Review of Plant Studies
2025 Vol. 12, No. 1, pp. 26-44
ISSN(e): 2410-2970
ISSN(p): 2412-365X
DOI: 10.18488/rps.v12i1.4384

Evaluating community perception and the impact of the billion tree afforestation project on key medicinal plants in Buner forest division, KP, Pakistan

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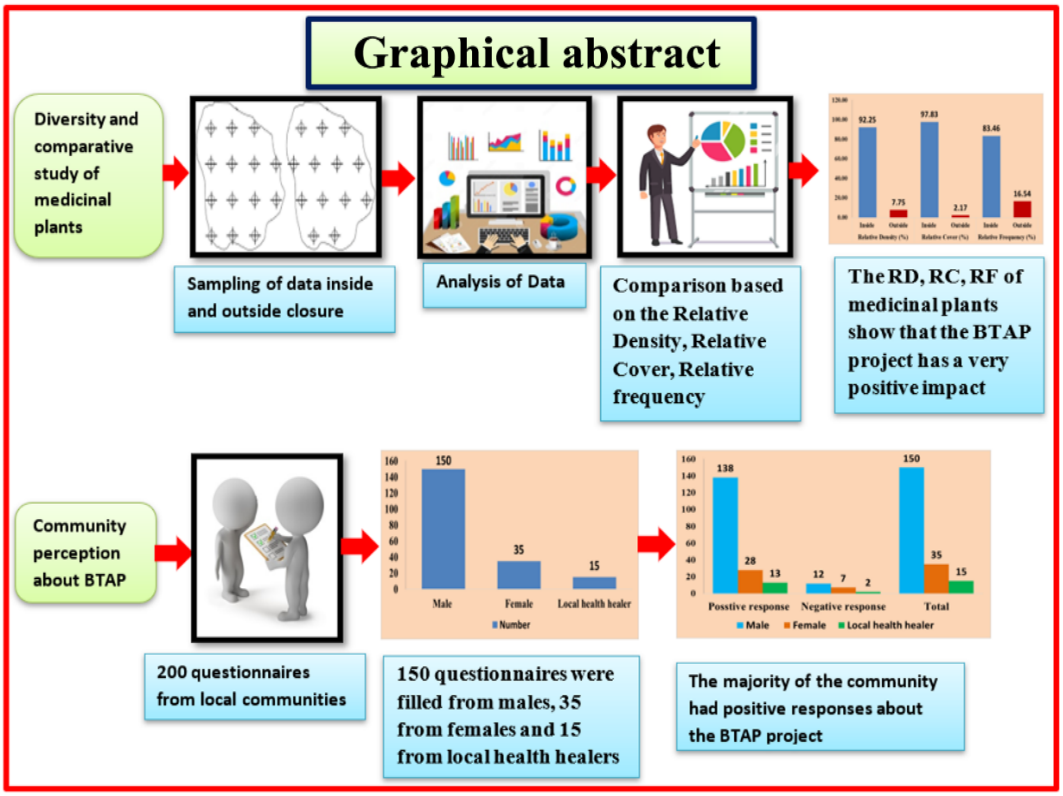
Article History
Received: 14 July 2025
Revised: 18 August 2025
Accepted: 22 August 2025
Published: 29 August 2025

Keywords
Assessment
Billion tree afforestation project
Buner
Closure
Medicinal plants
Pakistan
Regeneration.

ABSTRACT

Pakistan is a country of remarkable ecological and cultural diversity, featuring a wide range of climates, landscapes, and rich biodiversity from towering mountains and vast deserts to fertile plains and lush forests. To gain a better understanding of community perspectives, identify the primary threats to medicinal plants, and assess the impact of the Billion Tree Afforestation Project (BTAP) on medicinal plant conservation in the Buner Forest Division, this study was conducted for the first time in the region. A total of 28 sample plots were surveyed inside 14 BTAP-established closures, while another 28 plots were assessed in areas where no BTAP activities had taken place. In addition, a rapid assessment approach was employed, involving interviews with 200 local community members. The results revealed that the relative density of medicinal plant species was significantly higher inside the closures (92.25%) compared to outside (7.75%). Similarly, the relative cover of medicinal plants was greater within the closures (97.83%) than in non-protected areas (2.17%). The relative frequency of medicinal plant species also followed the same pattern, with a higher value inside the closures (83.46%) versus outside (16.54%). These findings demonstrate that the establishment of closures has a positive impact on the regeneration of medicinal plants and trees. By restricting activities such as grazing, browsing, cutting, and plant collection, closures contribute significantly to biodiversity conservation. Preserving and protecting our natural heritage is essential, as it plays a vital role in sustaining the ecological balance and supporting local livelihoods.

Contribution/Originality: This study contributes to the existing literature by providing the first empirical evidence from Buner Forest Division on BTAP's impact. This study is one of the few that combine ecological surveys with community perceptions. The primary contribution of the paper is the finding that BTAP closures significantly support medicinal plant conservation in the region.



1. INTRODUCTION

Plants that have been utilized to treat, prevent, or handle disease are known as medicinal plants [1]. The category of medicinal plants includes plants utilized for therapeutic purposes. **"Medicinal plant"** comprises several dissimilar plants used in herbalism (herbal medicine) [2]. The term "herb" originated from the Latin word *"herba"* and the ancient French word *"herbe"* [3]. Currently, an herb denotes every portion of the plant, such as seed, bark, fruit, stem, leaf, stigma, root, and flower, as well as a non-woody plant [4]. In the past, the word "herb" was used only for non-woody plants, including those that come from shrubs and trees [3]. Such plant species are also used in some spiritual practices as a fruit, food, flavonoid, medicine, or perfume. Plants are an essential medicinal source and have a significant role in health globally [5]. From earlier civilizations until now, almost every culture has utilized plants for medicinal purposes [6]. Medicinal plants are significant for the global economy today. Around 21,000 plant species may be used as medicinal plants [7].

Medicinal plants are the "backbone" of traditional medicine, meaning that over 3.3 billion people in developing nations regularly use medicinal plants [4]. "Nearly half of the population in developed countries now regularly uses Traditional Medicine (e.g., 42% in the US, 48% in Australia, 49% in France, and 70% in Canada), with extensive use also seen in developing nations like China (40%), India (70%), Chile (71%), Colombia (40%), and up to 80% in African countries [8]. In recent times, Beyene et al. [9] assessed that 80% of people globally depend on herbal remedies for some part of their basic health needs. Medicinal resources are frequently identified for their key role in rural livelihoods, conserving biodiversity, and earning exports [10]. Stakeholders have contributed towards this concern at multiple levels as well, and many initiatives have been introduced to ensure the environmental sustainability of the medicinal plants community forestry system [11]. It was identified that about 6,000 plant species are commonly distributed and that 600 to 700 species have the ability for medicinal activities in Pakistan [12]. More than 25 percent of medicine and herbal products are produced from medicinal plants. In the Himalayan ranges, a minimum of 70 percent of the medicinal plants and 70-80 percent of the people in this locality rely on native medicines for their primary healthcare [13].

There is a significant amount of research on the local population of Pakistan concerning the use of indigenous medicinal plants in traditional healthcare practices, with increasing interest in recent times [14-16]. Pakistan has an abundant variety of plants that are used for therapeutic purposes by local societies. As most of the inhabitants in rural areas have low literacy rates and an absence of recent health amenities, they mostly depend on plants for their healthcare [17]. In Pakistan, 84 percent of the population relies on indigenous medicine for their primary healthcare [18]. The studies on the ethnobotany of Machyara National Park described 104 essential medicinal plant species used by native communities [19, 20]. According to Bokhari, the ethnobotany and plant analysis of Machyara National Park, Muzaffarabad, Azad Jammu and Kashmir, represented 10 plant populations in different areas of the national park [16, 21]. The Himalayan medicinal plants are unique, and their distribution is dispersed. However, several areas of the country remain ethno-botanically undiscovered [22]. Documentation is a critical feature for sustainable consumption and conservation of medicinal plants [23, 24]. According to Raj and Toppo [25] evaluation and recording of plant diversity are the first steps forward before the next step in conserving these natural resources. There is no report on community perception and impact assessment of the Billion Tree Afforestation Project (BTAP) activities on important medicinal plants in the Buner Forest division, Pakistan. The present study is focused on assessing the effect on the status of medicinal plants after BTAP activities in the Buner Forest division, Pakistan. To find out the community perception toward BTAP and major threats to medicinal plants in the study area.

2. MATERIALS AND METHODS

2.1. The Study Area

Buner, one of the most attractive, beautiful, and peaceful districts of Pakistan, is located between latitudes 34-9 to 34-43 N and longitudes 72-10 to 72-47 E (Figure 1) [26]. It is surrounded on the North side by Swat District, on the West side by Malakand Agency, on the South side by Mardan District, and on the East side by the river Indus and Hazara Division. The total area of District Buner is 1726 sq km. The Barandu catchment makes up 15% of the Tarbela Watershed Project. The area is surrounded by hillsides and is divided by several mountains from Swat. Elevation is 1,200 ft at Totalai (Khudukhel) in the South and 9,550 ft at Dosara Peak in the North [27]. There are three major rivers in the center of the district, namely Barandu, Chamla, and Budal. Most of the population is rural, and agriculture is the principal source of their livelihood. The area's main crops include wheat, maize, tobacco, and sugarcane.

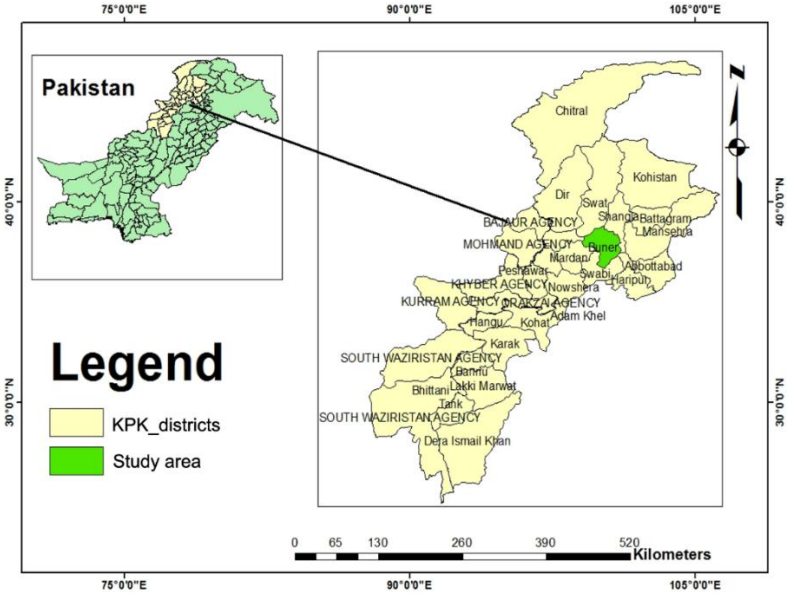


Figure 1. Study area map.

2.2. Methodology

Survey work was conducted compartment-wise in the Buner Forest division. The two potential sites were selected in the study area: Qaleel and Chagharzai. In Qaleel and Chagharzai, data were collected from closures and from areas where no BTAP activities occur. The seven (7) closures were selected for data collection in Qaleel, and seven (7) sites where no BTAP intervention occurred. Similarly, in Chagharzai, seven (7) closures and seven (7) sites without BTAP intervention were selected for data collection. The data were collected from a total of 14 closure areas and 14 non-closure areas in Qaleel and Chagharzai.

2.3. Calculation

The area of one closure was 40 ha, and the total number of closures was 14, so when multiplying 40 by 14, we will find the total area of a selected closure as shown in Equation 1.

$$40\ x\ 14\ =\ 560\ hectare \quad (1)$$

The 560 ha was the total closure area for data collection, and the same 560 ha area was also selected from outside the closure for data. By adding the area of the closure and the outside closure, the total area is 1120 ha, as shown in Equation 2.

$$560\ +\ 560\ =\ 1120\ ha \quad (2)$$

When the total area (1120 ha) is multiplied by sample intensity (0.5%) and divided by 100, we will get the sampling area as shown in Equation 3.

$$1120\ x\ 0.5/100\ =\ 560/100\ =\ 5.6\ ha \quad (3)$$

When dividing the sampling area by a single sample plot size, we will find the number of sample plots as shown in Equation 4.

$$5.6\ /.1\ =\ 56 \quad (4)$$

The 56 sample plots were taken for data collection in two potential sites (Qaleel and Chagharzai) in District Buner. In Qaleel and Chagharzai, a total of 28 sample plots were taken inside the closure, and 28 sample plots in areas where no BTAP intervention occurred. The circular sample plot of 17.84 meters was considered for data collection, with an area of 0.1 hectare. The imaginary sample plot was selected, and the remaining sampling plots were taken in the same direction. For randomization, the plots were taken after every 330 steps, approximately, as practicable under field conditions. The 28 sample plots were laid in the site where the BATP intervention had been made, and 28 sample plots were laid in the place where no BATP activities had been conducted. Several medicinal plants were recorded in the sample plots, and their distribution frequencies, blockwise, were also documented.

2.4. Data Analysis

The data analysis of medicinal plant species, including relative density (RD), relative frequency (RF), and relative cover (RC), was estimated as described by Hussain [28], Mollik et al. [29] and Sobuj and Rahman [30].

Is the proportion of the density of a species that stands as a whole. It is calculated by the following formula.

$$\%\ \mathrm{RD} = \frac{\text{Total number. of individuals of a species in all quadrats}}{\text{Total number of individuals of all species in all quadrats}} \times 100$$

Is the proportion of the total frequency of a species to the sum of the frequency of all the species in the area. It is determined by the following formula.

$$\%\ \mathrm{RF} = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100$$

Of a species is the proportion of the total of a species to the sum of the cover of all the plants of all species in the area. It is calculated by the following formula.

$$\%\ \mathrm{RC} = \frac{\text{Total cover of all plants of a species}}{\text{Total cover of all plants of all species}} \times 100$$

2.4.1. Importance Value Index

The IVI (Importance Value Index) provides the comprehensive structure of a species' ecological significance within a community [31-33]. The frequency, density, abundance, and basal cover of species are studied to determine the community structure. IVI represents the sum of relative frequency, relative density, and relative abundance to show the importance of a species in the location [34]. The IVI was calculated by the following equation [35].

$$IVI=\frac{(RF+RD+RC)}{3}$$

Whereas IVI is the Importance Value Index, RF is the Relative Frequency, RD is the Relative Density, and RC is the Relative Coverage.

2.5. Questionnaire Survey

Questionnaire surveys were also conducted in the study area to assess the effect of BTAP activities and major threats to medicinal plants. A total of 200 questionnaires were filled out by local communities to determine whether BTAP has a positive or negative effect on important medicinal plants. Of these, 150 questionnaires were completed by males, 35 by females, and 15 by local health healers in district Buner, Khyber Pakhtunkhwa, Pakistan, as shown in Figure 2.

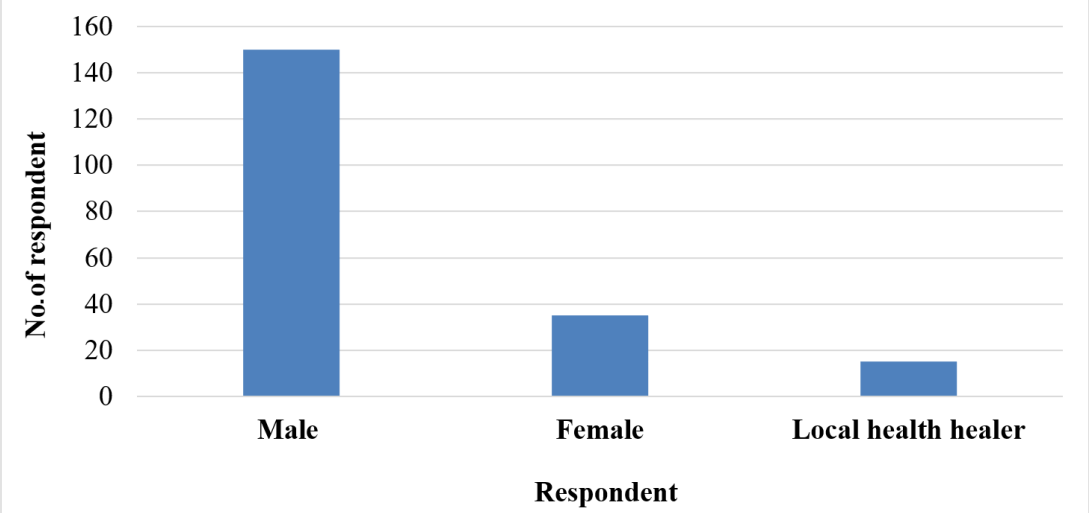


Figure 2. People were interviewed in the study area.

3. RESULT AND DISCUSSION

The present research focuses on the impact of BTAP intervention on important medicinal plants in the district of Buner, Khyber Pakhtunkhwa, Pakistan. During the field survey, the total number of medicinal plants recorded was 17,340 inside the closures. In contrast, in areas where no BTAP intervention occurred, the medicinal plants were counted at 1,457. The study involved multiple field trips to study sites to assess the effects of BTAP activities on medicinal plants. Additionally, questionnaires were administered to local communities to identify the major threats to medicinal plants and to gather their responses regarding BTAP activities.

3.1. Diversity of Important Medicinal Plants

The diversity of medicinal plants in District Buner was identified during the field survey. A total of 34 medicinal plant species were identified that belong to different families, as shown in Table 1. The species consisted of *Selaginella bryopteris, Salvia lanata, Rumex elipticus, Dodonaea viscosa, Cornus macrophylla, Olea europaea, Artemisia maritime, Berberis lycium, Indigofera heterantha, Plantago lanceolata, Mallotus philippinensis, Oxalis corymbosa, Viola surpersa, Xanthoxylum armatum, Rumex nepalensis, Mentha viridis, Mentha longifolia, Ficus carica, Justicia adhatoda, Cymbopogon citratus, Quercus*

incana, *Cannabis sativa*, *Paeonia emodi*, *Caralluma edulis*, *Coccinia indica*, *Punica granatum*, *Pistacia integerrima*, *Fumaria indica*, *Azadirachta indica*, *Solanum surattense*, *Echinops echinatus*, *Sageretia sagitifolia*, *Astragalus graveolens* and *Solanum nigrum*. Among them, some medicinal plant species are herbs, some are shrubs, and some belong to tree species.

Table 1. Total number of medicinal plant species inside and outside the closure.

Medicinal plant species	No of plants	
	Inside	Outside
Selaginella bryopteris	1291	83
Saliva lanata	379	63
Rumus elipticus	3141	268
Dodonaea vicose	1262	165
Cornus macrophylla	277	36
Olea europea	402	23
Artemisia maritime	691	118
Berberis lycium	2009	31
Indogofera heterantha	1768	19
Plantago lanceolata	455	39
Mallotus philipiriensis	789	53
Oxalis corymbosa	411	27
Viola surpens	348	29
Xanthoxyllum armatum	381	41
Rumex nepalensis	149	19
Mentha viridis	203	45
Mentha longifolia	163	24
Ficus carica	157	32
Justicia adhatoda	163	37
Cymbopogom citrus	800	16
Quercus incana	778	48
Canabis sativa	210	57
Paeonia emodi	147	21
Caralluma edulis	227	13
Coccinia indica	117	15
Punica granatum	67	11
Pistacia integerrima	46	15
Fumaria indica	89	12
Azadirachta indica	113	13
Solanum surrathensis	94	11
Echinops echinatus	39	26
Sagieearia sagitifolia	94	21
Astragalus graveolens	39	12
Solanum nigrum	41	14
Grand Total	17340	1457

3.2. Condition of Medicinal Plants Inside and Outside the Closure

The varieties of medicinal plants were identified in the study area. A total of 17,340 medicinal species were identified inside the closure, and outside the closure, a total of 1,457 species were identified that belong to different families as listed in Table 1. The sampling was carried out inside the closure for data collection, and the different medicinal plant species were identified, which are listed below species-wise in terms of relative density, relative cover, and relative frequency in percentage as shown in Table 2.

Table 2. The relative density, relative cover, relative frequency, and importance value index of medicinal plants inside and outside the closure.

Medicinal plant species	Relative density		Relative cover (%)		Relative frequency (%)		IVI	
	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
Selaginella bryopteris	6.87	0.44	7.39	0.17	3.12	0.46	5.79	0.36
Saliva lanata	2.02	0.34	1.74	0.11	4.05	0.65	2.60	0.36
Rumus elipticus	16.71	1.43	21.59	0.61	4.64	1.11	14.31	1.05
Dodonaea vicose	6.71	0.88	11.56	0.47	4.14	1.19	7.47	0.85
Cornus macrophylla	1.47	0.19	3.17	0.12	1.50	0.21	2.05	0.18
Olea europaea	2.14	0.12	5.53	0.11	1.61	0.37	3.09	0.20
Artemisia maritime	3.68	0.68	1.19	0.07	2.78	0.40	2.55	0.38
Berberis lyceum	10.69	0.16	13.81	0.05	4.22	1.21	9.57	0.47
Indigofera heterantha	9.41	0.10	8.10	0.02	4.31	1.30	7.27	0.47
Plantago lanceolata	2.42	0.21	1.04	0.02	2.36	0.28	1.94	0.17
Mallotus philipiriensis	4.20	0.28	3.61	0.09	3.12	0.28	3.64	0.22
Oxalis corymbosa	2.19	0.14	0.71	0.00	3.21	0.37	2.03	0.17
Viola surpens	1.85	0.15	0.60	0.00	1.42	0.19	1.29	0.11
Xanthoxyllum armatum	2.03	0.22	2.18	0.07	1.60	0.19	1.94	0.16
Rumex nepalensis	0.79	0.10	0.17	0.00	2.28	0.46	1.08	0.19
Mentha virdis	1.08	0.09	1.40	0.05	2.19	0.36	1.56	0.17
Mentha longifolia	0.87	0.13	1.31	0.05	1.57	0.19	1.25	0.12
Ficus caricus	0.84	0.17	0.90	0.04	1.86	0.28	1.20	0.16
Justicia adhatoda	0.87	0.20	0.37	0.00	2.03	0.22	1.09	0.14
Cymbopogom citrus	4.26	0.09	6.41	0.03	2.11	0.37	4.26	0.16
Quercus incana	4.14	0.26	1.78	0.01	2.35	0.84	2.76	0.37
Canabis sativa	1.12	0.33	0.72	0.03	2.28	0.56	1.37	0.31
Paeonia emodi	0.78	0.17	0.25	0.00	1.62	0.28	0.88	0.15
Caralluma edulis	1.21	0.07	0.39	0.00	2.36	0.37	1.32	0.15
Coccinia indica	0.62	0.09	0.54	0.00	1.43	0.28	0.86	0.12
Punica granatum	0.36	0.06	0.31	0.00	1.10	0.19	0.59	0.08
Pistacia integerrima	0.24	0.08	0.16	0.00	1.84	0.37	0.75	0.15
Fumaria indica	0.47	0.06	0.36	0.00	1.35	0.19	0.73	0.08
Azadirachta indica	0.60	0.07	0.13	0.00	2.78	0.65	1.17	0.24
Solanum surrathensis	0.50	0.06	0.11	0.00	3.46	0.42	1.36	0.16
Echinops echienthus	0.21	0.14	0.07	0.00	2.03	0.28	0.77	0.14
Sagieearia sagitifolia	0.50	0.11	0.11	0.00	3.12	1.11	1.24	0.41
Astragalus graveolens	0.21	0.06	0.09	0.01	2.11	0.65	0.80	0.24
Solanum nigrum	0.22	0.07	0.05	0.00	1.50	0.28	0.59	0.12
Grand total	92.25	7.75	97.83	2.17	83.46	16.54	91.18	8.82

3.3. Comparison Based on the Relative Density of Medicinal Plants Inside and Outside the Closure

The relative density of medicinal plants was determined using the above relative density formula. The *Rumus elipticus* exhibits the highest relative density, with 16.71% inside the closure and 1.43% outside the closure. Following this, *Berberis lycium* shows a relative density of 10.69% inside and 0.16% outside the closure. Similarly, *Indigofera heterantha* has a relative density of 9.41% inside and 0.10% outside the closure. The relative densities of various medicinal plants inside and outside the closure are summarized as follows: *Selaginella bryopteris* (inside 6.87%, outside 0.44%), *Artemisia maritime* (inside 3.68%, outside 0.63%), *Dodonaea viscosa* (inside 6.71%, outside 0.88%), *Salvia lanata* (inside 2.02%, outside 0.30%), *Xanthoxylum armatum* (inside 2.03%, outside 0.22%), *Cornus macrophylla* (inside 1.47%, outside 0.19%), *Olea europaea* (inside 2.14%, outside 0.12%), *Plantago lanceolata* (inside 2.42%, outside 0.21%), *Mallotus philippinensis* (inside 4.20%, outside 0.28%), *Oxalis corymbosa* (inside 2.19%, outside 0.14%), *Viola surpens* (inside 1.85%, outside 0.15%), *Rumex nepalensis* (inside 0.79%, outside 0.10%), *Mentha viridis* (inside 1.08%, outside 0.02%), *Mentha longifolia* (inside 0.87%, outside 0.13%), *Ficus carica* (inside 0.84%, outside 0.17%), *Justicia adhatoda* (inside 4.26%, outside 0.09%), *Cymbopogon citratus* (inside 4.26%, outside 0.09%), *Quercus incana* (inside 4.14%, outside 0.26%), *Cannabis sativa* (inside 1.12%, outside 0.30%), *Paeonia emodi* (inside 0.78%, outside 0.11%), *Caralluma edulis* (inside 1.21%, outside 0.07%), *Coccinia indica* (inside 0.62%, outside 0.08%), *Punica granatum* (inside 0.36%, outside 0.06%), *Pistacia integerrima* (inside 0.24%, outside 0.08%), *Fumaria indica* (inside 0.47%, outside 0.06%), *Azadirachta indica*

(inside 0.60%, outside 0.07%), *Solanum surrathensis* (inside 0.50%, outside 0.06%), *Solanum nigrum* (inside 0.22%, outside 0.07%), *Sagittaria sagittifolia* (inside 0.50%, outside 0.11%), *Astragalus graveolens* (inside 0.21%, outside 0.06%), and *Echinops echinatus* (inside 0.21%, outside 0.14%), as presented in Table 2 and Figure 3. The comparison of relative densities indicates that the density inside the closure is higher than outside the closure.

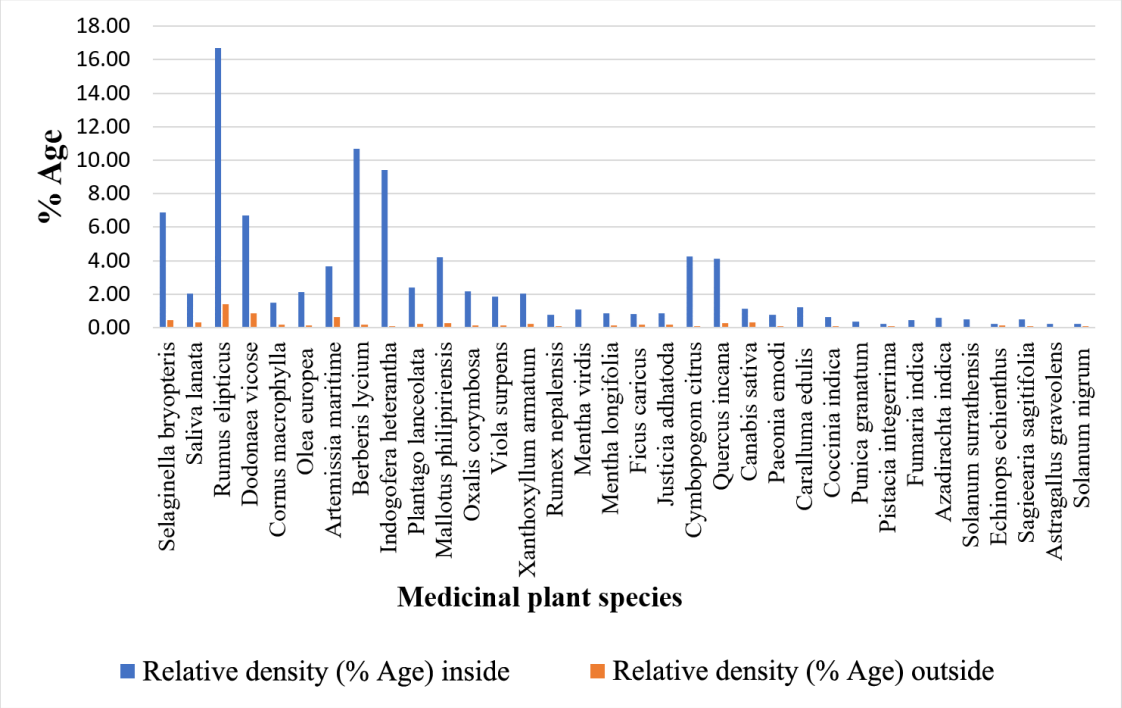


Figure 3. Relative density of Medicinal plants inside the Closure and outside the closure.

3.4. Comparison Based on the Relative Cover of Medicinal Plants Inside and Outside the Closure

The relative cover of medicinal plants in the study area was calculated using the above relative cover equation. The *Rumus elipticus* shows the highest relative cover (21.59%) inside the closure, and 0.61% outside the closure, followed by *Berberis lycium* inside (13.81%) and outside (0.053%), and *Dodonaea viscosa* inside (11.56%) and outside the closure (0.427%), respectively. The relative cover of medicinal plants such as *Selaginella bryopteris* inside (7.39%) and outside (0.166%), *Indigofera heterantha* inside (8.10%) and outside (0.022%), *Olea europaea* inside (5.53%) and outside (0.105%), *Mallotus philipiriensis* inside (3.61%) and outside (0.091%), *Salvia lanata* inside (1.74%) and outside (0.108%), *Cornus macrophylla* inside (3.17%) and outside (0.124%), *Artemisia maritime* inside (1.19%) and outside (0.068%), *Plantago lanceolata* inside (1.04%) and outside (0.022%), *Mentha viridis* inside (1.40%) and outside (0.052%), *Mentha longifolia* inside (1.33%) and outside (0.055%), *Quercus incana* inside (1.78%) and outside (0.005%), *Oxalis corymbosa* inside (0.71%) and outside (0.003%), *Viola surpens* inside (0.60%) and outside (0.003%), *Xanthoxylum armatum* inside (2.18%) and outside (0.070%), *Rumex nepalensis* inside (0.17%) and outside (0.002%), *Ficus carica* inside (0.90%) and outside (0.042%), *Justicia adhatoda* inside (0.37%) and outside (0.004%), *Cymbopogon citratus* inside (6.41%) and outside (0.027%), *Cannabis sativa* inside (0.71%) and outside (0.033%), *Paeonia emodi* inside (0.25%) and outside (0.002%), *Caralluma edulis* inside (0.39%) and outside (0.002%), *Coccinia indica* inside (0.54%) and outside (0.003%), *Punica granatum* inside (0.31%) and outside (0.003%), *Pistacia integerrima* inside (0.16%) and outside (0.002%), *Fumaria indica* inside (0.36%) and outside (0.001%), *Azadirachta indica* inside (0.13%) and outside (0.001%), *Solanum surrathensis* inside (0.11%) and outside (0.001%), *Echinops echinatus* inside (0.07%) and outside (0.001%), *Sagittaria sagittifolia* inside (0.11%) and outside (0.005%), *Astragalus graveolens* inside (0.09%) and outside (0.007%), and the relative cover of *Solanum nigrum* was inside (0.05%) and outside (0.002%), as shown in Table 2 and Figure 4. The comparison indicates that the relative cover inside the closure is higher than outside the closure.

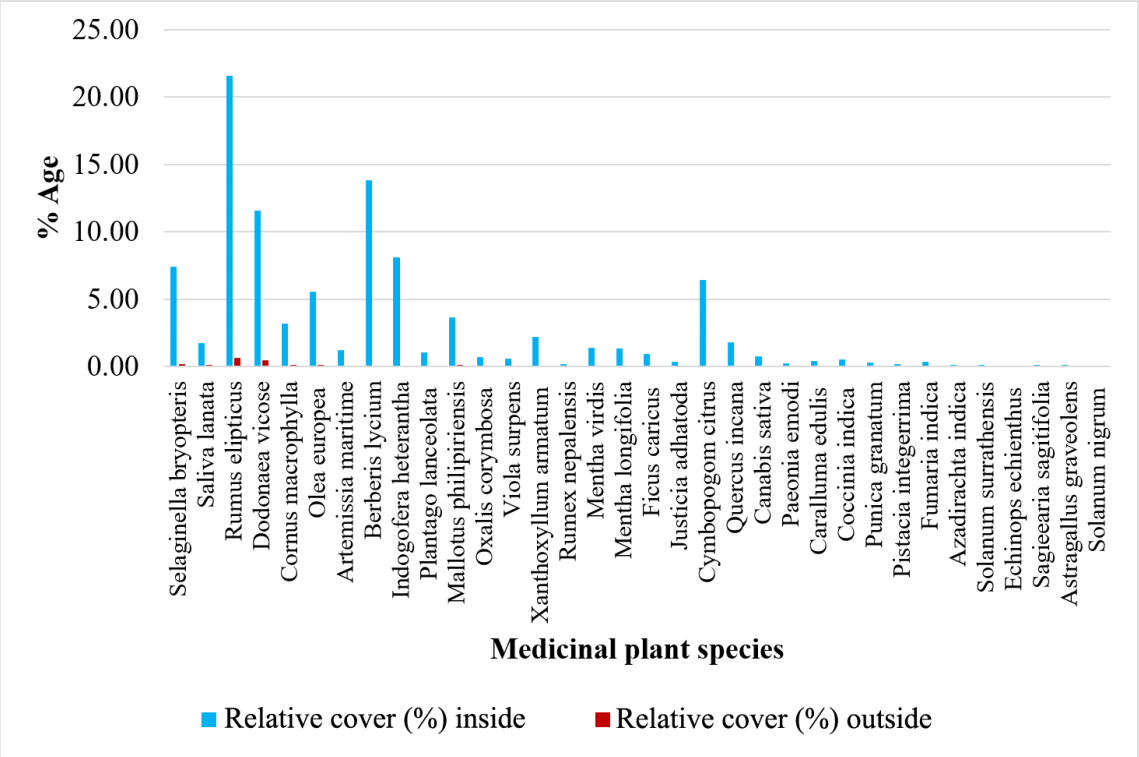


Figure 4. Relative cover of Medicinal plants inside and outside the closure.

3.5. Comparison Based on the Relative Frequency of Medicinal Plants Inside and Outside the Closure

The relative frequency of medicinal plants in the study area was calculated using the relative frequency equation as discussed in the methodology. *Rumus elipticus* shows the highest relative frequency (4.64%) inside the closure, and outside the closure was 1.11%. Followed by *Indigofera heterantha* inside (4.39%) and outside (1.30%), and *Salvia lanata* inside (4.05%) and outside (0.65%). The relative frequency of medicinal plant *Selaginella bryopteris* inside the closure was 3.12%, and outside was 0.46%. *Dodonaea viscosa* had a relative frequency of 4.14% inside and 1.39% outside. *Berberis lycium* showed 4.22% inside and 1.21% outside. *Mallotus philipiriensis* had 3.12% inside and 0.28% outside. *Oxalis corymbosa* was recorded at 3.21% inside and 0.37% outside. *Solanum surattensis* showed 3.46% inside and 0.46% outside. *Sagieearia sagitifolia* had 3.12% inside and 1.11% outside. *Echinops echinatus* was 2.03% inside and 0.28% outside. *Astragalus graveolens* showed 2.11% inside and 0.65% outside. *Plantago lanceolata* had 2.36% inside and 0.28% outside. *Rumex nepalensis* was 2.28% inside and 0.46% outside. *Artemisia maritime* recorded 2.78% inside and 0.50% outside. *Quercus incana* showed 2.45% inside and 0.84% outside. *Justicia adhatoda* had 2.03% inside and 0.28% outside. *Mentha viridis* was 2.19% inside and 0.46% outside. *Cannabis sativa* showed 2.28% inside and 0.56% outside. *Caralluma edulis* had 2.36% inside and 0.37% outside. *Azadirachta indica* recorded 2.78% inside and 0.65% outside. *Cornus macrophylla* was 1.60% inside and 0.19% outside. *Mentha longifolia* showed 1.77% inside and 0.19% outside. *Olea europea* had 1.69% inside and 0.37% outside. *Viola surpens* was 1.52% inside and 0.19% outside. *Xanthoxylum armatum* recorded 1.60% inside and 0.19% outside. *Ficus carica* showed 1.86% inside and 0.28% outside. *Cymbopogon citratus* had 2.11% inside and 0.37% outside. *Paeonia emodi* was 1.60% inside and 0.28% outside. *Coccinia indica* recorded 1.43% inside and 0.28% outside. *Punica granatum* showed 1.10% inside and 0.19% outside. *Solanum nigrum* had 1.60% inside and 0.28% outside. *Fumaria indica* was 1.35% inside and 0.19% outside. The relative frequency of *Pistacia integerrima* was 1.94% inside and 0.46% outside, as shown in Table 2 and Figure 5. Comparing the relative frequencies inside and outside the closure, the results indicate that the relative frequency is higher inside the closure.

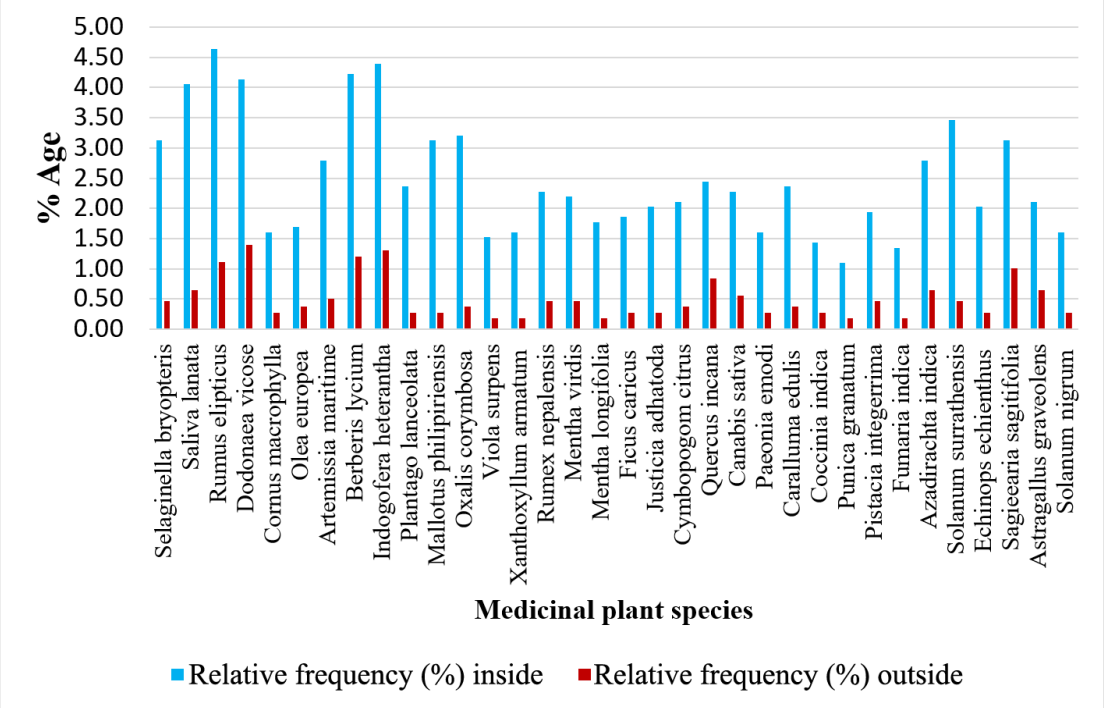


Figure 5. Relative frequency of Medicinal plants inside and outside the closure.

3.6. Importance Value Index

The IVI was calculated both inside and outside the closure for individual medicinal plant species as presented in Table 2. The IVI of inside and outside the closure results revealed that *Rumus elipticus* shows a higher IVI value (14.31%) inside the closure, while outside the closure it was 1.05%, followed by *Berberis lycium* which was inside (9.57%) and outside (0.47%), *Indigofera heterantha* which was inside (7.27%) and outside (0.47%), respectively. The IVI of *Dodonaea viscosa* inside the closure was 7.47% and outside was 0.85%. *Selaginella bryopteris* had inside and outside IVI values of 5.79% and 0.36%, respectively. *Cymbopogon citratus* showed inside and outside IVI values of 4.26% and 0.16%. *Mallotus philipiriensis* had inside and outside IVI values of 3.64% and 0.22%. *Olea europaea* showed inside and outside IVI values of 3.09% and 0.20%. *Quercus incana* had inside and outside IVI values of 2.76% and 0.37%. *Salvia lanata* showed inside and outside IVI values of 2.60% and 0.36%. *Artemisia maritime* had inside and outside IVI values of 2.55% and 0.38%. *Cornus macrophylla* showed inside and outside IVI values of 2.05% and 0.18%. *Oxalis corymbosa* had inside and outside IVI values of 2.03% and 0.17%. *Xanthoxylum armatum* showed inside and outside IVI values of 1.94% and 0.16%. *Plantago lanceolata* had inside and outside IVI values of 1.94% and 0.17%. *Mentha viridis* showed inside and outside IVI values of 1.55% and 0.17%. *Cannabis sativa* had inside and outside IVI values of 1.37% and 0.30%. *Solanum surattense* showed inside and outside IVI values of 1.36% and 0.31%. *Caralluma edulis* had inside and outside IVI values of 1.32% and 0.15%. *Viola surpers* showed inside and outside IVI values of 1.29% and 0.11%. *Mentha longifolia* had inside and outside IVI values of 1.25% and 0.12%. *Sagittaria sagittifolia* showed inside and outside IVI values of 1.24% and 0.41%. *Ficus carica* had inside and outside IVI values of 1.20% and 0.16%. *Azadirachta indica* showed inside and outside IVI values of 1.17% and 0.24%. *Justicia adhatoda* had inside and outside IVI values of 1.09% and 0.14%. *Rumex nepalensis* showed inside and outside IVI values of 1.08% and 0.19%. *Paeonia emodi* had inside and outside IVI values of 0.88% and 0.15%. *Coccinia indica* showed inside and outside IVI values of 0.86% and 0.12%. *Astragalus graveolens* had inside and outside IVI values of 0.80% and 0.24%. *Echinops echinatus* showed inside and outside IVI values of 0.77% and 0.14%. *Pistacia integerrima* had inside and outside IVI values of 0.75% and 0.15%. *Fumaria indica* showed inside and outside IVI values of 0.73% and 0.08%. *Solanum nigrum* had inside and outside IVI values of 0.59% and 0.12%, and the IVI value of *Punica* was inside the closure 0.59% and outside 0.08%, as presented

in Table 2. By comparing the IVI values of the closure and outside the closure, the results show that inside the closure, the IVI value is higher than outside the closure.

3.7. Comparison of Medicinal Plants Inside and Outside Based on a Total of Relative Density, Relative Cover, and Relative Frequency of Medicinal Plants

The sum of all relative density, relative cover, and relative frequency of a species inside and outside the closure can be seen in Figure 6. The total percentage of relative density of a species inside the closure was higher (92.25%) than outside the closure (7.75%). Likewise, the relative cover of medicinal plant species was also higher (97.83%) inside the closure, with 2.17% recorded outside the closure in the study area. Similarly, the relative frequency of medicinal plant species was higher (83.46%) inside the closure compared to outside (16.54%). The overall IVI value of important medicinal plants inside the closure was 91.18%, while outside the closure it was 8.82%. The comparison of the overall results—considering the number of medicinal plants, relative density, relative cover, and relative frequency—indicates that the BTAP project has had a very positive impact. These parameters were higher in areas where BTAP activities were implemented compared to areas without such interventions. The closure demonstrated positive results because activities such as grazing, browsing, collection of medicinal plants, and other activities were completely prohibited inside the closure. Conversely, outside the closure, all activities were permitted, which resulted in a minimal number of medicinal plants compared to inside the closure.

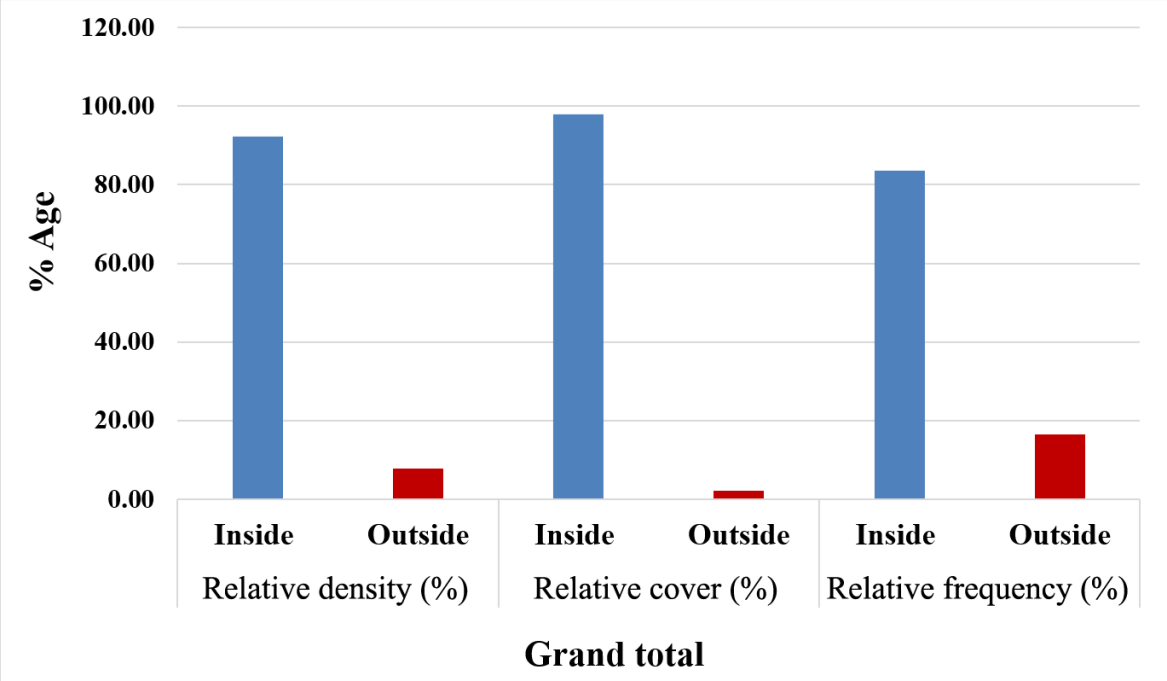


Figure 6. Overall relative density, relative cover, and relative frequency of medicinal plants inside and outside the closure.

3.8. Response of Local Communities to the BTAP Project

The questionnaire survey was conducted in local communities, with approximately 200 questionnaires completed by local residents. The respondents included males, females, and local health healers, aiming to gather community responses regarding the BTAP project. The majority of respondents expressed positive opinions about the BTAP project, while some held negative views. Specifically, 138 males, 28 females, and 13 local health healers responded positively, whereas about 12 males, 7 females, and 2 local health healers responded negatively about the project as can be seen in Figure 7.

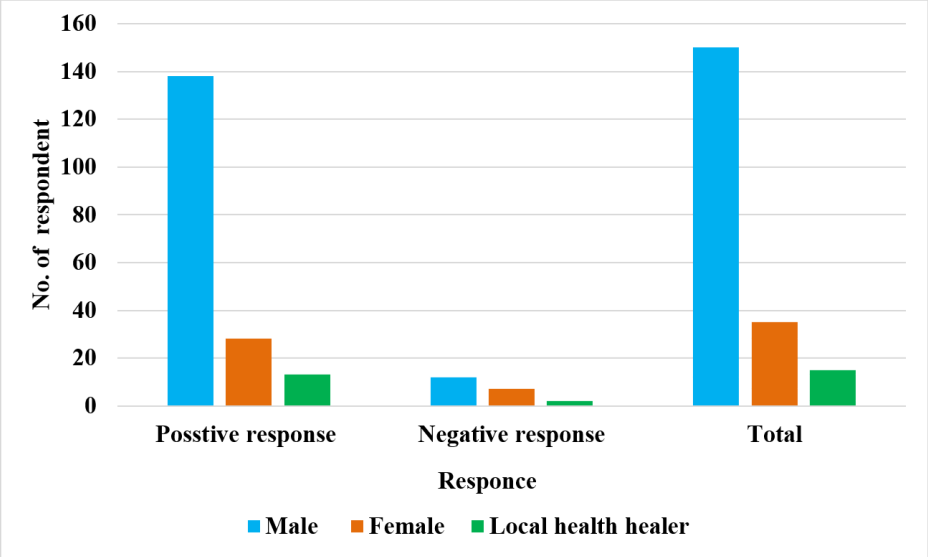


Figure 7. Response of local people in the study area.

3.9. Major Threats to Medicinal Plants in the Study Area

The present study provides information about the impact of BTAP activities on medicinal plants of the Buner Forest Division, Khyber Pakhtunkhwa, Pakistan. The total number of medicinal plants was recorded inside the enclosure as 17,340, and outside the enclosure as 1,557. Buner is one of the most important sites for a tremendous diversity of medicinal plants used by the local people. During the questionnaire survey, some major threats to important medicinal plants were identified, such as over-harvesting, fire, grazing, habitat destruction, and natural disasters. One of the main issues was improper collection methods. Among respondents, 83 people identified overharvesting as the major threat to medicinal plants in the study area, while 55 respondents cited grazing of local animals. Eighteen respondents stated that the collection methods of medicinal plants are not proper; they collect the plants not in a proper way, at an improper time, and with inadequate tools. Additionally, 10 people responded that fire poses a threat, and 4 people indicated that natural disasters also threaten medicinal plants in the study area, as can be seen in Figure 8.

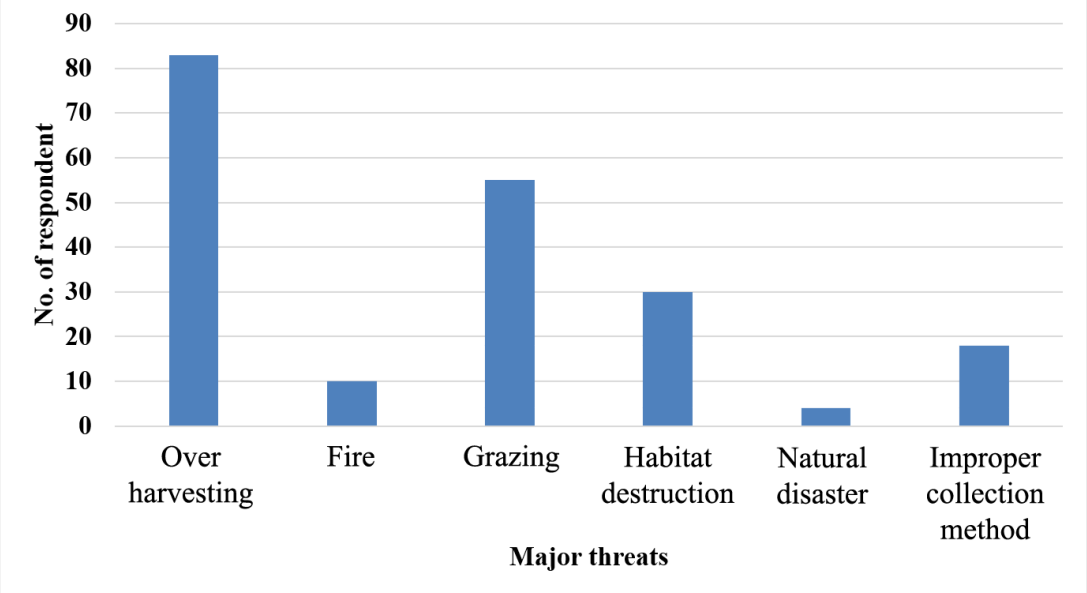


Figure 8. Major threats to medicinal plants in the study area.

4. DISCUSSION

The present research examines the effect of BTAP intervention on important medicinal plants in the district of Buner, Khyber Pakhtunkhwa, Pakistan. During the field survey, a total of 17,340 medicinal plants were recorded inside the closures, whereas 1,457 medicinal plants were counted in areas where no BTAP intervention occurred. The questionnaire revealed that the majority of respondents had positive responses regarding the BTAP project, although some expressed negative opinions. Specifically, 138 males, 28 females, and 13 local health healers responded positively, while 12 males, 7 females, and 2 local health healers responded negatively. The survey also identified several major threats to medicinal plants, including over-harvesting, fire, grazing, habitat destruction, natural disasters, and improper collection methods. Various comprehensive research studies have been conducted on BTAP for different purposes [36-42]. The results indicate that the relative density of medicinal plant species was significantly higher inside the enclosure (92.25%) compared to outside (7.75%). Similarly, the relative cover of medicinal plants was greater within the enclosure (97.83%) than outside it (2.17%). The relative frequency of medicinal plant species also followed the same trend, with a higher value inside the enclosure (83.46%) versus outside (16.54%). These higher values inside the enclosure can be attributed to strict restrictions on grazing, browsing, cutting, and plant collection activities. Globally, there is a substantial amount of research conducted on the status, cultivation, collection, consumption, threats, ethnobotanical value, assessment, and antibacterial activities of medicinal plants [16, 24, 43-52]. There are numerous medicinal plants in the district of Buner, and several comprehensive studies have been published on medicinal plants in the current study area. Jan et al. [53] conducted a comprehensive study on the ethnomedicinal use of medicinal plants employed to treat dental diseases by the indigenous population of District Buner, Pakistan. Jan et al. [54] carried out another study on an ethnomedicinal survey of medicinal plants in Chinglai Valley, Buner District, Pakistan. Jan et al. [55] conducted a similarly comprehensive study in district Buner on ethnomedicinal assessment of the plants used for gynecological diseases by the indigenous community. Likewise, another study was conducted on the Quantitative Ethnobotanical Study of Indigenous Knowledge of Medicinal Plants Used by the Tribal Communities of Gokand Valley, District Buner, Khyber Pakhtunkhwa, Pakistan [56]. Recently, another study was conducted on medicinal plants and related ethnomedicinal knowledge in the communities of Khadukhel Tehsil, Buner District, Pakistan [57]. Another study was also conducted by Hamayun et al. [58] in District Buner, NWFP, Pakistan, common medicinal folk recipes are documented. A study was also conducted on ethnobotanical aspects of some plants from Chagharzai Valley, District Buner, Pakistan.by Sher et al. [59]. Another study was conducted by Zaman et al. [60] on the traditional knowledge of plant resources of Ashezai and Salarzai valleys, District Buner, Pakistan. The study was carried out by Khan et al. [61] on the ethnobotany of Gokand Valley, District Buner, Pakistan. Shinwari and Qaiser [62] conducted a comprehensive study of indigenous knowledge of medicinal plants in Chagharzai Valley, District Buner, Pakistan. There have been many studies related to medicinal plants, but no study has been carried out on community perception and assessment of Billion Tree Afforestation Project activities on important medicinal plants in Buner Forest Division, Pakistan. The relative density, relative cover, and relative frequency of a species inside the closure were higher than outside the closure in the study area. The number of medicinal plants, relative density, relative cover, and relative frequency were higher in areas where BTAP activities were implemented compared to areas without BTAP project intervention. The closure demonstrated good results because inside the closure, grazing, browsing, collection of medicinal plants, and any other activity were completely prohibited. Outside the closure area, all activities were allowed, which is why the number of medicinal plants was lower outside the closure. Due to BTAP intervention, medicinal plants were conserved in the study area. Similarly different studies have been conducted all over the on the conservation of medicinal plants such as Dhar et al. [63] Setting priorities for conservation of medicinal plants in Indian Himalaya. In Rajasekharan and Ganeshan [64] conducted a study on the Conservation of medicinal plant biodiversity Indian perspective. The Bhakat and Pandit [65] surveyed the role of a sacred grove in the conservation of medicinal plants. Okigbo et al. [66] conducted a study on biodiversity and conservation of medicinal and aromatic

plants in Africa. In 2009, a study was carried out on the role of traditional management practices in enhancing the sustainable use and conservation of medicinal plants in the West Usambara Mountains, Tanzania by Msuya and Kideghesho [67]. Shinwari and Qaiser [62] conducted a study on efforts on the conservation and sustainable use of medicinal plants in Pakistan. Kasagana and Karumuri [68] study on conservation of medicinal plants (past, present & future trends).

A study was carried out on the conservation of medicinal plants and their sustainable utilization through in vitro technology in Western Ghats, India [69]. A similar study on conservation and sustainable use of medicinal plants: problems, progress, and prospects Chen et al. [24]. A study on medicinal plants conservation and development areas (MPCDAs)-An initiative towards conservation of medicinal plants Biswas et al. [70]. Kadam and Pawar [71] also review the conservation of medicinal plants. A comprehensive study was conducted on the exploration of medicinal plants and their conservation status at higher altitudes of District Shangla, Khyber Pakhtunkhwa, Pakistan [72]. The Tali et al. [73] conducted a study on prioritizing conservation of medicinal flora in the Himalayan biodiversity hotspot, using an integrated ecological and socioeconomic approach. Likewise, numerous studies have been conducted on medicinal plants conservation and protection [70, 74-78]. A comprehensive study in line with our study was carried out by Poudyal et al. [79] on impacts of forest management on tree species richness and composition, and the assessment of forest management regimes in Tarail and Scape, Nepal. In comparison to alternative management regimes, the results demonstrated that regularly harvested community forests could be effective in supporting tree species richness and composition.

The findings supported the prediction that both high and low levels of forest disturbance do not sustain tree species diversity and composition. Similarly, our study found that the majority of respondents had positive responses about the BTAP project, while some had negative responses.

The results demonstrated that proper management has a very positive impact on the conservation and protection of biodiversity, specifically medicinal plants in the study area. Prophet Muhammad (SAW), in his practices and various Hadiths, attached great importance to planting trees, protecting existing ones, planting forests, and conserving existing ones. Our study serves as the baseline study for further research on the impact assessment of BTAP on important medicinal plants. So far, no one has conducted a study on the assessment of the Billion Tree Afforestation Project activities on important medicinal plants in Pakistan.

5. CONCLUSIONS AND RECOMMENDATIONS

The findings of this study indicate that the area requires significant attention from the government, non-governmental organizations, and local communities for plant conservation and protection. Due to the closure, there has been substantial regeneration of medicinal plants and trees. Protecting our natural heritage, particularly medicinal plants and trees, is essential because they hold immense value in our daily lives. These plants provide critical resources for traditional and modern medicine, contribute to health, nutrition, and overall well-being. Preserving this biodiversity ensures that future generations can continue to benefit from nature's healing gifts. Data analysis shows that medicinal plants are increasing in the BTAP intervention area compared to areas where no BTAP activities have been implemented.

The results reveal a significant difference between closure and non-closure areas, with the number of medicinal plants inside the closure being much greater than outside. The number of medicinal plants in the closure area is approximately twelve (12) times higher than outside. Accordingly, BTAP has a very positive impact on the natural regeneration of important medicinal plants. The local community also suggests that BTAP positively influences natural regeneration. It is highly recommended to create awareness about protection, conservation, sustainable use, collection, processing, and post-harvest treatment of crude drugs derived from medicinal plants.

Funding: This study received no specific financial support.
Institutional Review Board Statement: The study involved minimal risk and adhered to ethical guidelines for social science fieldwork. Formal approval from an Institutional Review Board was not required under the policies of the Pakistan Forest Institute (PFI), Peshawar, Khyber Pakhtunkhwa, Pakistan. Informed verbal consent was obtained from all participants prior to the interviews. Participation was voluntary, and all responses were anonymized to ensure confidentiality.
Transparency: The author states that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The author declares that there are no conflicts of interest regarding the publication of this paper.

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