relative frequency of citation (RFC): The following formula was used to get the species' RFC value (Vitalini *et al*., 2013; Haq *et al*., 2022).

$$\text{Relative Frequency Citation (RFC)} = FC/N \quad (0<RFC<1)$$

where "FC" is the number of informants who claimed to have used a specific plant species and "N" is the total number of informants who participated part in the survey.

Phytogeographical distribution: The phytogeographical distribution of the plants was recorded with the flora of Pakistan (Ali & Qaiser, 1995-2018), and available literature (Ali & Qaiser, 1986; Takhtajan, 1986; Khan *et al*., 2020; Haq & Badshah, 2021b: Manan *et al*., 2023; Haq *et al*., 2023b).

Conservation status of selected plant species: Plant conservation was determined according to the standard procedure of the IUCN Red List Criteria (Anon., 2010; Bland *et al*., 2017).

Population structure, habit and habitat of species: Following the standard procedure, the field survey of selected plant species' habits, habitat, life form, population size, and structure were documented (Ali & Qaiser, 2010; Bland *et al*., 2017). Plants that produce fruit or flowers were regarded as mature in each community.

Threat factors identification and population trends: The populations of plant species in the area were at risk from deforestation, overgrazing, habitat damage, building and road construction, agricultural land extension, landslides, flooding and erosion. The information was gathered from the residents of the area about medicinal plant uses and their trade through interviews and documentation.

Estimation of area of occupancy and extent of occurrence of the species: The two "statistics" that form the basis of the IUCN's Red List of threatened species are the area of occupancy (AOO) and the extent of occurrence (EOO). The area of occupancy can be obtained by multiplying the area of each cell in a regular grid covering a taxon by the total number of occupied cells (Anon., 2010; Bland *et al*., 2017).

$$\text{Area of occupancy (AOO)} = N_{\text{occupied cells}} \times A_{\text{cell}}$$

where $N_{\text{occupied cells}}$ = Number of grad cells where the species is recorded and A_{cell} = Area of one grad cell

The extent of the occurrence of species was calculated with the standard method of α-Hull (Anon., 2005).

$$\text{Area of occupancy (EOO)} = A_{MCP}$$

where MCP is the area of Minimum Convex Polygon around occurrence points.

Data analysis: The documented data were analyzed following IUCN criteria, which specify five fundamental guidelines (A-E) for the classification of a taxa at a regional and classifying taxa at the regional level and worldwide.

When the data allow it, a taxon should be evaluated against a set of criteria, and the listing should contain as many criteria as are appropriate for each category.

Results and Discussion

Ecological characteristics of species: The ecological characteristics of the selected plants showed that six species were herbs, two shrubs, and one liana. The characteristic life forms of the species comprised Geophytes (03 species), therophytes, and nanophanerophytes (02 species each). The mesophyll (4 species), microphyll (3 species), and nanophyll (2 species) represented the leaf size spectrum, respectively (Table 1).

Ethnomedicinal uses: The present study revealed that these species were used by the locals to cure human and cattle health issues (Table 1). The common disorders such as abdominal discomfort, constipation, diarrhea, stomach ulcer, dyspepsia, cholera and dysentery were treated with four species (*Myrtus communis*, *Caralluma tuberculata*, *Eremurus himalaicus* and *Vitis jacquemontii*), asthma, a lung disease that affects millions of people with one species (*Bergenia ciliata*), jaundice and blood purifier with one species the *Teucrium stocksianum*, urinary infection with two species *Bergenia ciliata* and *Vitis jacquemontii*, and scorpion sting and snakebite with one species the *Arisaema flavum*. *Alnus nitida* fruits have been found to have the potential for treating inflammatory infections and are also used as an analgesic (Sajid *et al*., 2022). As a remedy, decoction and extract were mostly prepared from the plant parts (Haq *et al*., 2022). The parts that were used in the remedy preparation were leaves, roots, fruit, rhizomes and whole plants.

Two important quantitative metrics in ethnobotanical research are the Use Value (UV) and Relative Frequency of Citation (RFC). These metrics offer quantitative insights into the significance and prevalence of medicinal plants in diverse cultural contexts (Haq *et al*., 2023a). UV assesses the relative value of a plant species by accounting for the number of use reports or medical applications that community informants attribute to it (Zenderland *et al*., 2019).

The quantitative analysis of collected data reveals that *Myrtus communis* had the greatest used value of 0.21, followed by *Eremurus himalaicus* and *Teucrium stocksianum*, each with a used value of 0.13. UV values usually range between 0 and 1, though they occasionally go beyond 1 in research involving a large number of informants or near zero, which indicates that, the plant species has little to no medical usage (Amjad *et al*., 2020; Haq *et al*., 2022). Similarly, it was found that the RFC value of *Myrtus communis* was highest at 0.21, followed by *Eremurus himalaicus* at 0.17 and *Solanum surattense* at 0.16, while the *Bergenia ciliata* had the lowest RFC value, at 0.04 (Table 1). RFC values often range from 0 to 1, where 0 means that no informant has ever cited a specific plant species for that ailment and 1 means that all informants have cited it for that ailment.

High RFC values suggest strong agreement among informants on the medicinal usage of a given plant species for a certain ailment, while lower RFC values imply that the plant species is cited less frequently for the ailment in question (Umair *et al*., 2019; Amjad *et al*., 2020; Haq *et al*., 2022). Based on the results of this research, the indigenous population of the study area heavily depends on plant resources for medicinal purposes. Medicinal plants have been used to address various health issues, particularly in mountainous regions where they serve as a primary healthcare option. The utilization of medicinal plants for healing dates back to ancient times, as evidenced by previous studies (Grabherr, 2009; Jamshidi-Kia *et al*., 2018; Abdullah *et al*., 2021). These findings are further corroborated by the research conducted by other scholars who have also explored the healing properties of medicinal plants (Shaheen *et al*., 2017; Bahadur *et al*., 2018; Kassa *et al*., 2020; Haq *et al*., 2022).

Phytogeographical distribution: The phytogeographical distribution of the species reveals that *Alnus nitida*, *Eremurus himalaicus Arisaema flavum* and *Vitis jacquemontii* belong to Sino-Japanase and Western Himalayan elements. *Caralluma tuberculata* and *Teucrium stocksianum* belong to the Irano-Turanian region. Similarly, *Solanum surattense* belonged to the Paleotropical and Irano-Turanian regions. *Bergenia ciliata* belonged to Central Asian and Western Himalayan, while *Myrtus communis* belonged to the Irano-Turanian and Mediterranean regions (Fig. 2).

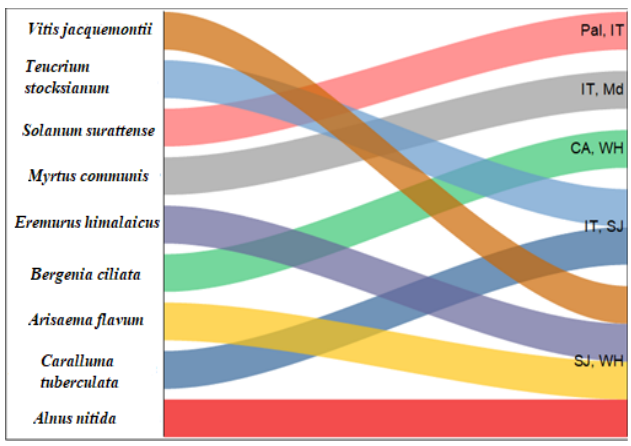
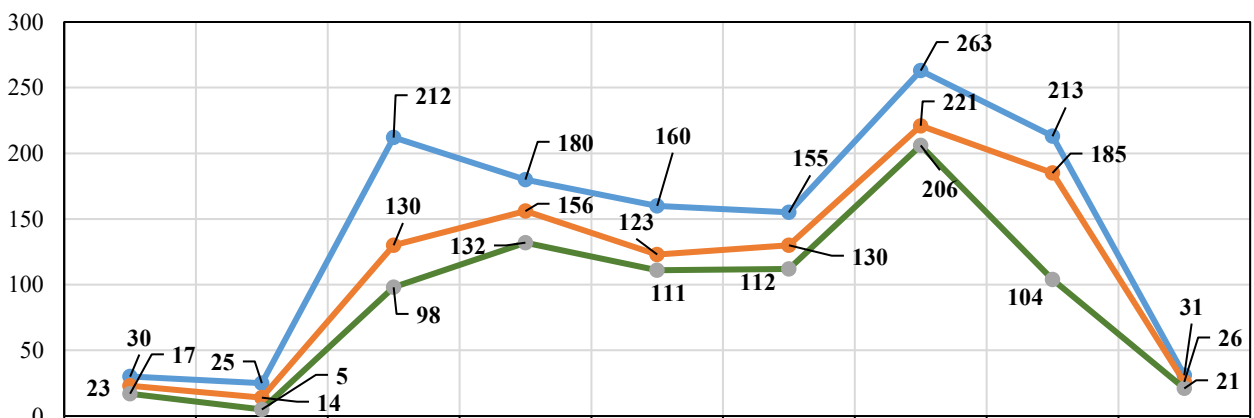


Fig. 2. Phytogeographical distribution of the threatened species.

The Irano-Turanian region is characterized by low annual and diurnal precipitation and extreme temperature changes (Haq & Badshah 2021a; Manan *et al*., 2022; Haq *et al*., 2023). Sino-Japanese and Irano-Turanian species diversity has grown well in the area because these flourishing plants are the indicators of dry and cold temperate climates (Khan *et al*., 2020; Haq *et al*., 2023). The flora of the western Himalayan region is situated between the ancient Mediterranean and Eastern Asian floras, displaying unique and dynamic vegetation (Takhtajan, 1986; Khan *et al*., 2020). Being a part of the Hindukush range, Bajaur contains a unique flora contributed from various phytogeographic elements with a substantial amount of medicinal plants (Haq and Badshah, 2021a). The distribution of phytogeographic elements helps in understanding the origin, evaluation, speciation, migration, and distribution range of plants. It also helps in assessing plant diversity, species richness, and conservation.

Threat assessment status: The conservation status of nine medicinal plant species was investigated in the Pashat valley near the Pak-Afghan Border, Bajaur, Pakistan. The IUCN criteria and category, 2010 classified the selected taxa as critically endangered and endangered The critically endangered species included *Eremurus himalaicus*, *Alnus nitida* and *Caralluma tuberculata*, while the endangered species comprised *Bergenia ciliata*, *Arisaema flavum*, *Myrtus communis*, *Vitis jacquemontii, Solanum surattense,* and *Teucrium stocksianum*. High elevations between 1309 and 2105 m were home to the species that were assessed as endangered and critically endangered. The sub-population, population size, altitudinal range, area of occupancy, extent of occurrence, and decline in the number of mature individuals were evaluated (Table 2). *Caralluma tuberculata* matures individuals have been discovered in three subpopulations among the critically endangered species (Bagendel, Mala Said and Batwar). Two subpopulations harboured *Eremurus himalaicus* i.e., the Saro Wano and Batwar. In the same way, three subpopulations of *Alnus nitida* were discovered in Gabar, Batwar, and Bagandel. Deforestation and habitat degradation were the instances of anthropogenic activities that had significant effects on the regional population of *Alnus nitida*. *Caralluma tuberculata* had 25 mature individuals in 2018, but that number declined to 14 in 2019 and 05 in 2020 (Fig. 3). The area of occupancy and the extent of occurrence were measured to be 03 km^2 and 25 km^2, respectively. The overexploitation of *C. tuberculata* for local uses resulted in a reduction of 10 mature individuals in 2019, and 06 in 2020. From two subpopulations, 394 mature *E. himalaicus* individuals were recorded: 130 in 2018, 93 in 2019, and 77 in 2020. There was a dramatic decrease in the sub-population in 2019 with the loss of 37 mature individuals (Fig. 3). *A. nitida* was found to have two subpopulations, each with 34 mature individuals. The AOO and EOO for *A. nitida* were found to be 4 km^2 and 34 km^2, respectively (Table 2). Decline mature individuals have been found in the population over the past three years, with a total of 13 mature individuals in all the subpopulations (Fig. 3).

The endangered species *Arisaema flavum* was found in three distinct locations of the valley i.e., Gaber, Tarano, and Bagendel. The mature individuals of *A. flavum* dwindled from 212 to 98 during 2018-2020. The Gaber site had the lowest subpopulation of *A. flavum*, with only 16 mature individuals in 2020 (Fig. 3). Across all subpopulations, a total of 114 individuals managed to survive for three years, signifying a notable decline in mature individuals. The area occupied by *A. flavum* was 54 km^2, with an extent of occurrence of 365 km^2 (Table 2). In the Pashat valley, four distinct subpopulations of *B. ciliata* were identified, with 180 mature individuals recorded in 2018, 156 in 2019, and 132 in 2020 (Fig. 3). The area of occupancy was calculated at 10 km^2, while the extent of occurrence was 450 km^2 (Table 2). The number of mature individuals, totaling 336, saw a significant decrease over the three-year period. *Myrtus communis* was observed in three subpopulations at Batwar, Bagendel, and Saro Wano, with an area of occupancy of 29 km^2 and an extent of occurrence of 330 km2. The population had 155 mature individuals in 2018, 130 in 2019, and 112 in 2020 (Fig. 3), resulting in a decrease of 43 mature individuals over the three years. *S. surrattense* had mature individuals documented in all four subpopulations, with 263 in 2018, 221 in 2019, and 206 in 2020 (Fig. 3). The extent of occurrence was 260 km^2, and the area of occupancy was 65 km^2, showing a decline of 57 mature individuals over the three years. *T. stocksianum*, like the other subpopulations, experienced a decline from 213 mature individuals in 2018 to 185 in 2019 and 105 in 2020 (Fig. 3). The area of occupancy was 12 km^2, and the extent of occurrence was 123 km^2. A general decline of 109 mature individuals was observed over the three years. In the Batwar and Saro Wano subpopulations, *V. jacquemontii* had 78 mature individuals, with an extent of occurrence of 129 km^2 and an area of occupancy of 13 km^2 (Table 2). Deforestation in the area over the past three years led to a reduction of 18 mature individual plants across all subpopulations (Fig. 3).



	Alnus nitida	*Caralluma tuberculata*	*Arisaema flavum*	*Bergenia ciliata*	*Eremurus himalaicus*	*Myrtus communis*	*Solanum surattense*	*Teucrium stocksianum*	*Vitis jacquemontii*
2018	*30*	*25*	*212*	*180*	*160*	*155*	*263*	*213*	*31*
2019	*23*	*14*	*130*	*156*	*123*	*130*	*221*	*185*	*26*
2020	*17*	*5*	*98*	*132*	*111*	*112*	*206*	*104*	*21*

Fig. 3. Decline in the mature individuals of critically endangered and endangered species.

Table 2. IUCN criteria for the threatened plant species.

Species name	SP	Localities	NMI	Population size in three years			AO (Km^2)	EO (Km^2)	Major threats to the species	IUCN category assigned	IUCN criteria meet
				2018	2019	2020					
Alnus nitida Endl.	3	Gabar Batwar Bagandel	85	34	30	21	4	34	Excessive use for local consumption, deforestation and habitat fragmentation	Critically endangered	A2, B 1 2 b (i, ii) c(iv)
Arisaema flavum (Forssk.) Schott	3	Bagandel Tarano Gabar	440	212	130	98	54	365	Habitat destruction and excessive use for local consumption	Endangered	B 2 a b(iv, v); C2 a (i)
Caralluma tuberculata N.E. Brown.	3	Bagandel	44	25	14	5	3	25	Invasive species, excessive use for local consumption and habitat fragmentation	Critically endangered	A 2 a; B1 2 b (i, ii, v); C1 2 a(i) D
Bergenia ciliata (Haw.) Sternb.	4	Bagandel Saro Wano Batwar Mala Said	468	180	156	132	10	450	Land sliding, overgrazing and excessive use for local consumption	Endangered	B 1 2 a b (i, ii, iv,v); C2 a(i); D
Eremurus himalaicus Baker	2	Saro Wano Batwar	290	120	93	77	6	56	Overgrazing, excessive use for local consumption and habitat destruction	Critically endangered	A 2 a c d; B1 B 2 b(i, ii) c (i, ii)
Myrtus communis L.	3	Bagandel Batwar Saro Wano	397	155	130	112	29	330	Land sliding, erosion, deforestation and excessive use for local consumption	Endangered	A 2 a d; B 1 2 a b(i, ii, iv);
Solanum surattense Burm.f.	4	Batwar Mala Said Gabar Saro Wano	690	263	221	206	65	260	Habitat fragmentation, excessive use for local consumption	Endangered	B 1 2 a b(i, ii, iv, v); C C 2 a(i) b
Teucrium stocksianum Boiss.	3	Saro Wano Batwar Bagandel	502	213	185	104	12	123	Habitat fragmentation, overgrazing, excessive use for local consumption and land sliding	Endangered	A 2 a c d; B 1 2 a b(ii, iv, v) C C 2 a(i)
Vitis jacquemontii Parker.	2	Batwar Saro Wano	78	31	26	21	13	129	Deforestation, excessive use for local consumption and destruction of habitat	Endangered	B 1 2 a b(iv, v)

Key: SP= Sub-population, NMI= No. of mature individuals, EO= Extent of occurrence, AO= Area of occupancy

Fig. 4. Threatened medicinal plants (a-i).

Operational threats: This research emphasizes the various risks that endanger the survival and growth of medicinal plants in their natural environments. Uncontrolled grazing, habitat degradation, deforestation, excessive local harvesting, landslides, flooding, erosion, and the introduction of exotic species all pose threats to the population of medicinal plants in the region (Table 2). There are numerous factors that influence the diversity of medicinal plants and put them at serious risk (Chen *et al*., 2016; Corlett, 2016). Due to their unsustainable use and inadequate habitat, these plants are classified as critically endangered, endangered, and vulnerable. The number of endangered species is increasing due to environmental pollution and overgrazing (Vesk & Westoby, 2000). Overgrazing not only compresses and mechanically damages the soil, but it also has a secondary effect on the growth of seedlings. These actions will lead to increased soil erosion and nutrient loss, causing plants in rangelands to become unpredictable (Sher *et al*., 2012; Haq & Badshah 2021b). Plants become threatened when they are completely or partially eradicated for local purposes (Ganie and Tali, 2013). Landslides caused by excessive rainfall make certain medicinal plants vulnerable and can lead to their destruction (Lapcha *et al*., 2011). Deforestation is another threat, leading to habitat loss, isolation from suitable habitats, and the fragmentation of ecosystems into small patches and core areas (MacDonald, 2003).

Some invasive species outcompete native species because they grow quickly and aggressively, produce large amounts of seeds, have no predators, and can flourish in all habitats. Sub-populations of these species are affected by threat syndromes caused by abiotic and biotic factors that restrict their population in their natural environments and elevate the risk of extinction. Biological characteristics that correlate with a species' risk of extinction include its habitat specialization, distribution range, population size, species diversity, growth rate, and reproductive system. Close to the findings of this study, numerous researchers documented the conservation of medicinal plants (Larsen & Olsen, 2007; Swarts & Dixon, 2009; Shinwari & Qaiser, 2011; Uprety *et al*., 2012, Bano *et al*., 2013; Ullah *et al*., 2014; Chen *et al*., 2016; Ali *et al*., 2018; Majid *et al*., 2019).

Conclusion

Nine threatened medicinal plant species' conservation status was documented in the region following IUCN regional guidelines 2010. The current findings revealed the species' threat status as well as the nature of the threats. A decline in the number of species in the area was triggered by deforestation, overexploitation for local use, the introduction of exotic species, soil erosion, landslides, flooding, and overgrazing. The area was found to have an exceptionally high degree of anthropogenic activities, which poses a major threat to biodiversity. Regretfully, no forest or vegetation conservation efforts have yet been carried out in the studied region. It is recommended that immediate conservation plans be implemented to ensure the long-term survival of the species in the region. Government agencies and other conservation groups in the region should implement in-situ and ex-situ conservation and restoration measures to protect vegetation. Strong action is required to minimize the overall impact of the current threats.

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