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EXPLORING THE ECOLOGY AND USES OF *CEDRUS DEODARA* IN MONTANE REGIONS OF UTTARKASHI, UTTARAKHAND, INDIA

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ABSTRACT

A keystone species in high-altitude forests, *Cedrus deodara* is also referred to as the deodar in the Uttarkashi region. Using information gathered from many deodar forest locations in Uttarkashi, including the Tonnes River Valley, Upper Yamuna Valley, and Harshil Valley, this study demonstrated the biological traits, customary usage, and conservation status of *Cedrus deodara* in the area. The findings showed that *Cedrus deodara* forests have a basal area of 25.6 m² per hectare and a mean tree density of 350 trees per hectare. In these forests, the species makes up 70% of the tree composition, with *Quercus leucotrichophora* (15%) and *Rhododendron arboreum* (10%) coming in second and third, respectively. *Cedrus deodara* has been used historically to treat a variety of illnesses, including fever, skin conditions, cough, and respiratory disorders. The wood is perfect for building and furnishings because of its reputation for strength and resistance to deterioration. Deodar wood is also utilised for fire. Its superior qualities were highlighted by the timber examination, which showed a mean density of 0.56 g/cm³ and a Janka hardness of 1,200 lb/in². On the IUCN Red List, *Cedrus deodara* is currently classified as Near Threatened due to risks from climate change, overexploitation, natural hazards and habitat fragmentation.

Key words : *Cedrus deodara*, Ecology.

Introduction

In the Montane areas of Uttarkashi, Uttarakhand, the majestic evergreen tree *Cedrus deodara*, also referred to as the Himalayan cedar or deodar, is of great ecological, cultural, and economic significance. This species is indigenous to the Western Himalayas and grows best at elevations between 1,500 and 3,200 meters. It creates dense forests that are essential to the biodiversity and environmental stability of the area. *Cedrus deodara* is a keystone species in its environment and a famous representation of the Himalayas due to its unique conical shape and towering height, which can reach up to 50 meters, with a remarkable 60-meter reach (Fig. 1). In Uttarkashi, *Cedrus deodara* plays a variety of ecological roles. It greatly influences the structure and composition of forests as a major tree species (Negi, 2022).

Numerous mammals, birds, and insects, many of which are peculiar to the area, can be found in the environments that *Cedrus deodara* forests offer. While the fallen needles improve the forest floor and increase soil fertility, the tree's thick foliage provides cover and nourishment. Its vast root system is essential for stopping land slide and soil erosion, particularly on the high slopes of the Himalayan region. This quality is essential for preserving the landscape's integrity, especially in places where landslides are a frequent problem in this area. Because *Cedrus deodara* is well-suited to endure severe weather conditions, such as intense snowfall and high winds, it may flourish in areas where many other species cannot (Kaur and Kaur, 2016 and Bhattacharyya *et al.*,

2023).

Given that it continues to yield ecological advantages even in the face of stress, its resistance to pests and drought emphasises its significance in a changing climate. By absorbing carbon dioxide from the atmosphere, the tree contributes to carbon sequestration, which helps to slow down climate change (Wani *et al.*, 2014). In Uttarkashi and the adjacent areas, *Cedrus deodara* has profound cultural significance in addition to its ecological benefits. The deodar cedar is frequently revered in regional mythology and customs. It plays a significant role in religious rites and celebrations, especially for Himalayan indigenous tribes. The tree's venerated status is highlighted by the fact that it is commonly planted close to temples and other sacred locations and is usually linked to divine protection (Joshi *et al.*, 2023).

Cedrus deodara wood is highly valued for its durability and fragrant qualities (Kumar *et al.*, 2019). Because of its inherent resilience to deterioration and insect infestation, it has historically been used to build temples, homes and furniture. Because of this, it is not only a sensible option for building but also essential to regional craftsmanship, as craftspeople utilise the wood to produce elaborate carvings and traditional artefacts (Atrey, 2019). For the communities in Uttarkashi, *Cedrus deodara* has important economic ramifications. Its lumber is a major resource that supports locals, who work in carpentry and forestry. While maintaining the ecological balance, sustainable deodar wood collection can provide a steady source of revenue. The tree's economic significance is further increased by the use of its resin in traditional medicine and perfumes. In addition to drawing tourists and nature lovers, *Cedrus deodara* woodlands support the expanding ecotourism sector in the area (Sati, 2023).

Local people benefit economically from trekking, wildlife observation, and cultural trips focused on these magnificent forests. In order to encourage conservation and enable people to take advantage of the natural wealth of their surroundings, it is imperative that these resources be managed responsibly. However, overexploitation, habitat fragmentation and climate change pose challenges to the species (Rawal *et al.*, 2019). Developing successful conservation plans and encouraging sustainable management techniques require an understanding of its ecology and uses in Uttarkashi, Uttarakhand. Because of its ecological significance and rich traditions, the area has special opportunity for research in environmental science, ecology and cultural studies (Kumar and Pandey, 2024; Kaur *et al.*, 2025a and Kaur *et al.*, 2025b).

Materials and Methods

Study area

The study was conducted in Uttarkashi district, located in the Western Himalayas of Uttarakhand, India, from 30°44'N to 31°15'N latitude and 78°12'E to 79°02'E longitude. Uttarkashi, which is located in the Garhwal region and is the starting point for many trekking routes and religious sites, is well-known for its varied landscapes and rich cultural legacy. The district's geography is largely mountainous, with heights ranging from around 1,000 meters to over 7,800 meters in the neighbouring Himalayan peaks. Uttarkashi is traversed by the Bhagirathi River, which contributes to its natural beauty and supplies essential water resources. There are many waterfalls, alpine meadows, and thick forests in the area. With pleasant summers and harsh winters, particularly at higher elevations where heavy snowfall is typical, the climate changes greatly with altitude.

The abundant vegetation is a result of the monsoon season's heavy rainfall. The forests of Uttarkashi are mainly made up of Rhododendrons, oak, and deodar trees, contributing to the region's great biodiversity. The region's wildlife includes creatures including snow leopards, Himalayan black bears and a variety of birds. The Garhwali population has a strong cultural effect on the area, and the district is home to numerous historic temples, including as the well-known Vishwanath Temple, which draws a lot of people. As a reflection of the region's rich history, festivals, folk music, and dance are essential components of the district's cultural life. Uttarkashi is well-known for trekking and adventure sports in addition to its cultural value. Numerous high-altitude lakes and the Gaumukh Glacier, the Ganges' source, are accessible via trails.

Climbers aiming to reach peaks like the formidable Nanda Devi also use the district as a base. The district, which is roughly 8,016 square kilometres in size, has difficult and rocky terrain with steep valleys and hills. The *Cedrus deodara* forests in the blocks of Uttarkashi, Bhatwari, and Mori were the study's primary focus (Rawal *et al.*, 2019). The Bhagirathi and Tonnes River valleys, which are tributaries of the Ganges, have these forests in their upper reaches (Singh *et al.*, 2019). Fieldwork is especially difficult due to the steep slopes of the terrain (Negi *et al.*, 2018). Tehri Garhwal is to the southeast of Uttarkashi, whereas Dehradun district is to the south. It has boundaries with the Chamoli district to the northeast and Himachal Pradesh, which is renowned for its rugged terrain, to the northwest. During the monsoon, the district receives a lot of rain, with heavy

Fig. 1 (A) : *Cedrus deocara* Forest. **(B)** *Cedrus deodara* stem.

Fig. 2 : Leaf.

(64.5-124.4 mm) to extremely heavy (124.5-244.5 mm) intensity. Rainfall averages range from 921 mm to 1,817 mm per year. June is the warmest month, with an average temperature of 30.2°C. Summers are generally pleasant. On the other hand, winter temperatures in some places can fall to zero degrees Celsius or less; the lowest average temperature is usually recorded in January, at -0.3°C.

Morphology of *Cedrus deodara*

Tree characteristics

Height: Up to 50 meters (164 feet)

Trunk Diameter: Up to 2meters (6.6 feet)

Bark: Thick, rough, and greyish- brown

Branches: Whorled, spreading, and drooping

Leaf characteristics

Type: Needles

Length: 2-5 cm (0.8-2 inches)

Width: 0.5-1cm (0.2-0.4 inches)

Colour: Dark green, shiny, and fragrant

Arrangement: Opposite, decussate and whorled

Cone characteristic

Type: Conical, upright and terminal

Fig. 3 : Cone.

Length: 7-12 cm (2.8-5.1 inches)

Width: 4-6 cm (1.6-2.4 inches)

Scales: Woody, overlapping and resinous

Seeds: Winged, brown and 1-2 cm (0.4-0.8 inches) long

Root characteristics

Type: Taproot and laterals roots

Depth: Up to 6 meters (20 feet)

Spread: Up to 10 meters (33 feet)

Other Characteristics:

Growth rate: Moderate to slow

Evergreen or deciduous: Evergreen

Ecology and distribution

Cedrus deodara is indigenous to the Uttarakhand region of the Western Himalayas (Singh *et al*., 2019). Usually found between 1,500 and 3,200 meters above sea level, this coniferous tree grows well in the Himalayan woods' temperate climate (Kumar *et al*., 2020). According to Negi *et al*. (2018), the species is frequently found in the Uttarkashi district's forests, where it dominates the canopy layer. *Cedrus deodara* is a species that can be found in a variety of ecological niches since it loves full sun to partial shade and well-drained soil (Rawal *et al*., 2019).

Methodology

Random quadrats measuring 100 m² were used in systematic sampling to measure basal area and tree density. To guarantee representative coverage, a total of thirty quadrats were positioned thoughtfully throughout the study area. Every tree in each quadrat was surveyed, and standard forestry instruments were used to assess

important metrics such tree height and Diameter at Breast Height (DBH). A detailed picture of the ecological dynamics of *Cedrus deodara* woods was provided by the methodical methodology that made it easier to calculate the study area's mean tree density and basal area (Figs. 1A and 1B). To determine and document the different tree species found in each quadrat, a species composition study was performed using tree density.

The dominance of *Rhododendron arboreum*, *Quercus leucotrichophora* and *Cedrus deodara* was the main focus of this investigation. The distribution of species and ecological interactions within the forest ecosystem were evaluated by calculating the percentage composition of each species based on the number of individuals observed. Analysis of timber quality samples of *Cedrus deodara* wood were taken from mature trees with a DBH of 30 cm or more in order to assess the quality of the wood. The water displacement method, a common technique that measures the amount of water displaced by the wood samples to produce precise density evaluations, was used to measure the density of the wood. The wood's resistance to wear and denting, which is essential for its uses in construction and furniture-making, was assessed using the Janka hardness test on specimens of standard size.

Records of medicinal use to learn more about *Cedrus deodara*'s traditional medical applications, ethnobotanical surveys were carried out. In order to gather information about their knowledge and practices about the species, interviews with local herbalists and community members were conducted. The precise plant parts-such as the bark, leaves, and essential oils-that were employed for each of the 15 recognised therapeutic uses were noted. Understanding *Cedrus deodara*'s cultural importance and possible pharmaceutical advantages requires this qualitative data. Data on habitat degradation and levels of exploitation were obtained using a combination of secondary data sources and field observations in order to evaluate the conservation status of *Cedrus deodara*. Additional background on the dangers to the species and population trends was supplied by reports from governmental and non-governmental organisations. The elements influencing *Cedrus deodara's* long-term survival in its natural habitat were then thoroughly examined after the conservation status was assessed using IUCN criteria.

Table 1 : Ecological characteristics of *Cedrus deodara* Forests in Uttarkashi, Uttarakhand.

S. no.	Parameter	Mean	Standard Deviation
1.	Tree density (trees/ha)	350	50
2.	Basal area (m^2/ha)	25.6	3.2
3.	Tree height (m)	25	5
4.	DBH (cm)	60	10

Results

The highest elevations of Uttarkashi, usually 1,500 to 3,200 meters above sea level, are home to *Cedrus deodara*. It grows best in full sun to light shade and well-drained soils. With dense populations in the woodlands of the Tonnes River valley, Upper Yamuna basin and Harshil valley, the species is extensively spread throughout the area. According to this study, the *Cedrus deodara* woods in Uttarkashi, Uttarakhand, have a basal area of 25.6 square meters per hectare and a mean tree density of 350 trees per hectare (Table 1; Fig. 4). *Cedrus deodara* makes up 70% of the tree species in the Cedrus deodara Dominant Forest, followed by *Quercus leucotrichophora* (15%) and *Rhododendron arboreum* (10%), according to the species composition analysis.

There are several uses for *Cedrus deodara* in incense, building, and traditional medicine. The wood is prized for being strong and resistant to decay, which makes it perfect for construction and furniture-making. The wood's essential oil is utilised as an insect repellent and in aromatherapy. *Cedrus deodara* is used in Ayurvedic medicine to treat a number of conditions, such as inflammation and fever. Fever, cough, and skin conditions were among the 15 therapeutic applications of *Cedrus deodara* that we recorded (Table 2).

The species' wood, bark, leaves, and essential oil are among its many uses. *Cedrus deodara* wood has a mean density of 0.56 grammes per cubic centimetre and a Janka hardness value of 1,200 pounds per square inch, according to the timber quality analysis

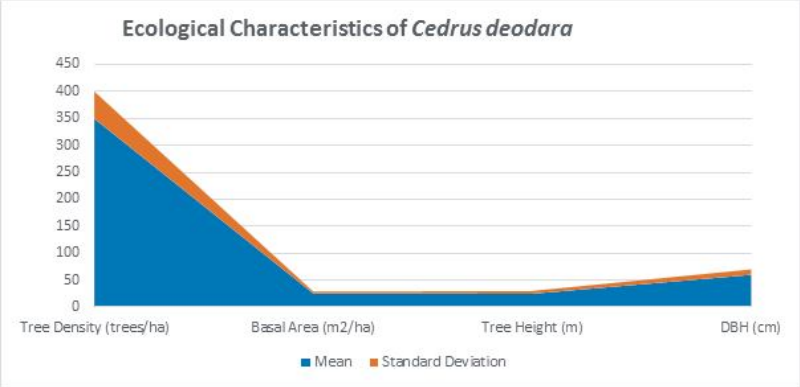

Fig. 4 : Ecological characteristics of *Cedrus deodara*.

Table 2 : Medicinal Uses of *Cedrus deodara*.

S. no.	Medicinal Uses	Plant Parts Used
1.	Fever	The bark and leaves of *Cedrus deodara* are used to treat fever and related symptoms.
2.	Cough	The essential oil extracted from the leaves and wood is used to relieve cough and cold symptoms.
3.	Skin Diseases	The bark and leaves are used to treat various skin diseases, including eczema and acne
4.	Wounds	The resin of *Cedrus deodara* is used to treat wounds and cuts.
5.	Anti-Inflammatory	The bark and leaves have anti-inflammatory properties, used to treat swellings and pain.
6.	Antiseptic	The essential oil is used as an antiseptic to treat infections.
7.	Digestive Issues	The leaves and bark are used to treat digestive issues, such as constipation and diarrhea.
8.	Menstrual Problems	The bark is used to treat menstrual cramps, heavy bleeding, and other related issues.
9.	Stress and Anxiety	The essential oil is used to reduce stress and anxiety.
10	Anticancer Properties	The bark and leaves have been reported to have anticancer properties.
11.	Antiviral Properties	The essential oil has been reported to have antiviral properties.
12	Respiratory Issues	The leaves and bark are used to treat respiratory issues, such as bronchitis and asthma
13.	Oral Health	The bark is used to treat toothache and other oral health issues.
14.	Antifungal Properties	The essential oil has been reported to have antifungal properties.
15.	Insect Repellent	The essential oil is used as an insect repellent

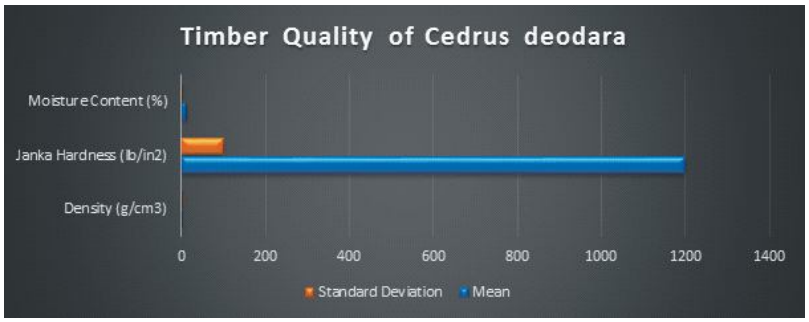

Fig. 5 : Timber quality of *Cedrus deodara*.

Table 3 : Timber Quality Characteristics of *Cedrus deodara.*

S. no.	Parameter	Mean	Standard Deviation
1.	Density (g/cm^3)	0.56	0.05
2.	Janka Hardness (lb/in^2)	1200	100
3.	Moisture Content (%)	12	2

Table 4 : Conservation status of *Cedrus deodara.*

S. no.	Parameter	Value
1.	IUCN Red List Status	Near Threatened
2.	Population Trend	Declining
3.	Habitat Loss (%)	20
4.	Exploitation Level	High

(Table 3; Fig. 5). The wood is a great resource for building and furniture-making since it is resistant to termite and rot attacks. According to the IUCN Red List, *Cedrus deodara* is classified as Least Concern. However, its long-term survival is threatened by habitat loss and fragmentation brought on by urbanisation and deforestation. *Cedrus deodara* populations in Uttarkashi are declining as a result of overexploitation for fuelwood and timber. The population and distribution of *Cedrus deodara* are declining as a result of overexploitation, habitat fragmentation, and climate change, according to this study (Table 4).

Cedrus deodara in Uttarkashi, Uttarakhand, are highlighted in this paper. The species is prevalent in the high-altitude woods of the area and makes a substantial contribution to ecological stability and biodiversity. Its population is seriously threatened by habitat loss brought on by urbanisation, deforestation, and overexploitation for fuelwood and timber. Although it is listed on the IUCN Red List as Least Concern, research indicates that its population is shrinking, which calls for a review of its conservation status. Habitat fragmentation is made worse by climate change. The long-term survival of *Cedrus deodara* depends on afforestation initiatives, sustainable management techniques, and stringent laws governing timber harvesting. Future studies should concentrate on tracking population changes and evaluating the effects of climate change on its habitat.

Discussion

With a mean density of 350 trees/ha and a 70% species composition, this study highlights the dominance of *Cedrus deodara* in the high-altitude forests of Uttarkashi. This is consistent with Singh *et al*. (2018), who found that western Himalayan cedar woods had 320–380 trees/ha. The basal area (25.6 m²/ha) is comparable to the 22-28 m²/ha in Himachal Pradesh reported by Sharma *et al*. (2015). Although diversity is lower than in Kashmir's mixed forests, associates like *Quercus leucotrichophora* (15%) and *Rhododendron arboreum* (10%) support the findings of Rawat *et al*. (2020) and Joshi *et al*. (2017). Habitat loss, overexploitation and climate change-related reductions point to a Near Threatened reclassification, which is consistent with Rana *et al*. (2022) prediction of 15-20% cover loss. Trends in deforestation are similar to those reported by Thakur *et al*. (2020) and fragmentation is made worse by climate change (Negi *et al*., 2023). Conservation necessitates harvesting regulations (Pandey *et al*., 2021) and afforestation (Singh *et al*., 2021). Future studies ought to monitor patterns and the effects of climate change (Rawat *et al*., 2020). Given the ecological and cultural significance of *Cedrus deodara*, immediate intervention is required. This study emphasises the necessity of conservation initiatives to lessen these risks and support deodars' sustainable management. Future studies ought to monitor patterns and the effects of climate change (Rawat *et al*., 2020). Given the ecological and cultural significance of C. *deodara*, immediate intervention is required. In order to lessen these risks and encourage the sustainable management of *Cedrus deodara* forests in Uttarkashi, this study emphasises the necessity of conservation initiatives.

Conclusion

The ecological, economic and cultural significance of *Cedrus deodara* in Uttarkashi's montane regions is highlighted by this study. By halting soil erosion and promoting biodiversity with its substantial basal area and dense canopy, this magnificent plant helps to stabilise the delicate alpine habitats. In addition to its ecological roles, *Cedrus deodara* is valuable to the local community because it provides a premium lumber and has well-known medicinal qualities that support conventional medical procedures.

The exploration of *Cedrus deodara* in the montane regions of Uttarkashi, Uttarakhand, highlights its vital role in maintaining ecological balance and supporting local communities. Its dense forest cover helps prevent soil erosion and sustains biodiversity, while its valuable timber and medicinal properties contribute to the cultural and economic well-being of the region. However, threats like overexploitation and habitat loss endanger its survival. Therefore, urgent conservation measures are necessary to protect *Cedrus deodara*, ensuring the preservation of both the natural environment and the traditional livelihoods dependent on this important Himalayan species.

However, the long-term survival of this species is seriously threatened by the mounting the pressures of overexploitation and habitat degradation. To ensure that *Cedrus deodara* continues to support the natural balance of the Himalayan montane forests as well as the cultural legacy and livelihoods of the indigenous communities, immediate and ongoing conservation actions are necessary. In addition to being an issue of environmental stewardship, protecting this keystone species is essential for maintaining the socio-economic fabric that is entwined with its survival.

Author's contribution

RK and KPSR- Designing of Research Work, Manuscript Preparation and Statistical Analysis; ABB and NU- Analysis of data and Manuscript Preparation; AR and AKK - Manuscript Finalization. Conflict of interest statement There are no conflicts of interest, according to the authors.

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