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Provisioning Ecosystem Services of *Rhododendron*-Rich Forests in the Western Himalayas †

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Abstract: Himalayan forests are an important component of the global biodiversity and play a crucial role in maintaining the ecosystem balance. The genera of *Rhododendron* belongs to the Ericaceae family and are found at an altitudinal range of 1500–3000 m in the Himalayan region. It acts as an important keystone species in the Himalayan ecosystem with high ecological and medicinal value. The present study focuses on highlighting the provisioning ecosystem services offered by the *Rhododendron* species, which provides a variety of services to the locals and its extraction for commercial utilization provides many livelihood opportunities for the Himalayan native communities. However, due to the high demand for *Rhododendron* products and services there has been a rampant harvest of the species in the Himalayan region posing a risk to the *Rhododendrons* which are an important keystone species for maintaining the Himalayan ecosystem. Hence our research lies in the assessment of the provisioning ecosystem services of the *Rhododendron* species and provides various conservation strategies for its sustainable utilization in the Western Himalayas.

Keywords: Himalayas; provisioning services; *Rhododendrons*; sustainable use

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1. Introduction

The Himalayan region covers approximately 18% of the geographical area of the country, but accounts for more than 50% of India's forest cover and harbors 40% of species endemic to the Indian subcontinent [1]. The rich plant diversity of the Indian Himalayas and its services are utilized by the native communities in various ways, as edible food, fodder, fuel, timber, and for different medicinal purposes. These plants are utilized in various forms such as fruits, shoots, leaves, flowers, and tubers to provide various forest-based resources to the local communities [2]. The Western Himalayas, Uttarakhand region of India, has a total area of 53,484 km^2 of which the total forest area is 38,000 km^2, and comprises around 71.05% of the total various forest-provided resources in the region [3]. *Rhododendron* species belonging to the Ericaceae family are found at an altitude of 1500–3000 m in the Himalayan region and provide a variety of ecosystem services to their communities. *Rhododendrons* are not only utilized for local use but are also utilized for their commercial and economic benefits, acting as an important source of livelihood generation for the locals [4,5]. However, with the increase in the demand of the species for its various provisioning services there exists a risk on the valuable *Rhododendron* forest resource. As *Rhododendrons* are an important keystone species in the Himalayan ecosystem, vital to maintaining the forest health and the vitality of other species, as they play a key role in maintaining the overall ecosystem balance [6]. Therefore, our research lies in the assessment of the provisioning ecosystem services of *Rhododendron*-rich forests in the Western Himalayas for their sustainable use.

2. Material and Methods

2.1. Description of the Study Location

The present study is undertaken in the Uttarakhand region of Indian, Western Himalayas, which is located between 30°17′ N–30°41′ N latitude and 79°40′ E–80°5′ E longitude as shown in Figure 1. The entire region is divided into three agroecological zones; the lower elevation (<1000 m asl); the middle elevation (between 1000 m and 1800 m asl); and the higher elevation (>1800 m asl). The fragile landscapes of the Himalayan region are highly susceptible to anthropogenic pressures posing a risk of natural hazards and the loss of biodiversity. In India's Western Himalayas, changes in altitude are intense and tend to produce a very specific pattern of vegetation types that include subtropical forests, alluvial grasslands, conifer mountain forests, and alpine meadows [7]. The Uttarakhand state of the Western Himalayas is of immense ecological importance due to its rich biodiversity and ecosystem services. *Rhododendron*-rich forests are widespread in the region and are utilized for providing various provisioning services to the communities. The Western Himalayas have six *Rhododendron* species viz., *Rhododendron arboreum, R. anthopogon, R. barbatum, R. campanulatum, R. lepidotum,* and *R. nivale,* which are present at different altitudinal ranges with the maximum *Rhododendron* species being present at the 1500–3000 m altitudinal belt and the minimum at less than 1000 m [8].

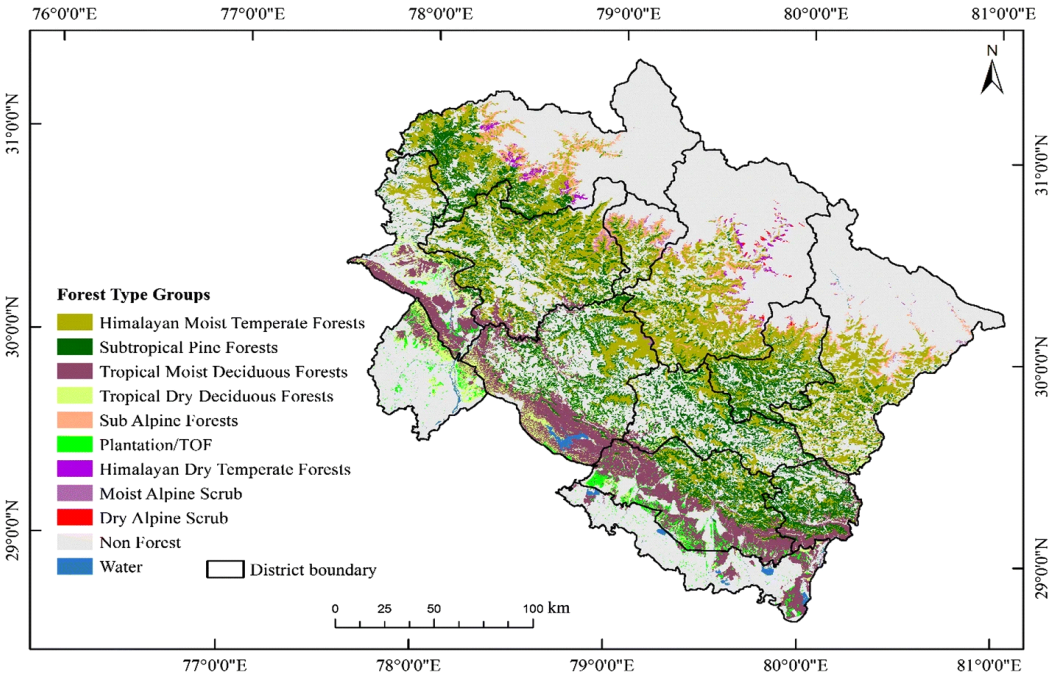

Figure 1. Map of study location with forest type groups [9].

2.2. Survey Methods

For the data collection on the provisioning ecosystem services of the *Rhododendron*-rich forests, an ethnobotanical survey was carried out in the study region to collect the baseline information on the utilization of the *Rhododendron* species. Structured questionnaires and interviews were carried out among the local communities following the methods by [10]. The questionnaire survey covered the utilization pattern of *Rhododendron* plant parts to provide the provisioning services for various local and medicinal use. Personnel interviews were also carried out from the collectors and local traders to collect information on the commercial market value of the selected *Rhododendron* species, such as *R. arboreum,* in the study area.

2.3. Ethnobotanical Index Used

The use–value (UV) index by [11,12] was used for analyzing the use value of *Rhododendron* species in Western Himalayas viz; *R. arboreum, R. anthopogon, R. barbatum, R. campanulatum, R. lepidotum,* and *R. nivale.* The index helps in listing the relative importance of the species with respect to the utilization by each of the species in the study location.

3. Results

Based on the observations from the data collection of the *Rhododendron* species, a variety of provisioning services to the communities ranging from medicinal services, beverages, food supplements, fuelwood, to various other local and cultural usages are provided. The flowers of *R. arboreum* are edible and are used for making of the local brew, *Rhododendron* squash, which is widely utilized by the local communities for generating livelihood. For medicinal services, *R. arboreum* and *R. campanulatum* are utilized medicinally for the treatment of diarrhea, blood dysentery, nasal bleeding, and for preventing high-altitude sickness and headaches. The wood of *R. anthopogon* and *R. campanulatum* are utilized for fuelwood and *R. lepidotum* is utilized in in the traditional medicine system. The parts of the *Rhododendron* species utilized for providing different provisioning services to the communities are listed in Table 1 and the category usage of *Rhododendrons* in the study area is shown in Figure 2.

Table 1. List of provisioning services by *Rhododendron* species in the study area.

Species	Part Used	List of Provisioning Services
R. arboreum	Flowers (dry)	• Treating diarrhea • Treating blood dysentery
R. arboreum	Flowers (fresh)	• Preparation of *Rhododendron* juice/squash • Appetizers , jams, and jellies • Prevent high-altitude sickness • Treating headaches (paste) • Treating asal bleeding • Local tea • Local use and religious purpose
R. campanulatum	Bark	• Medicinal use for treating jaundice, piles, liver disorder, and worms
R. campanulatum *R. anthopogon*	Stem/wood	• Fuel wood • Agricultural implements
R. barbatum *R. anthopogon*	Leaves	• Prevent headaches • Resting bed for animals
R. lepidotum	Corolla	• To get rid of the fish bones struck in the gullet used in homeopathic medicinal systems

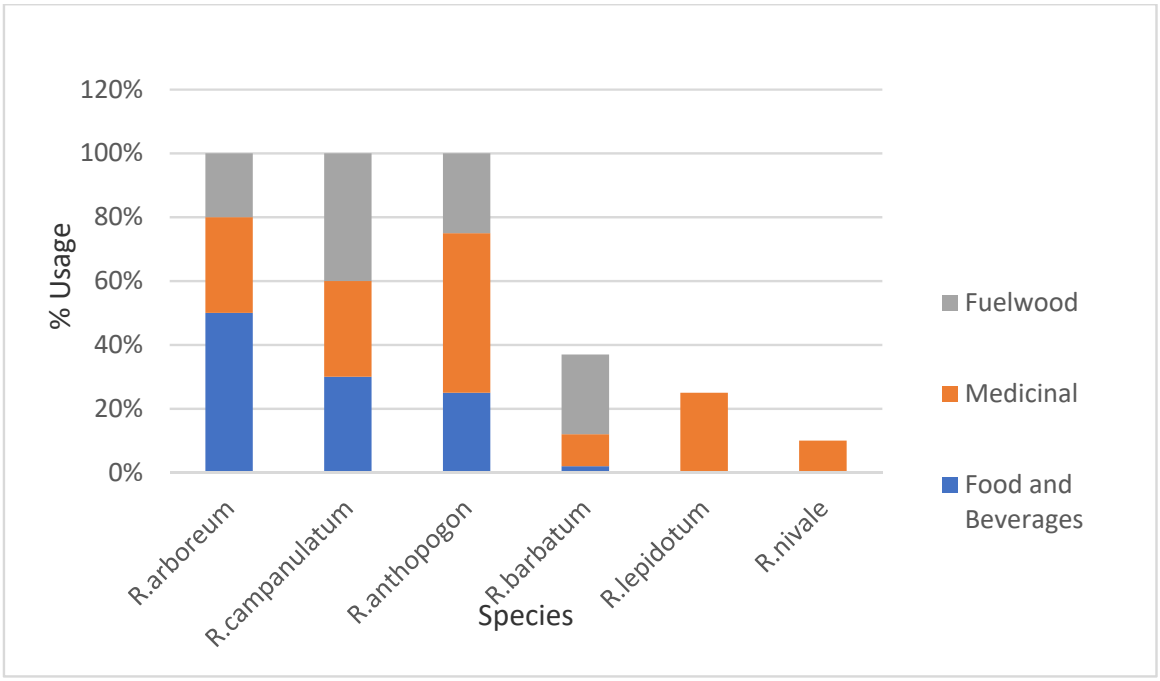

Figure 2. Use categories of *Rhododendron* species in the study area.

The use–value (UV) index was calculated for the *Rhododendron* species in the study area viz; *R. arboreum, R. anthopogon, R. barbatum, R. campanulatum, R. lepidotum,* and *R. nivale,* listed in Table 2. Based on the utilization of the provisioning services offered by each of the species, *R. arboreum* covers the highest UV index as it is widely used in all the categories of provisioning services such as for fuelwood, medicinal, and food industries at both local and commercial levels, where as *R. nivale* covers the lowest with its limited usage for medicinal purposes in the study location.

Table 2. Use–index values for *Rhododendron* species in study area.

Species	Use-Value Index
R. arboreum	0.81
R. campanulatum	0.54
R. anthopogon	0.45
R. barbatum	027
R. lepidotum	0.22
R. nivale	0.09

4. Discussion

The study highlights that *Rhododendron* species provide a variety of provisioning ecosystem services to the locals, which are utilized both domestically and commercially in the study location. These provisioning services are discussed below.

4.1. Fuel Wood

Native people of the Himalayan community collect the dry tree logs and branches from the forests for cooking food and for heating purposes, and the bark of *R .arboreum* and *R. campanulatum* which are found at high altitudes of the Himalayan region are widely utilized by the locals for these purposes. It has also been reported that *Rhododendron* fuelwood has the quality and efficiency to burn even under raw conditions due to the presence of poly-flavonoids and other resinous substances [13–15].

4.2. Food and Beverages

The flowers of *Rhododendron arboreum* are used in the making of *Rhododendron* juice/squash locally called as 'buransh' which possesses high medicinal properties. The ethyl acetate fraction of *R. arboreum* flowers is found to reduce magnesium sulfate-induced diarrhea, which could be due to increased absorption of water and electrolytes [16]. It also possesses high anti-inflammatory properties which are a result of the presence of flavonoids, tannins, saponins, and other phytochemicals present in the flower extract [17]. These flavonoids isolated from the *R. arboreum* were found to have high antioxidant properties [18]. The other food and beverages from these *Rhododendrons* are utilized in the preparation of jams, jellies, appetizers, and local brew. These products also offer a wide commercial market in the study area that aids to provide various economic benefits to the local communities.

4.3. Medicinal

The *Rhododendron* species contains several chemical constituents which are used for various medicinal purposes. Similar studies on the medicinal uses of *Rhododendrons* are also reported from other parts of the Himalayas, such as in [15,19–21]. From our study on the provisioning services of the *Rhododendron* forests in the Western Himalayas, it has been found that the fresh flowers of *R. arboreum* are used as a medicine for the treatment of hill diarrhea, dysentery, and for the curing of high-altitude sickness. The bark of *R. arboreum* is used by traditional practitioners in the study area to cure jaundice, piles, and liver disorders. Other important uses of the bark of *R. arboreum* and *R. campanulatum* are for the treatment of coughs and diabetes. The leaves of *R. campanulatum* are used in treating chronic rheumatism, syphilis, and sciatica, whereas the leaves of others species are used in the treatment of cold, coughs, and chronic bronchitis.

5. Conclusions

The *Rhododendrons* in the Western Himalayas provide a range of provisioning services to the communities and are utilized for their various medicinal and economic benefits. As *Rhododendrons* are an important species for the Himalayan ecosystem, it is vital to raise community awareness and engage the locals at the community level in maintaining the overall health of the *Rhododendron* forests. Some of the conservation methods and management strategies for the sustainable utilization of the *Rhododendron* species from the forests are suggested as follows:

- Effective engagement of the 'van samitis' or the community forest groups which play a key role in the management of the forests in the study area.
- Encouraging the plantations of locally grown, adaptable, and associative species such as the *Quercus* species which is found to increase the water holding capacity of soil, thus promoting the establishment of *Rhododendron* species [22].
- Plantation programs and training to raise the awareness of the native Himalayan communities.
- Engagement of the forest government officials for implementing strong policies and practices for the conservation of the *Rhododendron* species for its sustainable harvest.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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Conflicts of Interest: The authors declare no conflicts of interest.

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