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Arun Pratap Mishra · Amit Kumar · Naveen Chandra · Gajendra Singh · Chaitanya Baliram Pande *Editors*

Threatened Medicinal Plants in the Indian Himalayan Region

Sustainability Challenges and Conservation Strategies

Springer

World Sustainability Series

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About the Book

The book 'Threatened Medicinal Plants in the Indian Himalayan Region—Sustainability Challenges and Conservation Strategies' provides an in-depth analysis of the major issues related to the conservation of threatened medicinal plants in the Indian Himalayan region. The book is a comprehensive resource that highlights the critical role of medicinal plants in traditional healthcare systems and identifies the significant threats that these plants face due to various anthropogenic and natural factors. The book covers ten major themes that are critical to understanding the conservation of threatened medicinal plants in the Indian Himalayan region. It provides an essential resource for researchers, conservationists, policymakers, and practitioners interested in the conservation of threatened medicinal plants in the region. The book provides an overview of the major issues related to medicinal plant conservation and suggests strategies for the sustainable management of these plants. The authors have provided a comprehensive and insightful analysis of the conservation status of medicinal plants in the region, highlighting the urgent need for concerted efforts to conserve these valuable resources.

'Threatened Medicinal Plants in the Indian Himalayan Region—Sustainability Challenges and Conservation Strategies' is more than just a collection of chapters; it is a journey through the rich tapestry of biodiversity, traditional knowledge, and the critical need for medicinal plant conservation witnessed in the Indian Himalayan Region covering Ladakh, Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh.

The book opens with an exploration of alpine hay meadows of Ladakh, highlighting their ecological relevance and the diverse medicinal plant diversity. Traditional land use practices, including artificial irrigation, support the growth of essential medicinal and fodder plants. This sets the stage for understanding the significance of these habitats and their contributions to local communities.

Moving forward, the book delves into the vulnerability assessment of prioritized Medicinal and Aromatic Plants (MAPs) in Paddar Valley. Through surveys and rapid mapping exercises, the study identifies key threats, categorizes the level of endangerment, and emphasizes the importance of conservation efforts to safeguard these valuable plant resources.

Shifting focus to Himachal Pradesh, the narrative unfolds the current trends in wild medicinal herb extraction. The impact of market dynamics on specific species, such as *Trillium govanianum* and *Fritillaria cirrhosa*, leading to overharvesting and endangerment, is discussed. External factors, like the MGNREGA scheme and expanding horticulture, are explored, emphasizing the need for sustainable practices.

The narrative then comprehensively reviews *Rheum* species in the Indian Himalayan Region, covering ecology, traditional uses, phytochemistry, trade, and the escalating threats faced by these high-value medicinal plants. The urgency for conservation is emphasized due to their endemicity, restricted distribution, and increasing threats.

The book proceeds with an assessment of the extent, abundance, threats, and information gap on alpine medicinal plants in the western Himalaya. Analysing past and ongoing studies, it reveals gaps in knowledge on species abundance, habitat suitability, demand and supply ratio, and climate change impact, emphasizing the necessity for more comprehensive research and management strategies.

In the Kumaun Himalaya, the documentation of 82 threatened plant species across various families serves as a comprehensive database. Aimed at aiding researchers, conservationists, and policymakers, this chapter contributes to understanding the diversity of threatened plants in the region.

The exploration then shifts to Niti Valley in the Nanda Devi Biosphere, where 72 MAPs are surveyed. The study reveals insights into medicinal plant richness, usage, and conservation status. The escalating demand for MAPs poses threats to biodiversity, emphasizing the need to protect these resources and preserve traditional knowledge.

Addressing the impact of climate change on Himalayan medicinal plants, the narrative discusses the role of plant tissue culture as a conservation strategy. The synergistic effects of plant growth-promoting microorganisms in aiding the survival and growth of micro-propagated plants in changing environmental conditions are explored.

Focusing on *Polygonatum cirrhifolium*, the narrative reviews its ecology, phytochemistry, and conservation status. The species, known for its medicinal properties, faces threats from overexploitation and habitat degradation. The chapter emphasizes collaborative conservation initiatives at regional and international levels.

The book continues with the exploration of the commercialization and conservation potential of *Swertia chirayita.* It reviews the ecological significance, traditional uses, and challenges in cultivation. The chapter advocates for sustainable practices, including genetic enhancement, to alleviate strain on natural populations.

Providing a comprehensive assessment of *Phlomoides superba*, the narrative covers taxonomic history, growth phenology, and demographic characteristics. The species faces anthropogenic threats, prompting the need for conservation efforts. The chapter also explores alternative propagation methods through tissue culture.

Utilizing species distribution modelling, the book evaluates the potential distribution of 25 MAPs in the alpine region of Kumaun Himalaya. It identifies dominant habitats and assesses habitat suitability, offering insights for reintroduction efforts and highlighting influential environmental factors.

Focusing on *Withania somnifera*, the book predicts its potential distribution in Uttarakhand using MaxEnt modeling. The study emphasizes the importance of considering multiple environmental variables for accurate predictions and provides insights for species restoration, conservation planning, and localization efforts.

The book concludes with a review of the uses of 169 plant species among rural communities in the Sikkim Himalaya, documenting traditional knowledge associated with alpine and sub-alpine vegetation. It highlights the utilitarian importance of these plants and their role in traditional healthcare practices.

The final chapter focuses on indigenous medicinal plant utilization across Arunachal Pradesh. It documents traditional knowledge from various tribes, emphasizing the reliance on plant-based remedies. The study underscores the need for conservation efforts to preserve both traditional knowledge and medicinal plant resources in the region.

As we journey through the chapters of this book, a clear story emerges one of urgency, resilience, and the delicate interplay between nature and people in the vulnerable landscapes of the Indian Himalayan Region. This collection goes beyond being a set of scientific findings; it is a heartfelt call to action. It earnestly pleads for the conservation of our botanical heritage, emphasizing that these plant legacies are crucial for ensuring sustainable futures.

Arun Pratap Mishra
Amit Kumar
Naveen Chandra
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Introduction

Arun Pratap Mishra, Amit Kumar, Naveen Chandra, Gajendra Singh and Chaitanya Baliram Pande

Challenges and Conservation Strategies for Threatened Medicinal Plants in the Indian Himalayan Region

The Indian Himalayan region (IHR), towering and stretching from Jammu and Kashmir in the North to Arunachal Pradesh in the east, is one of the most prominent and ecologically sensitive zones in the country. This mountain range separates the vast plains of Indian sub-continent from the frigid Tibetan Plateau. Over the years, changes in the landscape and climate are not only having an impact on the majestic mountain range hosting myriad of communities living downstream. IHR is significant for economic development and human welfare as a result of the abundance of public goods and services it offers, including food, energy, water, and medicinal plants. The region is a rich repository of biodiversity, harbouring numerous plant species with medicinal properties that have been traditionally used by local communities for centuries. It is home to around 7,000 plant species, of which approximately 2,000 are used for medicinal purposes. The traditional healthcare system of the IHR relies heavily on the use of medicinal plants, and the knowledge of their use is passed down through generations. However, in recent years, the region has experienced rapid urbanization, deforestation, and overexploitation of natural resources, leading to the depletion of many medicinal plant species. This book aims to understand the challenges facing the conservation of threatened medicinal plants in the Indian Himalayan region and explore potential conservation strategies to address these challenges.

Challenges Facing Conservation

One of the key challenges of threatened medicinal plant conservation in the Indian Himalayan region is the lack of information on the population status, available growing stock and market chain. While some plant species are well-known and

actively harvested, others are less known and threatened due to decline in their population in wild. As such, there is a need for detailed research to identify medicinal plant species that are risk of extinction due to overexploitation, habitat loss, and other factors. Another challenge is the lack of effective management policies and regulations to protect medicinal plant species in the region. While some protected areas exist, they are often not well-enforced, and there are few restrictions on the harvesting and trade of medicinal plants. As such, it is a high time to enforce proactive legislation in order to ensure the sustainable harvesting and conservation of threatened plant species. Furthermore, the socio-economic factors driving the overexploitation of medicinal plant species in the region need to be better understood. Many local communities rely on the harvesting and sale of medicinal plants for their livelihoods, and as such, they may be reluctant to adopt conservation measures that limit their access to these resources. Understanding the economic incentives and disincentives for sustainable harvesting practices can help researchers develop more effective conservation strategies that balance the needs of local communities with the conservation of threatened plant species.

Anthropogenic Pressure on Medicinal Plants

In the IHR, anthropogenic pressure on medicinal plants is a significant threat to its biodiversity and traditional healthcare system. In recent years, the region has been facing an increasing anthropogenic pressure due to a variety of factors, which has put the region's biodiversity and the traditional healthcare system at risk. The anthropogenic pressure on medicinal plants in the IHR can be broadly categorized into four main categories:

Overharvesting and unsustainable collection practices: Medicinal plants are being collected from the wild in large quantities, often using unsustainable methods that hamper the plant life cycle and surround ecosystem. The high demand for medicinal plants of IHR, both nationally and internationally, has led to overharvesting of certain species, such as *Angelica glauca*, *Dactylorhiza hatagirea*, *Picrorhiza kurroa* and *Swertia chirayita* to name a few. This has not only deteriorated the population of these species in the region but has also led to the loss of genetic diversity, which is crucial for the long-term survival of the species.

Habitat loss and degradation: The IHR is undergoing rapid land-use changes due to expanding human settlements, agriculture, and infrastructure development. The conversion of natural habitats to agricultural land and the construction of roads and hydroelectric projects have resulted in the fragmentation and loss of habitats, making it difficult for threatened medicinal plant species to survive and reproduce.

Climate change: The IHR is highly vulnerable to climate change, which is affecting the distribution and phenology of medicinal plant species. The rising temperatures and changes in precipitation patterns have altered the timing of flowering, fruiting, and seed dispersal of many species, leading to a decline in their population in the region.

Lack of awareness and conservation efforts: There is a general lack of awareness and recognition of the value of medicinal plants in the IHR. The traditional knowledge of medicinal plants is not adequately documented, and the efforts to conserve medicinal plant species are minimal. There is also a lack of regulation and monitoring of the collection, trade, and use of medicinal plants, which makes it difficult to control the unsustainable harvesting practices.

Therefore, in order to address the anthropogenic pressure on medicinal plants in the IHR, several conservation strategies need to be practiced. Firstly, a comprehensive inventory of medicinal plant species, their distribution, and their population and conservation status needs to be studied. Secondly, efforts must be made to conserve and restore the habitats of medicinal plant species through specific micro-plans on habitat restoration and reforestation programs. Thirdly, sustainable harvesting practices need to be developed, which includes promoting the cultivation of medicinal plant species and developing regulations to control their trade and use. Further, there is an urgent need to address the issue through conservation efforts, sustainable harvesting practices, and promoting awareness and recognition of the value of medicinal plants. Failure to address this issue could lead to the loss of valuable medicinal plant especially threatened species and the loss of traditional knowledge that has been passed down through generations.

Conservation Strategies

Many local communities rely on the harvesting and sale of medicinal plants for their livelihoods, and as such, these communities should be actively involved in efforts to promote sustainable harvesting practices. As the book emphasizes on the importance of involving local communities in the conservation process, the strategies should involve providing education and training on sustainable harvesting techniques, as well as developing alternative livelihood options that are not reliant on the harvesting of medicinal plants. Another potential conservation strategy is the development of community-based conservation programs. These programs should involve the establishment of community-managed protected areas, where local communities are responsible for managing and conserving medicinal plant species within the area. This approach has been successful in other regions and could help promote the sustainable harvesting and conservation of threatened plant species in the Indian Himalayan region. Further, it is submitted that the conservation of threatened medicinal plants in the Indian Himalayan region is a complex and multifaceted issue that requires a comprehensive and collaborative approach. While there are many challenges facing the conservation of the threatened medicinal plant species, there is an urgent need of proactive legislation to support conservation strategies that can be employed to address these challenges. Additionally, involving local communities in the conservation process, developing community-based conservation programs, and conducting comprehensive studies of the threatened medicinal plant species,

researchers can help to promote the sustainable harvesting and conservation of threatened plant species in the Indian Himalayan region.

Knowledge Gaps

While this book provides a useful overview of the challenges facing the conservation of threatened medicinal plants in the Indian Himalayan region, there are several areas that could benefit from further research. One important area is the need for more comprehensive studies including long term monitoring of the medicinal plant species found in IHR. Through conducting more comprehensive studies of the medicinal plant species found in the region, researchers will be able to identify the species that are at higher risk of extinction and hence, develop targeted conservation strategies to address such threats. Further, there is urgent need to better understand the socio-economic factors that drive the over-exploitation of medicinal plant species in the region. Many local communities rely on the harvesting and sale of medicinal plants for their livelihoods, and as such, they may be reluctant to adopt conservation measures that limit their access to these resources. Understanding the economic incentives and disincentives for sustainable harvesting practices can help researchers develop more effective conservation strategies that balance the needs of local communities with the conservation of threatened plant species. There is also a need for more research on the potential uses of threatened medicinal plant species in modern medicine. While traditional healthcare systems in the region have long relied on the use of medicinal plants, there may be potential for these species to be used in modern medicine as well. Thus, exploring the potential uses of threatened medicinal plant species in modern medicine, researchers can help to promote the conservation of these species by demonstrating their value beyond their traditional uses. IHR is particularly vulnerable to the impacts of climate change, and changes in temperature and precipitation patterns could have significant impacts on the distribution and abundance of medicinal plant species. Therefore, it is imperative to understand the impact of climate change on medicinal plant species in the region to develop strategies and promote their conservation and adaptation to changing environmental conditions.

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About the Editors

Mr. Arun Pratap Mishra is a passionate environmental researcher with a masters degree in Environmental Science from Hemwati Nandan Bahuguna Garhwal (Central) University in Uttarakhand, India. His dedication to advancing ecological research and sustainability is evident in his extensive body of work, which includes 40 research articles, 10 book chapters, 3 conference papers, and 1 technical report. He also serves as the editor of four notable books that focus on Himalayan plant ecology, natural resource management, climate change in the Himalayas, and the Earth's carbon footprint, utilizing cutting edge techniques and cloud based solutions. With professional experience spanning esteemed institutions like the Uttarakhand Space Application Centre, Botanical Survey of India, Wildlife Institute of India, and RBased Services Private Limited, Mr. Mishra has developed a deep expertise in geospatial technologies. He has further solidified his credentials with a postgraduate diploma in Remote Sensing and GIS from the Indian Institute of Remote Sensing (IIRS, ISRO). Currently, Mr. Mishra holds the position of GIS Analyst at Earthtree Enviro Pvt. Ltd., Shillong, Meghalaya, where he focuses on utilizing innovative computational methods and geospatial analysis to advance ecological conservation and sustainable development. His goal is to address pressing global challenges such as climate change and carbon management through data-driven, practical solutions. Mr. Mishra is always open to collaboration, believing that interdisciplinary efforts are key to driving meaningful change. His work

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Dr. Gajendra Singh is a Scientist in Forestry and Climate Change Division at Uttarakhand Space Application Centre (USAC), Department of IT, Good Governance and Science Technology, Government of Uttarakhand. He has been conducting research on Himalayan Plant Taxonomy, Forest Ecology, Spatial Phyto-resource Monitoring and Natural Resource Management. Till date, he has contributed in over 65 research papers/book chapters, 04 Books and 02 Manuals. His significant contribution is in discovering one (01) new species of flowering plant to the science, addition of five (05) species to the flora of Western Himalaya, three (03) species to Uttarakhand state and one (01) species to Himachal Pradesh. Rediscovery of one (01) species from Uttarakhand and three (03) local check list of floras.

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Plant Diversity in the Hay Meadows of Ladakh, Indian Trans-Himalaya: Focus on Ethno-medicinal and Fodder Species

Aimon Bushra, Amit Kumar, Gautam Talukdar, Hitendra Padalia, Jikmat Stanzin, Mohd. Raza, and Gopal Singh Rawat

Abstract Hay meadows are among the most species-rich habitats in the Indian Himalayan Region (IHR), as well as in other parts of the world. However, their ecological relevance, species diversity and conservation significance remain largely underexplored. During recent floristic explorations in western Ladakh, we surveyed a few semi-natural or artificially irrigated hay meadows in the Suru, Drass, Aryan and Wakha valleys of Kargil district. The traditional land use practices such as diverting the glacial melt streams into stone-built walls or canals, allow growth of numerous plant species that are valuable medicinal and fodder plants, along with graminoids. Medicinal plants such as *Aconitum heterophyllum, Dactylorhiza hatagirea, Delphinium cashmerianum, Gentianella moorcroftiana, Heracleum pinnatum* and *Podophyllm hexandrumim* and fodder plants such as *Astragalus thomsonii, Cicer microphyllum, Medicago falcata, Trifolium pratense, Oxytropis hypoglottoides, Poa alpina and Prangos pabularia,* are harvested from these hay meadows by the locals. These plants are a valuable commodity for the local people due to low-cost source of livestock-feed and their healing properties. The present study documents the plant diversity observed in the mountain hay meadows of western Ladakh along with their ethno-medicinal and nutritional values.

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Keywords Agroecology · Cold desert · Grassland biodiversity · Medicinal plants · Traditional practices

1 Introduction

Hay meadows are semi-natural grasslands or pastures that are left to grow over the spring and summer before being harvested for hay. The vegetation of hay meadows is dominated by forbs and grasses, but unlike other pastures, they are protected from grazing during growing season (Kumar et al. 2023; Mishra et al. 2023). The meadows are maintained on well-drained and relatively more fertile soils. They are different from the natural rangelands and treeless vegetation in terms of management approaches and management intensity (Mucina et al. 2016; Rodríguez-Rojo et al., 2017).

The hay meadows are traditionally managed across temperate regions of Europe (also referred to as neutral grasslands) and adjacent parts of Asia (Mucina et al. 2016). Once wide spread across Europe such meadows have restricted distribution in transhumance pastoral areas of Norway (Bele et al. 2024), Carpathian mountains (Wehn et al. 2018; Janišová et al. 2023), Romania (Ivaşcu et al. 2016), Switzerland (Schwab et al. 2002) and Sweden (Dahlström et al. 2013). These meadows are categorized as endangered habitats in Europe due to their tremendous reduction in quantity and quality (European Red List of Habitats—Grasslands Habitat Group 2016). Such reduction has been attributed to less scientific attention to traditional management practices, agriculture mechanization and intensification over the past 100 years (Janišová et al. 2023; Bele et al. 2024).

In Tibet, maintaining hay meadows as a land-use practice has evolved following certain land policies resulting in sedantarization of pastoral communities (Ning et al. 2002). Some herders sow pastures for hay and have individual or exclusive rights over the field (Miller 1990). In the Indian Himalayan Region (IHR), agro-pastoral communities have developed hay meadow system for optimizing resource use from limited land-holdings. These hay meadows are maintained by the local communities to meet their winter forage requirements. Such hay meadows are locally called *Ghasnis* or *Phats* (Himachal Pradesh), *Mangs* (Uttarakhand), and *Lu-ungs* (Ladakh).

In Trans-Himalayan region of Ladakh, hay meadows are more common in the west, where subsistence farming is prominent than in eastern Ladakh where pastoral production is major land use practice. In western areas such as Kargil, water spillage from irrigation canals and restricted livestock grazing provide ample moisture and manure thereby allowing growth and regeneration of hay meadows. Additionally, livestock grazing follows a rotational scheme allowing growth and maintenance of alpine pastures. Hay produce are collected in autumn and stored as supplementary livestock feed in winter as extreme snow fall restricts livestock movement in alpine pastures. Moreover, the hay meadows are rich in plant diversity besides providing multiple services like controlling soil erosion, providing medicinal, fodder and food resources.

Several studies have been conducted in Ladakh to understand diversity, ethno-botany and phytogeography of plants (Stewart 1916a, 1916b; Kachroo et al. 1977; Dhar and Kachroo 1983; Murti 2001; Rawat 2007; Hartmann 2009; Srivastava and Shukla 2015; Dvorský et al. 2018). However, no research has been conducted on hay meadows, which serve as an oasis for alpine plant diversity in the region. It is worth noting that most studies have concentrated on eastern Ladakh, which is devoid of such meadows. We evaluated the significance of hay meadows in terms of their diversity, ethno-botanical and fodder values in an underexplored region of western Ladakh.

2 Study Area

The study was carried out in Kargil district of Ladakh, which forms the western part of the region, bordering Jammu & Kashmir (Fig. 1). Spanning an area of over 60,000 sq. km, the Union Territory of Ladakh is one of the most distinct regions in terms of biogeography, culture and topography. Drainage to this part of the country is through Indus river and its main tributaries, the Shayok, Chang Chenmo, Hanle, Zangskar and Suru-Drass (Warikoo 2020). Ladakh is delimited by the Karakoram Range in the northeast and Great Himalayan range in the southwest.

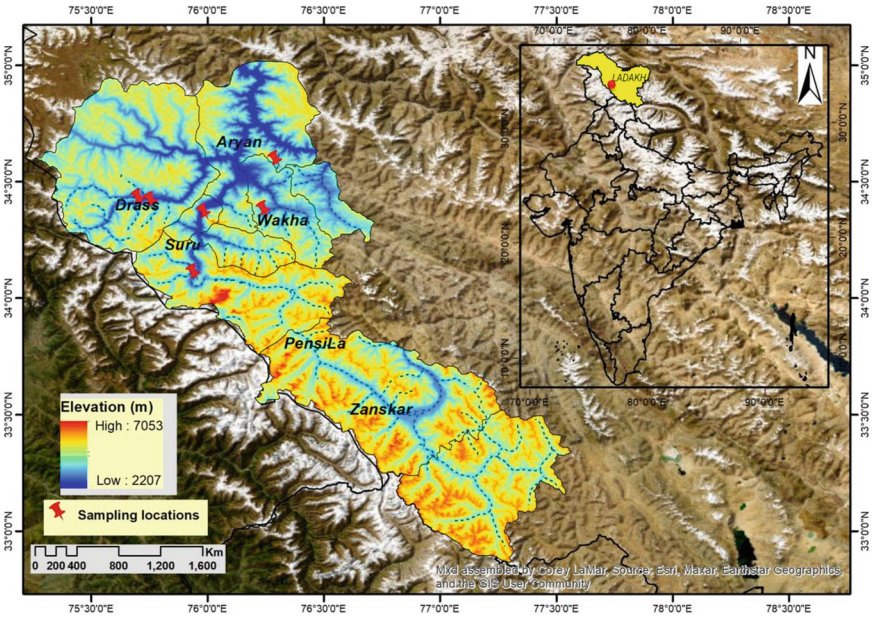

Fig. 1 Map showing the location of the study area and sampling sites; district Kargil is denoted with a red circle on the inset map

This region is characterized by sparse vegetation, generally devoid of trees and often dominated by alpine dry scrub (scrub steppe), alpine dry pastures (desert steppe) or mixed herbaceous formations and low primary productivity with a short growing season (Rawat and Adhikari 2005). Land use can be broadly divided in three production systems: nomadic, transhumance and agro-pastoralists. People in these landscapes are used to capitalize on suitable lands for food crop and livestock production. Livestock production is more intensive in areas above 4500 m (above mean sea level) elevation.

Likewise, agriculture is practiced in areas which have easy access to water and is more diverse at elevation below 3500 m. Moreover, eight ethnic groups are identified in the region, namely *Bot, Mon, Beda, Garra, Brokpa, Balti, Changpa* and *Purigpa.* Most of the ethnic groups are agro-pastoralists except the *Changpas* in eastern Ladakh who practice nomadic pastoralism. Livestock types include poultry, yak hybrids, cow, donkey, horse, mule, sheep and goats. Traditionally cultivated crop type includes barley, wheat, buckwheat, peas, lentils, foxtail millet, porso millet. Alfalfa, a traditional fodder crop is widely cultivated across the region.

3 Material and Methods

3.1 Field Sampling

The valleys were driven through, and hay fields near settlements were searched. The meadows were usually located on hills above the hamlet, and were also seen along the roads. In order to understand the plant diversity, a homogeneous one-hectare plot (100×100 m) was laid in each meadow. Within each plot, 5 sub-plots of size 2×2 m were laid on each corner and one at the center. The information on geo-coordinates, name of the species, habit of the species and their numbers were recorded in each 2×2 m plot, and the plant species were photographed for their identification. The plants were identified using relevant literature (Dhar and Kachroo 1983; Chowdhery and Wadhwa 1984; Polunin and Stainton 1984; Murti 2001; Dvorský et al. 2018; Shukla and Srivastava 2020) and online database such as Plants of World Online [https://powo.science.kew.org/] and subsequently verified with the help of experts.

3.2 Investigating Medicinal and Fodder Plants Species of the Hay Meadows

A wide number of alpine and sub-alpine plant species that grow in Ladakh, are utilized as food, fodder, fuel and for their medicinal benefits. A few important medicinal plants that have high value and significant use in the Ladakhi Amchi/Sowa-rigpa system of traditional medicines have been studied for their medicinal applications. Similarly,

commonly observed forage and fodder plants of hay meadows were investigated for their dietary and fiber subsistence needs.

4 Results

4.1 Plant Species Richness in the Hay Meadows

The current study investigated hay meadows in villages across four valleys, i.e. in Suru valley (Faruna and Panikhar), Drass valley (Lhamochan and Holiyal), Wakha valley (Fokar), and Aryan valley (Chulichan). The study revealed a total of 47 unique species under 21 families. The highest number of species (n = 19) were recorded in the hay meadow of Suru valley, at Panikhar which was located along the road, nearby agricultural fields. Another site, Faruna which was located above the village, on a mountain slope and irrigated by the waters of Ghangshalmo glacier had 11 species. The hay meadows of Drass valley were also species rich, with Holiyal and Lhamochan having 15 and 12 species respectively. The meadows of Aryan and Wakha valleys were relatively low in species number. Chulichan had seven species, whereas Fokar had five species only. The number of species and families recorded at each site is provided in Fig. 2. Figure 3 shows the typical hay fields of Kargil. Of the plant species recorded in these hay meadows, one is critically endangered *Dactylorhiza hatagirea* (D.Don) Soó, two are endangered *Aconitum heterophyllum* Wall ex Royle, and *Podophyllm hexandrum* Royle while three species, namely *Aconitum violaceum* Jacquem. ex Stapf, *Physochlaena praealta* (Decne.) Miers, and *Ferula jaeschkeana* Vatke are vulnerable as per the IUCN. The elevation range, vegetation structure and dominant species of each site are provided in Table 1.

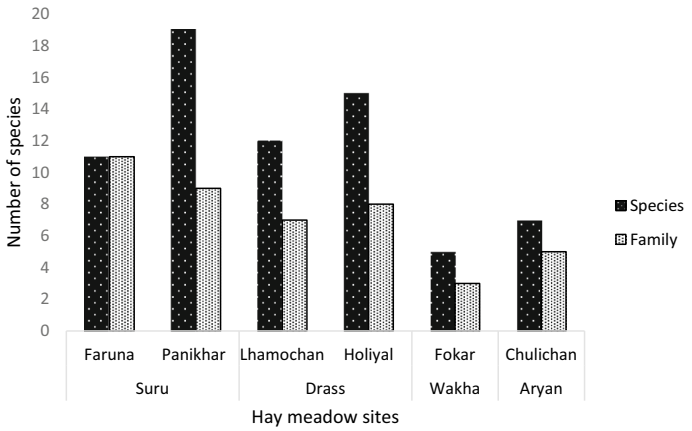

Fig. 2 Number of species and families recorded in different hay meadows of Kargil

Fig. 3 Hay fields at **a** Faruna and **b** Panikhar, villages of Kargil

Table 1 Topography, vegetation characteristics and commonly occurring species in the hay meadows

S. no.	Valley	Hay meadow site	Elevation (m)	Vegetation structure	Dominant species
1	Suru	Faruna	2990–3000	Shrubs, herbs and grasses	*Epilobium angustifolium, Medicago falcata, Oxytropis* spp., *Androsac* spp.
2		Panikhar	3215–3276	Herbs and grasses	*Aconitum heterophyllum, Delphinium cashmerianum, Heracleum pinnatum, Phragmites australis*
3	Drass	Lhamochan	3190–3243	Herbs and grasses	*Taraxacum officinale, Artemisia* spp., *Poa alpine, Medicago varia*
4		Holiyal	3059–3158	Herbs and grasses	*Prangos pabularia, Medicago falcata, Medicago sativa, Calamagrostis* spp.
5	Wakha	Fokar	3792–3815	Trees (planted), shrubs, herbs and grasses	*Medicago falacta, Rosa webbiana, Artemisia* spp.
6	Aryan	Chulichan	3665–3773	Herbs and grasses	*Cicer microphyllum, Medicago falacta*

4.2 Medicinal and Fodder Plants of the Hay Meadows and Their Usage in Ladakh

Though, the majority of the plant species harvested from the hay meadows are used for hay-making, some of the species are occasionally collected by the local inhabitants and utilized as medicines. Out of the 47 plant species recorded from the hay meadows, 19 species have been commonly reported to have some or the other medicinal applications (Table 2).

Several plant species that occur in the hay meadows, belonging to Fabaceae and Poaceae families offer good fodder because of their high protein and fiber content (Table 3).

5 Discussion

Hay meadows are considered biodiversity-rich areas holding both ecological and ethno-botanical importance. Additionally, hay meadows have received less attention in terms of their ecological importance in the region. Neither their difference from natural herbaceous meadows has been assessed. But in most of Europe studies it is revealed that such areas contain more than 60% of the native plants (Myklestad and Sætersdal 2004). In Kargil, the present study reports 47 species in different valleys with varying species counts. Besides, a trend between plant diversity, moisture, and elevation in the hay meadows of the region was also observed. Compared to other valleys, Suru and Drass receive more precipitation in the form of snow and rain, which increases the concentration of glaciers and water. Maximum species were recorded in Suru and Drass valley compared to other valleys of the region. This discrepancy can be attributed to higher precipitation and their location at mid-elevations, as indicated by Namgail et al. (2012) and Klimešová et al. (2011) in Ladakh, Singh et al. (2007) in Himachal Pradesh, and Sekar et al. (2023) in Uttarakhand. Such an increase in plant species richness at mid-elevation is also reported by Austrheim (2002) in Norway. Additionally, topographical differences (Rawat and Adhikari 2005; Marini et al. 2007) and the age or development history of hay meadows (Homburger and Hofer 2012) affect species composition and diversity. It is noteworthy that agriculture practice and acreage under agriculture are more profound in Drass and Suru valley, thus hay meadows are widespread in these areas. However, these observations need to be statistically tested and verified in future studies to understand the effect of such environmental variables on plant diversity in the hay meadows of the region. Furthermore, in Kargil, Behera et al. (2014) found higher herb diversity in agro-forest areas compared to alpine scrubs and pastures. Similarly, Ghimire et al. (2006) report that in contrast to alpine meadows, pastures with controlled grazing and more precipitation were richer in medicinal plants in Nepal. This illustrates the significance of customs and culture employed in the management of these hay meadows which harbour local biodiversity.

Table 2 Medicinal plants recorded from hay meadows and their use in Kargil, Ladakh

Scientific name	Local name	Family	Part used	Medicinal uses
Aconitum heterophyllum Wall ex Royle	Buma-karpo	Ranunculaceae	Roots	Used for treating jaundice, stomach ache, arthritis, and body inflammation pain
Aconitum violaceum Jacquem. ex Stapf	Buma-nakpo	Ranunculaceae	Roots	Used in treatment of asthma, cough, joint pain, stomach pain, as well as neural disorders, and cardiac diseases
Artemisia sieversiana Ehrh.	Kha-khaz/ Khamchu	Asteraceae	Aerial parts i.e. leaves, stem, flowers and fruits	Used for detumescence, hemostasis and reduce kidney inflammation/pain and urinary tract burning sensation
Bunium persicum (Boiss.) B.Fedtsch	Zeur	Apiaceae	Aerial parts	Treating abdominal pain, relieving flatulence, cold, headache, stomachache, joint pain, tuberculosis, fever etc.
Carum carvii L.	Ko-snyot	Apiaceae	Fruits and seeds	Treating gastrointestinal including dyspepsia, and various spasmodic conditions, bloating, diarrhea and also or improving eye vision
Cicer microphyllum Benth.	Sari	Fabaceae	Roots	Treating asthma and enlargement of liver
Dactylorhiza hatagirea (D.Don) Soó	Angu-lakhpa/ Wang bolakpa	Orchidaceae	Roots	Used by the locals for treating diarrhoea, dysentery, chronic fever and kidney problems

(continued)

Table 2 (continued)

Scientific name	Local name	Family	Part used	Medicinal uses
Datura stramonium L.	Datur/Dhadura	Solanaceae	Flowers, fruits and seeds	Used to alleviate stomach and intestinal pain caused by worm infestation, toothache, and fever caused by inflammation
Delphinium cashmerianum Royle	Charkyang	Ranunculaceae	Aerial parts	Used as cardiac and respiratory depressant; used in local medicine for destroying maggots in wounds of livestock (especially sheep); treating dysentery, diarrhoea with bleeding, inflammation, and wounds
Epilobium angustifolium L.	Punar	Onagraceae	Flowers	Treating stomachache
Ferula jaeschkeana Vatke	Prangos	Apiaceae	Roots	Used as antihistaminic, antiseptic; and to cure a variety of ailments such as chest pain, tumors, ulcers, and chronic wounds
Gentianella moorcroftiana (Wall. ex Griseb.) Airy Shaw	Chu-bitik	Gentianaceae	Aerial parts	Used to cure jaundice
Heracleum pinnatum C.B.Clarke	Spru/Spisho	Apiaceae	Stem, fruits	Used as digestive, and to cure abdominal cramps caused by intestinal worms
Mentha longifolia (L.) L.	Phololing	Lamiaceae	Leaves	It is used for the relief of congestion, edema, indigestion, asthma and body pain

(continued)

Table 2 (continued)

Scientific name	Local name	Family	Part used	Medicinal uses
Pedicularis punctata Decne.	Lugru-marpo	Orobanchaceae	Flowers	Used for their antioxidant, anti-inflammatory, antimicrobial, anticancer, and antispasmodic properties
Podophyllm hexandrum Royle	Denmo-kushu	Berberidaceae	Fruits and roots	Used for joint pain, skin allergies and blood purification
Rosa webbiana Wall. ex Royle	Sia-marpo	Rosaceae	Flowers and fruit	Used for treating skin diseases, gastrointestinal and respiratory disorders
Taraxacum officinale F.H.Wigg.	Hand/Khurma	Asteraceae	Whole plant	Used as anti-fungal, diuretic, liver tonic and in fever
Verbascum Thapsus L.	Monmoshing	Scrophulariaceae	Flowers and seeds	For treating fever and skin allergies

Of the 47 recorded species, more than 19 species are used in traditional medicines while 11 species have fodder value. Communication with herders in Drass and Suru valley revealed that species such as *Prangos pabularia*, *Cicer microphyllum*, *Astragalus* spp., *Epilobium angustifolium*, *Lindelofia stylosa*, and *Medicago falcata* are considered important fodder plants and are used as supplementary livestock feed in winter. Similar results were also found by Tiwari et al. (2016) in Ladakh and in northern areas of Pakistan by Khan (2003) where *Cicer microphyllum* and *Medicago sativa* is fed to livestock in colder winter months. This indicates that Traditional Ecological Knowledge (TEK) among local agro-pastoralists, as held among *Amchis* practitioners, is still intact in the region. Thus, this study emphasizes on preserving this knowledge system as otherwise loss of TEK and policies undermining traditional practices have led to decline in hay meadow in most of European region (Dahlström et al. 2013; Wehn et al. 2018).

Moreover, conservation of plant diversity along with their habitats in Ladakh is critical for multiple reasons such as climate change (Pant et al. 2018; Kattel 2022), longer growing seasons (Dolezal et al. 2016) and rapid glacier retreat (Schmidt and Nüsser 2017). Likewise, there has been a shift in the employment avenues among the local people of Ladakh, with younger generations opting for modern education and moving out jeopardizing traditional medicine system (Angmo et al. 2017).

Table 3 Important fodder plants occurring in the hay meadows

S. no.	Scientific name	Common name	Family	Indigenous uses
1	*Medicago falcata* L.	Alfa-alfa, Yellow clover	Fabaceae	Important fodder species, preferred by livestock, also stocked for winters
2	*Astragalus thomsonii* Podlech	Thomas milkvetch	Fabaceae	Fodder species
3	*Trifolium pratense* L.	Red clover	Fabaceae	Important fodder species, stocked for winter in dried form
4	*Oxytropis hypoglottoides* (Baker) Ali	Hypoglottis locoweed	Fabaceae	Palatable during flowering, used as forage
5	*Taraxacum officinale* F.H.Wigg.	Common dandelion	Fabaceae	Leaves and young shoots of plant are utilized in preparation of local food
6	*Lotus corniculatus* L.	Common bird's foot trefoil	Asteraceae	Important fodder species, stocked for winter in dried form
7	*Geranium himalayense* Klotzsch	Himalayan Crane's-bill	Geraniaceae	Fodder species; Flowers have aesthetic values
8	*Agrostis gigantea* Roth	Redtop	Poaceae	A good fodder and forage species, important for soil erosion control
9	*Poa alpina* L.	Alpine meadow grass	Poaceae	An excellent forage and fodder species
10	*Phragmites australis* (Cav.) Trin. ex Steud	Common reed	Poaceae	Invasive species, but a strong soil binder and fodder alternative
12	*Prangos pabularia*	Prangos	Apiaceae	Important fodder plant

6 Conclusion

Keeping in view the aforementioned challenges, it is evident that the hay meadows are critical plant habitats and their age-old management practices are of prime significance for their conservation in Ladakh. The grassland management plans should assess their current status across the region. Their conservation and management should be prioritized as these meadows not only provide surplus fodder for the livestock in wintertime but also act as reservoirs of some of the highly threatened plant species. Given the variety of species recorded from the studied hay meadows, it is highly possible that these areas attract good numbers of birds and insects and other faunal species. The significance of such agro-ecological strategies, which emerged as a result of the challenges faced by the people of mountains, should be well studied and preserved. However, a larger study would be required to draw any conclusions on the comparative status of plant diversity and environmental factors across different

valleys. Nonetheless, hay meadows are species-rich habitats that should be prioritized for conservation and management.

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