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Community Perceptions of *Eucalyptus camaldulensis Dehnh* Plantations: Implications for Biodiversity, Ecosystem Services, and Native Tree Restoration in the Hindukush Region of Pakistan

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Abstract

Eucalyptus camaldulensis Dehnh plantations have expanded widely across northern Pakistan because of their rapid growth and economic value, yet their perceived ecological consequences and local ethnobotanical knowledge remain poorly understood. In this context, our research focuses on the ecosystem services associated with *Eucalyptus* plantations in Malakand Division (Hindukush region) of Pakistan, with specific importance given to provisioning service, livelihood outcomes, and ethnomedicinal resources as well as regulatory ecosystem services. The study highlights the socio-economic effects, biodiversity loss, and usage of natural traditional medicinal plants in *Eucalyptus*-dominated areas as gauged through household surveys (n = 212). Results suggest that respondents observe a decrease in the native flora, especially, medicinal plants, alongside a reduction in agricultural productivity, increase in water scarcity, and loss of soil fertility as a result of *Eucalyptus* plantations**.** Respondents identified several native tree species, particularly fruit-bearing taxa, as ecologically suitable alternatives for replacing the existing *Eucalyptus* plantation. Olive trees were particularly highlighted for their economically valuable oil-bearing fruits and relatively low water requirements. As ecologically sound in tropical and temperate regions, Olive trees were strongly recommended due to their high support for local biodiversity and their nutrient-dense fruits, representing an important food source for wildlife. The study showed an important gap in current forestry frameworks, especially where policy makers support exotic plantations over native species. Integrating traditional ecological knowledge into community-led forest management is essential for promoting biodiversity restoration and enhancing ecosystems.

Keywords: community perception; socioeconomic impacts; *Eucalyptus camaldulensis Dehnh*; ethnobotany; ecosystem services; conservation; forest management

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1. Introduction

Forests provide a wide range of ecosystem services that play an important role in sustaining human well-being, regulating biological processes, and supporting

biodiversity at local, regional and global scales [1]. These services are commonly categorized into provisioning, regulating, supporting, and culture services, broadly including fuelwood and timber production, carbon sequestration, nutrient recycling, soil conservation, hydrological climatic regulation, and the maintenance of biological diversity [2]. Forests, therefore, are vital in sustaining livelihoods, balancing ecological processes, and supporting socio-ecological resilience. In recent decades, reforestation and afforestation efforts have intensified across subtropical regions worldwide, with extensive establishment of fast-growing exotic *Eucalyptus* plantations [3]. This expansion has been driven primarily by increasing demand for timber and wood products, rapid economic development, and large-scale land restoration and rehabilitation programs [4].

Eucalyptus forest plantations are mostly carried out due to their high biomass productivity, broad ecological adaptability, and strong capacity to sequester atmospheric carbon, making them crucial components of afforestation and reforestation efforts globally [5]. However, along with these benefits, concerns have been raised regarding their ecological and social consequences, especially when plantations are established as monocultures and managed intensively [6].

In the Hindu Kush mountainous ranges of Malakand Division, widespread degradation and decline of the natural old-growth forests has prompted the promotion of afforestation measures, particularly the plantation of fast-growing non-native tree species [7]. Among the species, monoculture *Eucalyptus* plantation has been extensively promoted by the government as well as non-governmental organizations, private stockholders, and local farmers [8]. This expansion is mostly driven by the apparent economic benefits of *Eucalyptus* plantations for smallholder farmers. Due to rapid growth, a short harvest rotation cycle, and high market demand with regard to wood and construction timber, small stockholders increasingly rely on these plantations. Current approaches, such as the Joint Forest Development (JFD) system [9] have encouraged public land for afforestation, with smallholder agriculturalists having a crucial role in the expansion and development of *Eucalyptus* woodlots. In Malakand Division, small parcel holders account for a substantial proportion of *Eucalyptus* plantations, which are typically harvested within a brief period of 4–8 years. However, poor plantation management practices often result in low productivity and adverse ecological impacts. The excessive planting densities, improper harvesting practices, and limited silviculture knowledge often lead to major ecological issues such as reduced productivity and degradation of soil, impacting the understory vegetation [10]. Numerous studies have described the negative effects of exotic *Eucalyptus* plantations on soil fertility, water availability, and natural vegetation diversity [11]. In Malakand Division, exceptionally high planting densities among smallholders, mainly practicing linear-boundary and ultra-dense block planting of fast-growing species like *Eucalyptus* to maximize immediate farm income and fuelwood yield, often exceed standard forestry stocking guidelines.

Eucalyptus plantations, no doubt, provide important commercial benefits, such as providing fuelwood, timber for construction, poles and other wood-based products to local stockholders, to support their needs and income generation [12]. A similar pattern has been documented across many developing countries, where monoculture *Eucalyptus* plantation contributes significantly to local demands for fuelwood, timber and construction materials [13]. In Pakistan, *Eucalyptus* is often preferred over native species due to its higher economic value and productivity [14]. Despite these economic benefits, several socioeconomic and management-related challenges undermine the long-term sustainability of monoculture plantations. These include limited access to agricultural extension services, low market returns, insufficient stakeholder collaboration, inadequate planting spacing, suboptimal thinning and harvesting practices, and ineffective policy frameworks. Additionally, factors like landholding size, labour availability, farmers'

knowledge, and access to alternative income sources significantly affect the income generation from such plantations.

Pakistan has a rich diversity of medicinal flora, mostly concentrated in its northern Hindukush mountainous regions, including Malakand Division [15]. The local population in this region rely heavily on native medicinal plants for healthcare, income generation, and their cultural identity [16]. However, habitat loss, overharvesting, and the invasion of exotic species such as *Eucalyptus* pose increasing threats to native medicinal plant diversity [17]. The replacement of heterogeneous native vegetation with *Eucalyptus* monocultural plantations may decrease accessibility to these important medicinal species, ultimately impacting traditional healing practices and compromising indigenous ethnobotanical knowledge. Most of the published literature has focused on the physical and ecological impacts of *Eucalyptus* plantation, such as water table depletion [18], allelopathic effects [19], understory suppression [20], carbon sequestration [21], etc. Although the biophysical impacts of *Eucalyptus* plantations have been widely studied, the views and experiences of local communities, resource managers, and farmers remain poorly documented. In particular, little is known about how communities in northern Pakistan, whose livelihoods depend on these plantations, perceive and balance their economic benefits against the associated ecological costs.

To address this knowledge gap, the present study examines the ecosystem services associated with *Eucalyptus* plantations in Malakand Division, with particular emphasis on provisioning services, their contribution to local livelihood, and the availability of ethnomedicinal resources. Specifically, the study aims to answer the following questions: (i) what medicinal plant species do local respondents perceive to be associated with *Eucalyptus* plantations; (ii) what socioeconomic and management factors influence the commercial value of *Eucalyptus* woodlot products; and (iii) what are the primary opportunities and challenges associated with *Eucalyptus* plantation in the study area? By integrating traditional ecological knowledge (TEK) with ecological assessments, this multidisciplinary study aims to provide a more comprehensive understanding of how *Eucalyptus* expansion affects native biodiversity, soil- and water-related ecosystem services, and local communities' reliance on medicinal plants.

2. Materials and Methods

2.1. Study Area

The study was conducted in Malakand Division, located within the Hindu Kush Mountain range in the northwestern Khyber Pakhtunkhwa province, Pakistan (34.31 to 34.97 N° and 71.4797 to 72.6414 E°). The region occupies a strategically important position, extending from Besham, where it adjoins the Karakorum Highway, to the Afghan border with the Dir region (Figure 1), and northward to the Wakhan corridor, which shares a boundary with District Chitral [22]. The study area is mountainous and contains both broad-leaved and coniferous forests. In the middle and lower elevation regions of the study area, *Eucalyptus* plantations are extensively cultivated and represent a common component of the landscape [23]. Annual precipitation in the study area ranges from 800 mm to 1500 mm, exhibiting considerable spatial variability, primarily influenced by topographic gradients and latitudinal variation (Figure 2). The higher-elevation regions, including parts of Chitral, Upper Dir and Upper Swat, receive greater precipitation, with substantial snowfall during winter months. In contrast, lower-elevation areas, such as Buner and Dargai, experience comparatively lower annual rainfall due to reduced orographic influence and warmer climatic conditions [24]. Furthermore, altitudinal gradients strongly influence thermal regimes, resulting in elevated temperature at lower elevations and progressively cooler conditions towards higher elevations [25]. Such climatic and elevation-driven variations are key

determinants of vegetation composition, forest structure, and ecosystem functioning across mountain landscapes [26].

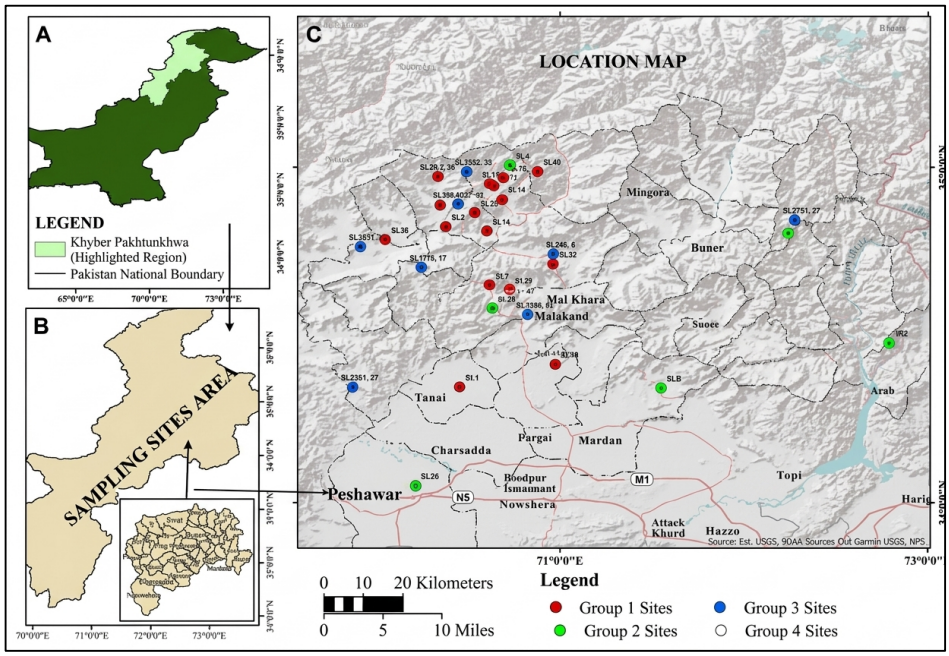


Figure 1. Study area map displays the distribution of *Eucalyptus* plantation (red colour = pure *Eucalyptus* plantation; green = low *Eucalyptus* plantation; blue = moderate *Eucalyptus* plantation) in Malakand Division.

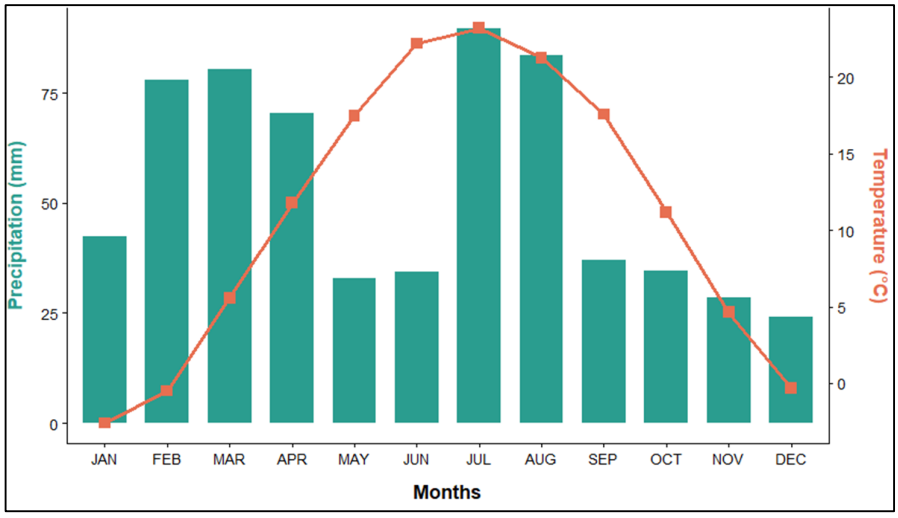


Figure 2. Climate bar chart of mean temperature (°C) and precipitation (mm) of the study area.

2.2. Data Collection

To document local ecological knowledge and ethnobotanical uses of plant species, field surveys were conducted between April 2023 and August 2024. Data were collected through semi-structured interviews, informal discussions, and direct field observations, using a random sampling approach to select participants. A total of 212 participants from the selected study sites were interviewed, with all responses recorded anonymously to protect their identities. Participants were selected through random sampling and represented a range of occupational backgrounds, including farmers, teachers, students,

other local stakeholders, and traditional herbalists. A structured questionnaire was used to gather data on their socioeconomic and demographic characteristics, including age, gender, education, household size, sources of income, land ownership, and reliance on forest resources. The survey followed the methodological approach described by [27]. More than one-hundred *Eucalyptus* woodlot producers were selected through the random sampling technique, using a household population list from three selected sites. The survey collected information on land allocated to *Eucalyptus* cultivation, total wood production, plantation management and harvesting practices, land ownership (public or private), economic returns, and logistical challenges faced by growers. Data collection followed the methodological approach described by [28]. Local perceptions of the impacts of *Eucalyptus* plantations on soil fertility, water availability, crop production, and biodiversity were assessed using perception-based indicators. Participants were asked to rate the effects on each of these factors as positive, neutral, or negative.

Medicinal uses of *Eucalyptus* were documented through ethnobotanical interviews, focusing on plant part use, i.e., leaves, bark, roots, etc., ailments treated, and the frequency of use [29]. In addition, information on socio-economic factors and forest management practices, including plantation management, harvesting methods, government or private ownership, economic benefits, and logistical constraints, were recorded to understand management challenges for the locals.

2.3. Statistical Analysis

To identify gender-based differences in perceptions and experiences, survey data were disaggregated by gender and analysed using descriptive statistics, including frequencies and percentages. Comparisons between male and female respondents were conducted using SPSS (Ver. 27.0), R (Ver. 4.3.2), and Microsoft Excel (Ver. 2021). Qualitative responses were analysed thematically to identify recurring patterns and key themes related to ecosystem services and their perceived benefits and impacts. Graphs were constructed using Microsoft Excel and GraphPad Prism (Ver. 8.02) to visualize categorical frequency distributions. Bar charts and a pie chart were constructed to show the percentage distributions of treated ailments, plant growth forms, and harvested plant parts. A Chi-Square ($\chi 2$) test was applied to categorical data, to identify gender-based differences and perceptions regarding *Eucalyptus* plantations and forest management logistics. For the medicinal plant data, ethnobotanical indices, specifically Use Value (UV), were used to quantitatively evaluate the relative importance of plant parts and respondents' agreement. The formula used was RFC = $\frac{FC}{N}$, where RFC is the relative frequency citation, FC is the frequency citation, and N is the total number of the interviewed respondents. The ethical considerations were maintained throughout the study, with particular emphasis on voluntary participation, informed consent, and the confidentiality of all respondents.

3. Results

3.1. Socio-Demographic Features of the Respondents

A total sample size of 212 respondents was obtained from across Malakand Division. The selected sample size was considered adequate to satisfy the assumptions and requirements of quantitative analysis and bivariate statistical techniques. Demographic information, including gender, age (ranging from 18–80 years), and educational background was collected from all the respondents (see Table 1). Based on age distribution, respondents were categorized into three age groups: 18–30 years (Group 1A), 30–50 years (Group 1B), and above 50 years (Group 1C), accounting for 16.32%, 22.18%, and 16.50% of the participants, respectively. Further demographic categorization

was performed based on education status, occupation, household size, and gender distribution. Among the respondents, 126 were males and 86 were females. Regarding educational status, 74.53% had received formal education, while 25.47% were illiterate; the latter category predominately comprised older respondents. A substantial proportion of the participants were students (40.56%) with a higher education level, both male and female, who were more informed about *Eucalyptus* plantation in the region. Among the respondents, 26.88% were teachers, comprising 18.88% males and 8% females. Furthermore, 7.07% of the respondents were businesspeople, representing a group with limited association with *Eucalyptus* plantations. In addition, a small proportion of the respondents (6.6038%) were local herbalists, reflecting their involvement in traditional ethnobotany knowledge and practices. Owned land on which *Eucalyptus Camaldulensis Dehnh* forests had been planted comprised 5–10 acres. However, most plantations in the area had been established by the government or by non-government organizations. Most participants reported a monthly household income of less than PKR 30,000. Both male and female respondents demonstrated a high level of awareness of *Eucalyptus camaldulensis Dehnh* plantations in Malakand Division, largely due to their widespread presence in the region and their use by local communities for various purposes.

Table 1. Socio-demographic characteristics of respondents from the study sites.

Demographic	Number	Percentage %
Gender		
Male	126	59.43
Female	86	40.57
Age group		
18–29	130	61.32
31–50	47	22.18
Above 50	35	16.50
Education		
Literate	158	74.53
Illiterate	54	25.47
Occupation		
Student	86	40.56
Teacher	57	26.88
Shop keeper	26	12.26
Public service	29	13.67
Local healer	14	6.63
Household size		
2–4	60	28.30
5–6	89	41.98
7 and above	63	29.71

3.2. Socio-Economic Characteristics of the Respondents

Table 2 presents the gender distribution of respondents who participated in the *Eucalyptus* plantation survey. Male respondents accounted for 59.43%, whereas females were 40.55%, indicating a statistically significant difference in gender representation (χ^2 = 7.647, p = 0.005). The higher proportion of male participants may reflect gender-related differences in involvement in plantation management and forestry-related activities, which are traditionally more male-dominated in the study area. Household size also varied among respondents, ranging from two to more than seven members, with an average of 5.3 individuals per household.

Table 2. Gender-wise distribution of the respondents and their household size.

Variable	Status		Total	χ^2	*p*-Value
	Yes	No			
Male	118 (55.66)	8 (3.77)	126	7.647	0.005
Female	70 (33.01)	16(7.54)	86		
Household size					
2–4	24 (11.32)	14 (6.60)	38	0.430	0.511
	12 (5.66)	10 (4.71)	22		
5–6	34 (16.03)	15 (7.07)	49	1.954	0.148
	22 (10.37)	18 (8.49)	40		
7 and above	23 (10.84)	16 (7.54)	39	0.0025	0.959
	14 (6.60)	10 (4.71)	24		

Note: The values found in the parenthesis are the frequency percentages of the respondents with Yes/No responses.

3.3. Interviews with the Respondents

Respondents were interviewed to evaluate their local perceptions and observations of the ecological impacts associated with *Eucalyptus camaldulensis* plantations in Malakand Division (Table 3). Among the reported crop impacts, wheat was identified as the most affected crop, cited by 30 respondents, followed by maize (21 respondents), whereas other crops and vegetables were mentioned less frequently. Prior to the establishment of *Eucalyptus* plantations, land-use patterns were more diverse, with approximately 45% of land allocated to agriculture, 23% to grazing, 15% covered by grasslands, and 5% classified as forested zones. Harvested *Eucalyptus* wood was primarily transported to local markets using dumpers (45%), followed by trucks (12%) and donkeys (5%). Respondents were further asked to identify alternative tree species that could replace *Eucalyptus camaldulensis* while supporting native biodiversity conservation and reducing the ecological impacts associated with its plantation. Among the 126 male respondents, fruit-bearing tree species were identified as the most suitable alternatives by 46 respondents (relative frequency of citation; RFC = 0.365), followed by Olive (*Olea ferruginea*) trees, which were specifically recommended by 40 respondents (RFC = 0.317; 31%). Other proposed species included *Melia azedarach* L., *Pinus roxburghii*, *Ailanthus altissima*, and *Morus alba*. Similarly, female respondents ranked fruit trees as the most suitable alternatives, with 0.279% of relative frequency citation, followed by *Olea ferruginea* (RFC = 0.244; 24%), *Melia azedarach* (RFC = 0.162; 16%), *Pinus roxburghii* (RFC = 0.139; 13%), and *Ailanthus altissima* (RFC = 0.116; 11%). The recorded plant species belong to several botanical families, as illustrated in Table 3. Lamiaceae and Asteraceae were the most represented families, each comprising six species, followed by Polygonaceae and Poaceae, with two species each. All remaining families were represented by a single species.

Table 3. Community perceptions and gender-based preferences for alternative tree species as substitutes for *Eucalyptus* plantations in Malakand Division.

Alternative Plants	Male	Total	RFC	Percent (%)
Fruit plants	46	126	0.365	36%
Olea ferruginea (Royle)	40	126	0.317	31%
Melia azedarach L.	15	126	0.119	11%
Pinus roxburghii Serg.	10	126	0.079	7%
Ailanthus altissima (Mill.)	10	126	0.079	7%
Morus alba L.	5	126	0.047	4%

Alternative Plants	Female	Total	RFC	Percent (%)
Fruit plants	24	86	0.279	27%
Olea ferruginea (Royle)	21	86	0.244	24%
Melia azedarach L.	14	86	0.162	16%
Pinus roxburghii Serg.	12	86	0.139	13%
Ailanthus altissima (Mill.)	10	86	0.116	11%
Morus alba L.	5	86	0.058	5%

3.4. Effects of Eucalyptus Plantations

Table 4 shows that the majority of male (110 out of 126) and female (75 out of 84) respondents recognised the negative ecological impacts of *Eucalyptus* plantations, particularly land degradation. Most of the respondents also suggested the negative impacts of *Eucalyptus* plantations, such as biodiversity loss, groundwater depletion, and high water consumption. Respondents also shared their views on the economic importance of these plantations, their contribution to local livelihoods, and the need for ecological rehabilitation to address their wider environmental impacts (Table 4). More specifically, among the surveyed respondents, 38 males and 35 females reported perceived impacts of *Eucalyptus* on their personal lands. A considerable proportion of participants (102 males and 65 females) expressed concerns regarding the groundwater table decline, whereas 96 males and 70 female respondents agreed that suggested vegetation depletion, beside these 111 men and 72 female respondents, agreed that *Eucalyptus* plantation was associated with water-related problems. However, 38 males and 21 females also acknowledged certain positive effects of *Eucalyptus* on these environmental factors. The main factors influencing respondents' perceptions included awareness regarding *Eucalyptus* plantations (p = 0.0057 **), livelihood implications (p = 0.0007 ***), economic impacts (p = 0.0236 *), rehabilitation measures (p = 0.0003 ***), and other impacts (p = 0.00006 ***), while perceived negative impacts showed a marginal trend toward significance (p = 0.037 *). Among all concerns, water-related issues emerged as a dominant theme, with both male and female respondents strongly recognizing *Eucalyptus* as a high water-demanding species and expressing concerns regarding its potential role in groundwater depletion and increasing water scarcity.

Additionally, the majority of the respondents identified the adverse ecological effects of *Eucalyptus*, reflecting a broad awareness of the environmental costs associated with its plantation. In contrast, only a small proportion of male and female respondents acknowledged the positive impacts of *Eucalyptus* plantations (38 males and 21 females), suggesting that perceived economic benefits, particularly timber and fuelwood production, are largely outweighed by concerns regarding their ecological impacts. Interestingly, gender-based comparisons revealed no substantial differences in perception, as both male and female respondents exhibited similar response patterns. This consistency indicates that awareness of the potential negative consequences of *Eucalyptus* plantations is widespread and equally recognized across the community.

Table 4. Multidimensional impacts of *Eucalyptus* plantations on ecosystem functions, vegetation structure, water resources, livelihoods, and environmental sustainability.

Variables	**Gender**	**Yes**	**No**	**Total**	***p*-Value**
Information	Male	118 (111.74)	8 (14.26)	126	0.0057 **
	Female	70 (76.26)	16 (9.74)	86	
Personal land	Male	38 (43.39)	88 (82.61)	126	0.1127 ^{ns}
	Female	35 (29.61)	51 (56.39)	86	
Negative effects	Male	105 (110.39)	21 (15.61)	126	0.037 *
	Female	80 (80.61)	6 (11.39)	86	

Effects on land	Male	110 (109.95)	16 (16.05)	126	0.984 ^{ns}
	Female	75 (75.05)	11 (10.95)	86	
Vegetation depletion	Male	96 (98.66)	30 (27.34)	126	0.3666 ^{ns}
	Female	70 (67.34)	16 (18.66)	86	
Water decrease	Male	102 (99.25)	24 (26.75)	126	0.3477 ^{ns}
	Female	65 (67.75)	21 (18.25)	86	
Livelihood	Male	75 (86.18)	51 (39.82)	126	0.0007 ***
	Female	70 (58.82)	16 (27.18)	86	
Economic impact	Male	70 (77.86)	56 (48.14)	126	0.0236 *
	Female	61 (53.14)	25 (32.86)	86	
Adverse impacts	Male	105 (108.76)	21 (17.24)	126	0.1254 ^{ns}
	Female	78 (74.24)	8 (11.76)	86	
Role for domestic needs	Male	105(102.23)	21 (23.77)	126	0.3214 ^{ns}
	Female	67 (69.77)	19 (16.23)	86	
Other impacts	Male	89 (100.44)	37 (25.56)	126	0.00006 ***
	Female	80 (68.56)	6 (17.44)	86	
Water pollution	Male	111 (108.76)	15 (17.24)	126	0.3627 ^{ns}
	Female	72 (74.24)	14 (11.76)	86	
Rehabilitation	Male	84 (94.5)	42 (31.5)	126	0.0003 ***
	Female	75 (64.5)	11 (21.5)	86	
Effect on economy	Male	105 (104.01)	21 (21.99)	126	0.7150 ^{ns}
	Female	70 (70.99)	16 (15.01)	86	
Minimal effects	Male	109 (109.95)	17 (16.05)	126	0.6893 ^{ns}
	Female	76 (75.05)	10 (10.95)	86	
Govt. role	Male	84 (77.86)	42 (48.14)	126	0.0770 ^{ns}
	Female	47 (53.14)	39 (32.86)	86	
Positive effects	Male	38 (35.07)	88 (90.93)	126	0.3598 ^{ns}
	Female	21 (23.93)	65 (62.07)	86	

Note: ", **, and *** indicate statistical significance at $p < 0.05$, $p < 0.01$, and $p < 0.001$, respectively; ns indicates non-significant ($p > 0.05$)."*

3.5. Medicinal Uses of Plant Parts

Local respondents reported diverse traditional medicinal applications of *E. camaldulensis*, highlighting its significant role in indigenous healthcare practices (Table 5). The reported therapeutic uses were quantified based on their percentage occurrence among male and female respondents. Among male respondents, *E. camaldulensis* was most frequently used as an antibacterial agent (61.905%), followed by remedies for malaria (42.875%), nose bleeding (38.889%), and bronchitis (36.508%). In contrast, female respondents primarily reported use as a laxative (90.698%), followed by pain relief (65.1165%), as an antibacterial agent (62.23%), and as a cooling agent and a remedy for nose bleeding (62.791%). Across all respondents, the species was commonly used for the treatment of malaria (53.484%), bronchitis (52.36%), and as a tonic to reduce fever (35.71%). Other ethnomedicinal applications included the treatment of sneezing (34.12%), pain relief (30.95%), stomach disorders (29.35%), fungal infections (27.77%), and even cancer-related ailments (26.98%). Additional reported uses included remedies for respiratory disorders (20.63%) and applications as a cooling agent, laxative, and source of alkaloid contents (19.04%) among the male respondents. Furthermore, local respondents and traditional healers (Hakims) reported its use against vomiting (16%). These findings demonstrate the broad ethnomedicinal significance of *E. camaldulensis* and its continued relevance in traditional healthcare systems.

Table 5. Medicinal uses reported by the interviewed respondents for the treatment of various ailments in the study region.

S. No	Medicinal Uses	M (FC)	(N)	RFC	Percentage (%)	F (FC)	(N)	RFC	Percentage (%)
1	Coughing	23	126	0.183	18.254	35	86	0.407	40.698
2	Fever	45	126	0.357	35.714	34	86	0.395	39.535
3	Bronchitis	46	126	0.365	36.508	45	86	0.523	52.326
4	Malaria	54	126	0.429	42.857	46	86	0.535	53.488
5	Cancer	34	126	0.270	26.984	18	86	0.209	20.930
6	Stomach	37	126	0.294	29.365	14	86	0.163	16.279
7	Headache	23	126	0.183	18.254	11	86	0.128	12.791
8	Alkyl sub	24	126	0.190	19.048	28	86	0.326	32.558
9	Respiratory	26	126	0.206	20.635	32	86	0.372	37.209
10	Sneezing	43	126	0.341	34.127	43	86	0.500	50.000
11	Antifungal	35	126	0.278	27.778	46	86	0.535	53.488
12	Antibacterial	78	126	0.619	61.905	43	86	0.500	50.000
13	Vomiting	16	126	0.127	12.698	45	86	0.523	52.326
14	Cool agents	24	126	0.190	19.048	54	86	0.628	62.791
15	Laxative	24	126	0.190	19.048	78	86	0.907	90.698
16	Pain	39	126	0.310	30.952	56	86	0.651	65.116
17	Bleeding nose	49	126	0.389	38.889	54	86	0.628	62.791

Note: M (male), F (female), FC (frequency citation), RFC (relative frequency citation), N (number of respondents), and UV (use value).

Figure 3 depicts the widespread ethnomedicinal utilization patterns of medicinal plants. Among the reported uses, wound healing was the predominant application (13.4), followed by nutritional uses (13.2). Medicinal plants were also widely utilized for their antibacterial properties (11.8%) and in managing skin disorders (10.0%), highlighting their significant therapeutic importance in traditional healthcare practices. Respondents reported that medicinal plants were commonly used to treat fever (8.6%) and respiratory ailments (6.9%). Other reported uses included the treatment of digestive and urinary disorders, along with their anti-inflammatory and antioxidant properties, each accounting for 5.2% of the responses. All remaining medicinal uses were reported less frequently, each representing less than 5%, as illustrated in Figure 3.

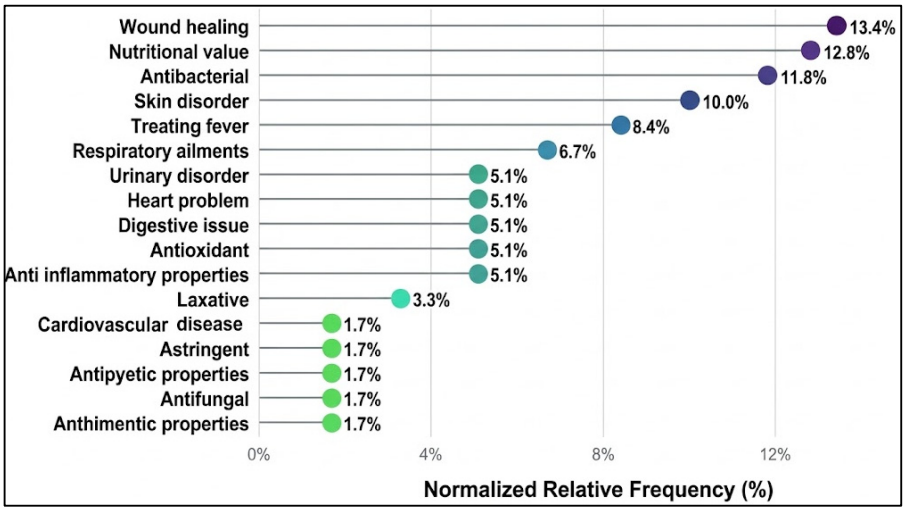


Figure 3. An overview of the ethnomedicinal uses of plant species for various ailments as suggested by the respondents.

Based on respondents' observations, vegetation within *E. camaldulensis*-dominated forests was classified into three main growth forms: herbs, shrubs, and trees. Among these, the respondents showed that herbs accounted for the highest proportion, contributing (39%), followed by shrubs (32%) and trees (29%), as shown in Figure 4. This showed that people use the herbaceous plants more easily as compared to shrubs and trees. In addition, local informants reported the use of different plant parts for various purposes, including leaves (48.6%), roots (40.5%), the whole plant (21.6%), seeds (18.9%), bark (16.2%), and stems (5.4%) (Figure 5).

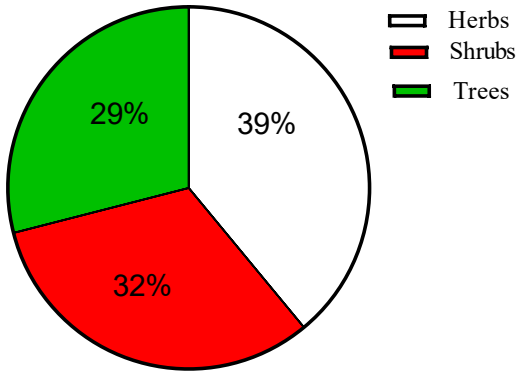


Figure 4. Distribution of growth habitats among ethnobotanical plant species associated with *E. camaldulensis* as reported by the respondents.

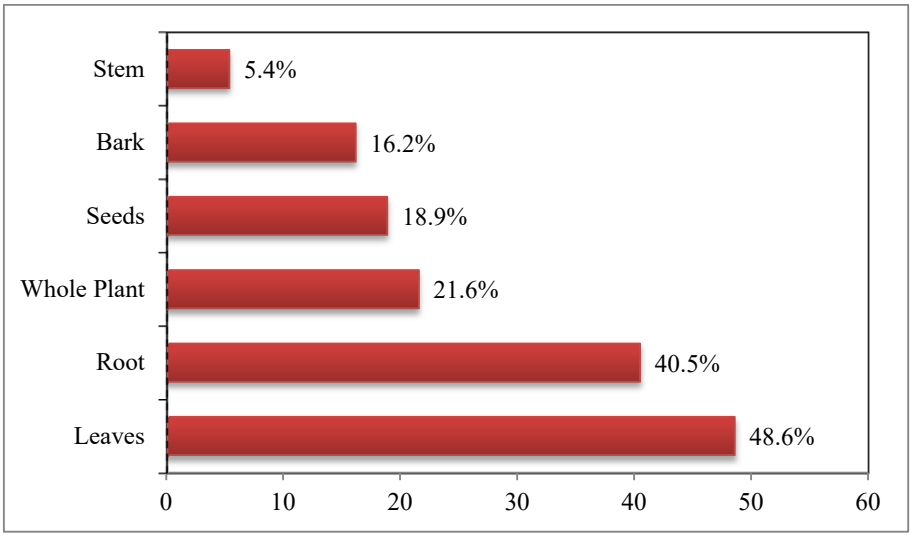


Figure 5. Percentage use of different ethnobotanical plant parts as reported by respondents in the study area.

3.6. Socio-Economic Factors and Special Planning of Forest Management

Table 6 presents the key characteristics of *Eucalyptus* plantations and their management, including respondents' distance from the forest, plantation cover area, factors influencing the decision to establish plantations, income generated from timber, forest duration, production, and methods used to transport harvested wood to the local markets. About 46.82% of the respondents were located within 5 km of the *Eucalyptus* forests, 30.95% lived at a distance of approximately 10 km, and 22.22% resided more than 10 km from the forests. In addition, the forests varied considerably in terms of their spatial extent. Most of the forest patches covered an area of less than 5 km^2, accounting

for 31.74% of the surveyed sites, while a substantial proportion (60.31%) consisted of plantations ranging from 1 to 2 hectares in size. The *Eucalyptus* plantations in the study area were predominately established approximately 10 years ago, as indicated by 68.25% of the respondents. In the case of motivation behind forest plantation, local inhabitants represented the largest group responsible for plantation establishment (46.83%). Furthermore, 48.41% of respondents reported that local communities could generate an income of approximately PKR 10,000–50,000 per month from these plantations. This income was mainly derived from harvesting *Eucalyptus* wood and its transportation to the local markets using various means of transportation, including trucks, dumpers, donkeys, and other available resources.

Table 6. Socio-economic factors and special planning of forest management by respondents.

Variables	Division	Numbers	Percentage,%
Distance to forest	5 km	59	46.82
	10 km	39	30.95
	<10 km	28	22.22
Land cover	>5 km	40	31.74
	1–2 ha	76	60.31
	3–5 ha	10	7.93
Forest age	5 years	30	23.81
	10 years	86	68.25
	>10 years	10	7.93
Convincing agents	Forest officer	45	35.71
	Self	22	17.46
	Local inhabitants	59	46.83
Earning in PKR (Thousands)	<10	27	21.43
	10 to 50	61	48.41
	>50	38	30.16
Transport used for loading wood	Truck	31	24.60
	Dumper	28	22.22
	Donkey	15	11.90
	Other	52	41.26

4. Discussion

The present study provides a comprehensive assessment of the ecosystem services and socioeconomic implications of *Eucalyptus* plantations by drawing on community perceptions, traditional ethnobotanical knowledge, and household-level socioeconomic data. By combining structured interviews with ethnobotanical surveys, the study offers a broader understanding of how these plantations influence local livelihoods, ecological conditions, and forest management practices in the study area. A total of 212 questionnaires were distributed across Malakand Division to examine the non-native plantation species behaviour of *Eucalyptus camaldulensis Dehnh*, evaluate the status of the *Eucalyptus* Forest, assess its medicinal uses, analyse biodiversity impact, and address other research objectives. Both male and female participants were interviewed, including elders, teachers, students, farmers, local residents, and traditional healers (Hakims). Men showed higher involvement in timber extraction, tree harvesting, and plantation management logistics, whereas women networked more regularly with understory non-timber forest products (NTFPs) and household-level provisioning services. These results are similar to previous socio-ecological studies in Pakistan [30], which reported that gender-differentiated forest access shapes primary environmental perceptions. To safeguard illustrative sampling across resource-user groups, male respondents were

reported in higher proportions (59.43%) due to their direct engagement in forestry, following standard methodological frameworks for socio-ecological surveys [31].

The respondents also suggest that *Eucalyptus camaldulensis Dehnh* exhibits aggressive characteristics in the lower-elevation areas of Malakand Division. The species produces large quantities of seeds, with protective seed coats that may enhance seed survival and contribute to successful germination and establishment [32]. Additionally, due to its non-native properties, grazing animals tend to avoid these plantations, giving a competitive edge to *Eucalyptus* domination in the area. Respondents confirm these environmental trends; the plant becomes dominant and shows its non-native species character in new environments, as reported by [33]. It has spread throughout Pakistan due to its rapid growth and high wood production. However, as noted by respondents, its dominance has had harmful effects on the natural flora as well as on soil physiochemical properties, as reported by [34–36]. In Malakand, *Eucalyptus* plantation is found mostly in low-elevation areas, where its environmental impact is more severe. Education level and household size were found to influence perceptions of *Eucalyptus* plantations, suggesting that awareness and livelihood play a key role in shaping community attitudes toward plantation forestry. Survey results revealed that both genders wisely recognized the negative ecological influences of *Eucalyptus*, especially in relation to loss of biodiversity, land degradation, and groundwater depletion, with males representing a higher proportion as compared to females. Few respondents suggested its positive benefits, such as timber and fuelwood production [37]. These insights are in line with previous works, which report that *Eucalyptus* plantations are a source of carbon mitigation [38] but reduce soil fertility [39] and decrease native flora due to allelopathic effects and high evapotranspiration rates [40]. Though some respondents suggested its economic benefits, these were generally presented as dominated by its ecological drawbacks, an assessment also reported by [41,42]. Particularly, the gender-based variances in insight reflect a common awareness within the community, as supported by [43], who studied community concern about monoculture plantations in Malakand Division.

Based on the data, local respondents widely perceive *Eucalyptus* plantations to affect understory plantation. A previous study showed that *Eucalyptus* trees add allelopathic chemicals to the soil and have a harmful effect on many plants, such as *Artemisia annua* L., *Allium sativum* L. (garlic), *Mentha longifolia* (L.), *Rheum emodi Wall. ex Meisn.*, *Nigella sativa* L., *Berberis lyceum Royle*, and other vegetables [44]. Such allelopathy contributes to the reduction of biodiversity and can lead desertification and deforestation. The respondents also suggest that there is no clear strategy for governmental and non-governmental organizations to control the adverse effects of *Eucalyptus* trees on the ecosystem. Many medicinal plants were also studied in the survey. *Ajuga bracteosa* Wall. ex Benth. leaves are used for the treatment of jaundice, hypertension, and sore throat [45,46]. Such perceptions are consistent with scientific data that report high water consumption, allelopathic effects, and reduced understory vegetation in *Eucalyptus*-dominated plantations. However, some respondents reported neutral or positive effects, particularly in degraded lands, suggesting that site conditions and management practices strongly affect ecological consequences. These findings emphasize the importance of context-specific assessments when evaluating the ecological sustainability of *Eucalyptus* plantations. The root of *Justicia adhatoda* L. is used in treating cough, pneumonia, and rheumatism, while its leaves serve as an expectorant, antiseptic, and demulcent, as suggested by the respondents. *Chenopodium betrays* produces a special oil used for antibacterial and anti-fungal properties, as reported by [47], and is used locally to treat cough and hepatitis. *O. ferruginea* is noted for its nutritional and therapeutic applications [48]. Similarly, the pericarp of *Punica granatum,* when grinded, dried and converted to

powder, is used for blood purification, swelling, gastrointestinal ailments and cough, such as dysentery, and is also used as a laxative [49]. In addition, the fruit of *Punica granatum* L. is used in stomach and cardiac applications, while the rind of the fruit is used for dysentery, diarrhoea and itching, as suggested by the respondents.

The findings highlight the medicinal and cultural significance of *Eucalyptus*, alongside its contribution to local ecosystem services. Other plant species recorded in the study, such as *Melia azedarach* L., were also valued by local respondents for their use as animal fodder and in traditional medicine, particularly for treating digestive disorders, fever, and cough. The wood is also used by locals for different purposes, i.e., timber, fuel, furniture, etc. *Solanum nigrum* L. is also known for its antipyretic properties, as reported by [50]. Similarly, ethnobotanical use of these plants has also been documented in studies in northern areas of Pakistan, such as [51]. *Rumex hastatus D.Don* is used for the treatment of digestion and stomach ailments, as reported by [52]. In upper Malakand regions, where livelihood consists of simple practices, the residents use dairy products and edible wild plants (vegetable), such as *Amaranthus viridis* L., *Chenopodium album* L., *Malva sylvestris* L., and *Nasturtium officinale R.Br*. Due to financial constraints, many local people cannot afford LPG as fuel, with the major alternative being wood. Species such as *Artemisia scoparia* Waldst. & Kit., *Acacia modesta* Wall., *Celtis australis* L., *Dodonaea viscose (*L.*)* Jacq., *Melia azedarach* L., and *Ailanthus altissima* (Mill.) Swingle are widely used as fuelwood [53,54]. Timber from trees such *Artemisia scoparia Waldst. & Kit. ex Willd.* Waldst., & Kit. ex Will *Juglans regia* L., *Melia azedarach* L., and others are also used for furniture and house construction, while *Artemisia scoparia Waldst. & Kit. ex Willd*., and *Dodonaea viscosa (*L.*) Jacq.,* are used as thatching material for the traditional construction of muddy houses. Because natural vegetation may provide fuel, timber, and medicinal materials without degrading the ecosystem, the systematic control of *Eucalyptus* expansion is ecologically necessary.

The findings regarding forest management practices indicate that socio-economic constraints, limited expertise, and minimal institutional support influence the sustainable management of *Eucalyptus* plantation. The respondents suggest that challenges are related to harvesting practices, market access, and limited support from both government and non-government initiatives. These constraints may limit the long-term benefits of plantations and exacerbate negative ecological impacts if not properly addressed. The results suggest that participatory forest management approaches and improved extension services could enhance both economic returns and ecological sustainability.

The study highlights growing ecological pressures in Malakand Division, where the introduction and spread of non-native species, particularly *Eucalyptus*, are affecting native biodiversity and the health of local ecosystems. Natural flora is rapidly declining due to poor forest management, deforestation, and overgrazing, as suggested by both male and female respondents. Conservation strategies are needed on an urgent basis to protect and sustainably manage the area's rich biodiversity and medicinal plants. Active ecological management and community-based conservation strategies are essential to safeguard regeneration, so that the community can continue to benefit from the natural resources of Malakand Division.

5. Conclusions

The findings of this study highlight the complex trade-offs associated with *Eucalyptus camaldulensis Dehnh* plantations in Malakand Division, particularly between their contributions to local livelihoods and the ecological impacts perceived by surrounding communities. While local communities recognise the economic value of *Eucalyptus* for timber, fuelwood and income generation, respondents consistently associated its expansion with declining native biodiversity, reduced availability of

medicinal plants, soil degradation and increasing pressure on local water resources. The findings also highlight the continuing importance of traditional ecological knowledge and strong community preference for native and locally beneficial alternatives, particularly *Olea ferruginea*, *Melia azedarach* and fruit-bearing trees. Given that these findings are based primarily on community perceptions rather than direct biophysical measurements, they should inform, rather than substitute for, further ecological and hydrological assessment. Overall, integrating local knowledge with evidence-based plantation management, native species restoration and participatory forestry could help balance rural livelihoods with biodiversity conservation and the long-term sustainability of ecosystem services in the Hindu Kush region of Pakistan.

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

Data Availability Statement: The data presented in this study are available on request from the corresponding author due to the confidential and anonymous nature of the responses, as participation was voluntary and participants were assured of the confidentiality and anonymity of their responses.

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Reference

1. Brockerhoff, E.G.; Barbaro, L.; Castagneyrol, B.; Forrester, D.I.; Gardiner, B.; González-Olabarria, J.R.; Jactel, H. Forest biodiversity, ecosystem functioning and the provision of ecosystem services. *Biodivers. Conserv.* **2017**, *26*, 3005–3035.
2. Ryan, C.M.; Pritchard, R.; McNicol, I.; Owen, M.; Fisher, J.A.; Lehmann, C. Ecosystem services from southern African woodlands and their future under global change. *Philos. Trans. R. Soc. B Biol. Sci.* **2016**, *371*, 20150312.
3. Enescu, C.M.; Mihalache, M.; Ilie, L.; Dincă, L.; Timofte, A.I.; Murariu, G. Afforestation of degraded lands: A global review of practices, species, and ecological outcomes. *Forests* **2025**, *16*, 1743.
4. Lamba, K. A Comparative Study of the Global and Indian Timber Industries: Market Dynamics, Sustainability, and Trade Challenges. *SSRN Electron. J.* **2026**. https://doi.org/10.2139/ssrn.6763778.
5. Mensah, P.; Pimenta, A.S.; Melo, R.R.D.; Amponsah, J.; Rusch, F.; Danso, H.; Gama, R.S.P. Benefits of Eucalyptus Plantations: Ecological Services, Socioeconomic Contributions, and Innovation—A Global Review. *Forests* **2026**, *17*, 644.

6. Liu, C.L.C.; Kuchma, O.; Krutovsky, K.V. Mixed-species versus monocultures in plantation forestry: Development, benefits, ecosystem services and perspectives for the future. *Glob. Ecol. Conserv.* **2018**, *15*, 00419.
7. Kamal, A.; Yingjie, M.; Ali, A. Significance of billion tree tsunami afforestation project and legal developments in forest sector of Pakistan. *Int. J. Law. Soc.* **2019**, *1*, 157–162.
8. Baig, M.B.; Ahmad, S.; Khan, N.; Ahmad, I.; Straquadine, G.S. The history of social forestry in Pakistan: An overview. *Int. J. Soc. For.* **2008**, *1*, 167–183.
9. Meng, F.; Liu, Y.; Ma, W.; He, J. Effects of environmental and topographic factors on plant diversity and community composition in temperate forests. *Glob. Ecol. Conserv.* **2023**, *43*, e02475.
10. Belachew, K.G.; Minale, W.K. Socioeconomic and environmental impacts of eucalyptus plantations in Ethiopia: An evaluation of benefits, challenges, and sustainable practices. *Sci. World J.* **2025**, *2025*, 1780293.
11. Gelaye, Y.; Getachew, K. Environmental Impacts, Land-Use Trade-Offs, and Sustainable Management Pathways of Eucalyptus Plantation Expansion in Ethiopia. *Sci. World J.* **2026**, *2026*, 6629432.
12. Molla, G.; Addisie, M.B.; Ayele, G.T. Expansion of Eucalyptus plantation on fertile cultivated lands in the North-Western highlands of Ethiopia. *Remote Sens.* **2023**, *15*, 661.
13. Girma, G.; Melka, Y.; Haileslassie, A.; Mekuria, W. Participatory forest management for improving livelihood assets and mitigating forest degradation: Lesson drawn from the Central Rift Valley, Ethiopia. *Curr. Res. Environ. Sustain.* **2023**, *5*, 100205.
14. Khan, N.; Fahad, S.; Faisal, S.; Akbar, A.; Naushad, M. Socio-economic and medicinal review of Eucalyptus tree in the world. *SSRN Electron. J.* **2020**, *preprint*. https://doi.org/10.2139/ssrn.3644215.
15. Bibi, N.; Khan, M.; Murad, A.; Subhan, G.; Rahim, G.; Ullah, S. Ethnomedicinal plant knowledge of dheri julagram, District Malakand, Pakistan: Diversity, traditional uses, and conservation implications. *Pak. J. Weed Sci. Res.* **2026**, *32*, 211.
16. Khan, K.; Jan, G.; Irfan, M.; Jan, F.G.; Hamayun, M.; Ullah, F.; Bussmann, R.W. Ethnoveterinary use of medicinal plants among the tribal populations of District Malakand, Khyber Pakhtunkhwa, Pakistan. *Ethnobot. Res. Appl.* **2023**, *25*, 1–24.
17. Hussain, B.; Abbas, Z.; Alam, J.; Harun, N.; Khan, S.M.; Ahmad, Z.; Raposo, A. Cross-cultural ethnobotany of the Baltis and Shinas in the Kharmang district, Trans-Himalaya India-Pakistan border. *Heliyon* **2024**, *10*, 28551.
18. Medeiros, P.L.D.; Pimenta, A.S.; Miranda, N.D.O.; Melo, R.R.D.; Amorim, J.D.S.; Azevedo, T.K.B.D. The myth that eucalyptus trees deplete soil water—A review. *Forests* **2025**, *16*, 423.
19. Bughio, F.A.; Jahangir, T.M.; Memon, A.A.; Jamali, A.R.; Bozdar, H.B.; Simair, A.A.; Otho, A.A. Analysis of phenolic compounds and allelopathic effects of Eucalyptus on Prosopis cineraria. *Sindh Univ. Res. J.—SURJ Sci. Ser.* **2023**, *55*, 18–28. https://doi.org/10.26692/surj-ss.v55i02.6632.
20. Smith, G.F.; Iremonger, S.; Kelly, D.L.; O'Donoghue, S.; Mitchell, F.J.G. Enhancing vegetation diversity in glades, rides and roads in plantation forests. *Biol. Conserv.* **2007**, *136*, 283–294.
21. Akbar, M.; Qadir, I.; Arif, A. Assessment of carbon sequestration rate in eucalyptus-based irrigated forest plantation Bahawalpur. *Glob. For.* **2022**, *1*, 33–53.
22. Din, N.U.; Khan, N.W.; Ullah, R.; Okla, M.K.; Abdel-Maksoud, M.A.; Saleh, I.A.; Abu-Harirah, H.A.; AlRamadneh, T.N. Does pruning affect the structural and ecological productivity of Juniper woodlands in the eastern Hindu Kush? *PeerJ* **2025**, *13*, 19184.
23. Ullah, T.; Khan, N.; Ullah, R.; Ullah, Z.; Uddin, M.N.; Kazi, M. Soil stoichiometry patterns and their driving mechanisms: Exploring nutrient dynamics in Eucalyptus plantations in Malakand Division. *Environ. Monit. Assess.* **2025**, *197*, 746. https://doi.org/10.1007/s10661-025-14182-4.
24. Zafar, M.; Ahmad, M.; Sultana, S.; Khan, M.A. Altitudinal effects on precipitation and temperature profiles: A comparative study of the Hindu Kush and Malakand divisions. *Environ. Earth Sci.* **2024**, *83*, 201–215.
25. Ahmad, N.; Khan, I.; Rahman, M. Socio-economic impacts of Eucalyptus, Robinia pseudoacacia, and Acacia modesta plantations for timber and soil stabilization in Pakistan. *J. Sustain. For.* **2021**, *40*, 489–504.
26. Bisht, A.S.; Bhat, A.B. Vegetational structure and plant diversity relation in a sub-alpine region of Garhwal Himalaya, Uttarakhand India. *Afr. J. Plant Sci.* **2013**, *7*, 401–406.
27. Garekae, H.; Thakadu, O.T.; Lepetu, J. Socio-economic factors influencing household forest dependency in Chobe enclave, Botswana. *Ecol. Process* **2017**, *6*, 40.
28. Mulu, S.; Asfaw, Z.; Alemu, A.; Teketay, D. Determinants of decision making by smallholder farmers on land allocation for small-scale forest management in northwestern Ethiopian Highlands. *Land* **2022**, *11*, 838.

29. Khoza, N. An Ethnobotanical Study of Indigenous Knowledge of the Medicinal Plants Used by Traditional Healers in the Rural Communities of Nkomazi Local Municipality, Mpumalanga Province. Master's Thesis, University of the Witwatersrand: Johannesburg, 2024.
30. Zeb, N. Impact of Personality Traits on the Development of Entrepreneurial Intentions: Interactive Role of Gender, Education and Culture. Doctoral Dissertation, University of Azad Jammu and Kashmir, Muzaffarabad, Pakistan, 2022.
31. Maina, P.M. Analysis of Household Socio-Economic Drivers of Cattle Grazing and Grass Harvesting in Mount Kenya West Protected Forest, Kenya. Ph.D. Thesis, St. Paul's University, Limuru, Kenya, 2021.
32. Bareke, T. Biology of seed development and germination physiology. *Adv. Plants Agric. Res.* **2018**, *8*, 336–346.
33. Garkoti, M.; Chandra, N.; Shah, Z.; Kumar, R.; Pandey, B.; Joshi, N.; Arya, D. Impact and management of invasive plant species in Champawat District, Western Himalayas: Community awareness and perceptions. *Env. Dev. Sustain.* **2025**, *3*, 53–61.
34. Khan, A.; Ali, S.; Shaukat, S.S. Evaluation of afforestation projects and tree planting selection in lower elevation zones of Pakistan. *Int. J. Env. Sci.* **2015**, *6*, 341–355.
35. Hussain, M.S.; Nawaz, M.F.; Tanvir, M.A. Comparative effect of drought on Eucalyptus camaldulensis Dehnh and Tamarix aphylla at early stages of growth. *Pak. J. Agric. Sci.* **2020**, *57*, 1021–1028.
36. Rahman, M.A.; Das, A.K.; Al Riyadh, Z.; Suhag, M.; Rahman, M.M. Eucalyptus in Agriculture: Friend or Foe? Analyzing its impact on crop yields, soil dynamics, and farmers' perceptions in Bangladesh. *Agrofor. Syst.* **2024**, *98*, 3109–3128.
37. Eneji, C.V.O.; Ajake, O.; Mubi, M.; Husain, M. Gender participation in forest resources exploitation and rural development of the forest communities in Cross River State, Nigeria. *J. Nat. Sci. Res.* **2015**, *5*, 61–71.
38. Singh, A.; Singh, P.; Dhillon, G.P.S.; Sharma, S.; Singh, B.; Gill, R.I.S. Differential impacts of soil salinity and water logging on Eucalyptus growth and carbon sequestration under mulched vs. unmulched soils in south-western Punjab, India. *Plant Soil* **2023**, *482*, 401–425.
39. Hussain, F.; Shah, S.M.; Badshah, L. Impact of exotic Eucalyptus species on native biodiversity in Pakistan. *Pak. J. Bot.* **2011**, *43*, 1601–1606.
40. Shah, S.S. Unlocking the potential of Albizia procera: A multifunctional tree for sustainable development and climate resilience. *Bangladesh J. Plant Taxon.* **2024**, *31*, 329–347.
41. Häyhä, T.; Franzese, P.P. Ecosystem services assessment: A review under an ecological-economic and systems perspective. *Ecol. Model.* **2014**, *289*, 124–132.
42. Dhinsa, M.; Mammo, S. Perception of Local Community on Socioeconomic Benefits and Hydrological Impact of Eucalyptus Tree in Amuru District, Oromia, Ethiopia. *Res. Sq.* **2026**. https://doi.org/10.21203/rs.3.rs-8776044/v1.
43. Bayle, G. Ecological and social impacts of eucalyptus tree plantation on the environment. *J. Biodivers. Conserv. Bioresour. Manag.* **2019**, *5*, 93–104.
44. Valiño, A.; Pardo-Muras, M.; Puig, C.G.; López-Periago, J.E.; Pedrol, N. Biomass from allelopathic agroforestry and invasive plant species as soil amendments for weed control—A review. *Agronomy* **2023**, *13*, 2880.
45. Bachheti, A.; Sharma, A.; Bachheti, R.K.; Husen, A.; Pandey, D.P. Plant Allelochemicals and Their Various Applications. In *Co-Evolution of Secondary Metabolites*; Merillon, J.M., Ramawat, K.G., Eds.; Springer: Cham, Switzerland, 2020; pp. 441–465.
46. Wariss, H.M.; Wang, H.F.; Anjum, S.; Mukhtar, M. Quantitative assessment of medicinal flora and ethnobotanical appraisal of Olea ferruginea Royle in Northwest Himalayas. *Biodivers. Conserv.* **2021**, *30*, 1415–1438.
47. Chekem, M.S.G.; Lunga, P.K.; Tamokou, J.D.D.; Kuiate, J.R.; Tane, P.; Vilarem, G.; Cerny, M. Antifungal properties of Chenopodium ambrosioides essential oil against Candida species. *Pharmaceuticals* **2010**, *3*, 2900–2909.
48. Montant, M.E.S.; Novidzro, M.; Djeri, B.; Poli, S.; Alognon, A.; Hoinsou, Y.; Karou, S.D. Ethnobotanical investigation of medicinal plants traditionally used for the management of hepatitis B in Togo. *J. Appl. Biosci.* **2025**, *213*, 22555–22568.
49. Ali, S.; Munazir, M.; Sher, H.; Qureshi, R.; Akram, M. An ethnobotanical study of aromatic medicinal plants of Swat Valley, Pakistan. *Asian J. Ethnobiol.* **2023**, *6*, 101–112.
50. Bhat, N.A.; Jeri, L.; Karmakar, D.; Mipun, P.; Bharali, P.; Sheikh, N.; Kumar, Y. Ethnoveterinary practises of medicinal plants used for the treatment of different cattle diseases: A case study in East Khasi Hill district of Meghalaya, North East India. *Heliyon* **2023**, *9*, 17902.
51. Aziz, M.A.; Khan, A.H.; Adnan, M.; Ullah, H. Traditional uses of medicinal plants used by Indigenous communities for veterinary practices at Bajaur Agency, Pakistan. *J. Ethnobiol. Ethnomed.* **2018**, *14*, 11.
52. Qazi, N.G.; Khan, A.U.; Abbasi, S.W.; Shah, F.A.; Rasheed, F.; Ali, F.; Bungau, S. Pharmacological basis of Rumex hastatus D. Don in gastrointestinal diseases with focusing effects on H+/K+-ATPase, calcium channels inhibition and PDE mediated signaling: Toxicological evaluation on vital organs. *Molecules* **2022**, *27*, 5919.

53. Muhammad, S.; Hussain, M.; Saqib, Z.; Alam, J.; Mujtaba, G.; Shah, Z.A.; Abideen, Z. Flora of the Kurram Valley (tribal area. *Pak. J. Bot.* **2023**, *55*, 199–212.
54. Mehmood, A. Floristic Diversity Along Environmental Gradients In District Tor Ghar. Ph.D. Thesis, Hazara University, Mansehra, Pakistan, 2016.

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