# The Effect of Medium-term Protection on the Abundance and Diversity of Natural Flora in District Kohat, Pakistan

**Muhammad Zamin**
Kohat University of Science and Technology
**Muhammad Adnan** (ghurzang@hotmail.com)
Kohat University of Science and Technology
**Shaheen Begum**
Fatima Jinnah Women University
**Waheed Murad**
Abdul Wali Khan University
**Sardar Khan**
University of Peshawar

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## Abstract

This study was conducted to investigate the effects of human disturbances on plant abundance and diversity and to suggest conservation measures in District Kohat, Pakistan. A total of 25 plots were randomly selected for each type of land-use to assess the ecological status, plant abundance, and plant diversity. Overall, 67 plant species were reported, including 39, 18, and 10 herbs, shrubs, and trees, respectively. In trees, *Sideroxylon mascatense* (A. DC.) T.D. Penn., *Olea europaea* L., *Dalbergia sissoo* DC., and *Acacia modesta*Wall., had significantly higher basal area, diameter at breast height and diversity indices. As for shrub species, *Withania coagulans* (Stocks) Dunal, *Gymnosporia royleana* Wall. ex M.A. Lawson, and *Rhazya stricta* Decne., had the highest species density. Data regarding herb species showed that *Euphorbia serrata* L., *Sonchus arvensis* L., *Peganum harmala* L., and *Amaranthus viridis* L., have attained maximum diversity and coverage. As per the IUCN red list, *W. coagulans*(critically endangered) and *G. royleana* (nearly threatened) along with other species of international, national, and local importance were disappearing from the unprotected area. In conclusion, the protected area exhibits a higher abundance and diversity of plants compared to unprotected area, highlighting the positive impact of conservation efforts on ecological richness.

## INTRODUCTION

In Pakistan (4.6 Mha) and throughout the temperate zone, the forest cover is decreasing rapidly at an alarming rate of 3.1% per year due to unsystematic extinctions of economically important plant species, resulting in the disappearance of forests by 2035 [1]. A recent report by the Worldwide Conservation Planning of Biodiversity said over 15,000 medicinal and aromatic plants are endangered [2]. In addition to meeting primary healthcare needs, forest clearing leads to a higher percentage of medicinal plants exported to neighboring countries for easy cash [3]. Agricultural, forestry, herding, and ethnobotanical practices may pose alarming threats to plant diversity and abundance. The disappearance of medicinally important plant species and the spatial withdrawal of forests are threatening global abundance and diversity. As per [4,5] once rare species have become extinct, they take longer to regenerate than the common species. Earlier studies have also concluded that anthropogenic disturbances have a negative feedback cycle that adversely affects plant species, saplings, and seeding biodiversity [6]

The vegetation of District Kohat is favored by the most conducive hot and semi-arid climatic conditions, but unfortunately, it faces incredible man-made, natural, and environmental calamities. The residents of the study area as well as Internally Displaced Persons (IDPs) face argumentative challenges, such as irregular wellbeing services, poor educational opportunities, and squandering income ways. Plant species are the only discreet and readily accessible alternative to financial and health-related issues in the rural areas of the research region. According to edaphology and literature, the soils of the Kohat region are fertile; thus, the region provides a favorable and fruitful environment for cultivating and conserving medicinal and aromatic plants. Furthermore, a geological survey revealed clay, silt, gypsum, and limestone in the soil of Kohat, suggesting a relatively favorable environment for plant growth [7].

Until a few decades ago, Kohat had an impressive vegetation cover, but as indigenous people have increasingly focused on urban life, as well as IDPs have been displaced and settled in Kohat, native plant species are disappearing at an incredible rate and invasive species are emerging. Increasing urbanization is causing native plants to be replaced by weedy exotic species [8], which may result in local extinctions of medicinal plants. Anthropogenic activities may greatly impact ecological functions, which could be restored if a regenerative area is protected [9]. Even though some of these imperative features have not been adequately addressed and no detailed work has been carried out in this area. We therefore conducted ecological assessment and conservation in the wild protected area of Kohat University of Science and Technology (Fig. 1C) and its surroundings. The study aimed to determine the following objectives: (1) to assess the vegetation abundance and diversity between protected and unprotected areas (2) to determine how soil influences plant diversity and abundance across both land-use types and (3) to examine the current threats to medicinal plants and their potential for recovery under regeneration and conservation.

## MATERIALS AND METHODS

## • The study area

The present study was conducted near the Indus Highway Chowk Jarma, Kohat, Khyber Pakhtunkhwa in the northern part of Kohat city (Fig. 1A). Kohat covers an area of 983 sq. miles [10]. In terms of elevation, Kohat is approximately 1768 feet above sea level, and its population is 169,003. It is located between 32° 47' and 33° 53' from the north latitude and 70° 34' from the east longitude (Fig. 1B). The climate in the area is humid, temperate, and clear, and it varies from hot and long summers to cold and short winters. In the summer season, the average rainfall is approximately 638 mm with maximum humidity, and the minimum rainfall (2 mm) is recorded in the dry month of December [11]. While rain falls throughout the year, August is the wettest and rainiest month, with an average of 114 mm; the highest rainfall in winter happens in March. The climate in June to January is moderately hot and humid with fluctuations in temperature between 40 ºC -50 ºC and 27 ºC to 06 ºC and 08 ºC. According to an investigation [12], the soils in District Kohat range from clay to sandy loam and have an alkaline pH. In general, soils in the district are shallow, calcareous, and containing little organic matter. A total of 67 native plant species have been recorded, spread across 10 trees, 18 shrubs, and 39 herbs respectively. As typical vegetation, the area comprises *A. nilotica, A. modesta, Z. nummularia, S. mascatense, O. europaea*, and other xerophytes. Tangi Banda and Kharot Abad, located around the study area, are home to approximately 45,000 people. In addition, fuel wood consumption (25%), fodder consumption (25%), and medicinal collection (90%) have all been observed [13]. Plant specimens were identified, recommended, and confirmed using the online assistance of Flora of Pakistan, The Plant List as well as the taxonomic expertise of Department of Botany, KUST, and Peshawar University. An herbarium card is made of each pressed specimen and displayed in the botany department's herbarium.

## • Study land use types and plot selection

Two land-use types have been differentiated based on conservation and regeneration for the assessment of ecological aspects and vegetation structures within the northern wild extremity of KUST and its outlying localities. Since 2005, the wild area (so called protected area) has been preserved by semi-government authorities, excluding human access to recreation, fodder, medicinal plant collection, and livestock grazing. Plant diversity and natural resources are being replenished by well-organized, reliable, and durable fencing (barbed wire), which protects biodiversity from human invasion. The protected area has been fenced and kept out of community reach for almost two decades. In contrast, the unprotected area was situated near members of the community and was extensively consumed because of a lack of safety measures. A restored forest managing system could also contribute to both producing wood and preserving the environment [13]. Ecological data was observed and collected by visiting both land-use types concurrently.

To regenerate and restore degraded areas, a range of methods can be employed. These include introducing new plant species or restoring the native species through artificial means. Seedlings and saplings of species of *A. modesta, D. sissoo, O. ferruginea* and *E. camaldulensis* have been cultivated in the planned protected area. Despite fencing and planting for two decades, the degraded area has started to improve spatially. According to the same results of the plantation experiment, degraded areas can easily be restored by planting native plant species [14]. A man-made plantation could be used for various purposes, like controlling soil erosion, stopping desertification, and protecting slopes. This regeneration of the study area also serves as an in-situ conservation program for specific species of *A. modesta, D. sissoo, O. ferruginea, and E. camaldulensis.*

# • Vegetation inventory and assessment of abundance and diversity

Twenty-five plots were designed as sampling tools for each protected and unprotected area (Fig. 1C). The abundance and diversity of vegetation at regular intervals in both land-use types were determined using transects and quadrates as sampling tools. Further, these sampling tools were divided into three sub-plots to assess variations in tree, shrub, and herb species [15]. Accordingly, the quadrates were calculated to be {10m × 10m} for tree species, {5m × 5m} for shrub density, and {2.5m × 2.5m} for herb density (Fig. 1D). To determine which tree species, dominate each plot, it was calculated the Basal Area (BA) from the diameter circumference of the individual tree at diameter breast height (DBH), using the formula; [$\pi\times(\frac{\mathrm{DBH}}{2})^2$] exercised by [16]. According to [17], the DBH of an individual tree measured 4.5 feet or 1.35 meters above the ground. In both cases, the DBH and basal area (BA) were measured in centimeters and square meters, respectively. A quadrate plot per land-use type was surveyed to determine the average number and thickness of each plant species. In the average values across all quadrate samples on protected area, there is an excessive concentration of plants, indicating the number of plants in proportion to the quadrate area. Using the following formula population measurement can be estimated:

$N = (\frac{\mathrm{A}}{\mathrm{a}}) \times n$ Where.

N = estimated size of total population

A = total area

a = area of the quadrate

n = number of individuals per quadrate

Plants diversity and species richness of specific species were determined by way of making use of an easy technique of counting the variety of species in every quadrate, and technique to show the alternate in variety.

A variety of diversity indices, including those developed by Simpson and Shannon in [18,19], were used to evaluate the composition and diversity of trees, shrubs, and herbs within the communities. The Simpson's diversity index (D) is a measure of biological diversity which develops the probability of any two individuals (number and abundance of species) being selected from the considerable community that is associated with different species of plants. The following formula can be used to determine the Simpson's diversity index for a particular community:

$$\mathbf{D = 1-}\sum \frac{n(n-1)}{N(N-1)}$$

D = the Simpson's diversity index

n = the number of individuals of a particular plant species

N = the number of individuals of all plant species

According to the Shannon Index (H), it can be concluded that all plant species were represented in a sample and are sampled at random. This index widely used to compare vegetation diversity between different habitats [20].

A Shannon-Wiener Index, the most used index in ecological studies, is used to evaluate the diversity of plant species in a community according to the following formula based on the abundance of the plant species: $H\acute{} = \sum_{\mathrm{i}=1}^{\mathrm{S}} pi \mathrm{In} pi$

Where, $H\acute{}$ = the Shannon Diversity Index.

*pi* = relative amount of each plant species *i* in the quadrate

ln *pi* = is the natural logarithm of this proportion

$\sum$ = sum from species *i* to S

S = number of species encountered

In a sample, finding a single individual does not necessarily indicate the presence of many individuals of a species. In most cases the Shannon Index value ranges between 1.5 and 3.5, rarely exceeding 4.5, whereas 4.6 values suggest that the number of plants is distributed equally among all the species of plants.

# • Rapid Vulnerability Assessment

A rapid vulnerability assessment was performed using an approach certified to Cunningham [21]. Individual species vulnerability is assessed using a set of criteria of sustainability, including habit/life form, habitat, parts used, season of collection, use values, population size, regeneration status, threat status/notional conservation. For every decisive factor (criterion), a score ranging from 1 to 6 (minimum score indicates high and maximum score indicates low vulnerability) was assigned for all the reported species (Table 6). This information was gathered from a variety of sources, including interviews with locals, secondary literature, survey results, and regional flora. A final threat score was calculated in the exploration step by counting all the scores for each parameter and incorporating them into a single score. A vulnerability calculation was performed on the species collected to categorize them into the following groups: highly threatened (1–19), moderately threatened (20–30), and less threatened (30–50).

# • Review Data Collection

The data regarding the vulnerability and conservation status of the reported plant species was collected from different articles and research papers, using various search engines, including Google Scholar, Sci-Hub, Pub Med, Scopus, and Web of Science. This information was gathered exclusively from articles and research papers published in highly regarded English-language journals. Furthermore, only those medicinal and aromatic plants that were internationally, regionally, or nationally declared as endangered, critically endangered, or nearly threatened were included in the investigation. The data search was conducted using a range of keywords, including anthropogenic activities, conservation status, vulnerability assessment, plant abundance and diversity, protected areas, unprotected areas, and regeneration. Following various studies of the literature, the data was organized, processed, and presented in Table 7 using MS-Office 2007.The online botanical databases, including Flora of Pakistan, Tropicos, Global Tree Search, BGCI Databases, and the IUCN Red List of Threatened Species were utilized to determine the international conservation status and taxonomic categorization of the documented species.

# • Statistical analysis and Soil Sampling

In both the protected and unprotected regions of District Kohat, five samples with a depth of 15–20 cm were taken for soil analysis. The procedures described by Hussain [22], were used to calculate the total amounts of calcium carbonate ($CaCO_3$), organic matter (OM), nitrogen ($N_2$), phosphorus (P), and potassium (K). Electrical conductivity (EC) and pH were calculated from soil-water extracts using conductivity and pH meters.

The Mann-Whitney U test was applied to calculate differences between the two types of land use in terms of stem density, species richness, and diversity indices. The significance of the variation in soil variables in unprotected and protected areas was assessed by comparing both variables. Accordingly, Pearson's correlation Coefficient (r) or Pearson product-moment correlation coefficient (PPMCC), was conducted using Microsoft Excel and SPSS version 16.0 [23].

## RESULTS

- **Ecological aspects, vegetation structure and diversity in both land-use types**

The study involved 25 quadrate plots within each protected and unprotected area and within an altitudinal range of 504 to 558 masl, located within 81.23 ha and > 81.23 ha of sample area. In both cases, the land use type was oriented toward the north-south slope of the mountains with 45% and 38% of their northern aspects, respectively. A total of 67 medicinal and aromatic plant species were found on both land-use study plots, including 10 trees, 18 shrubs, and 39 herbs. Among tree species with diameter at breast height of ≥12 cm in both land-use types, six species were common, while four species were found only in the protected area. As for shrubs, there were only 12 common species out of 18, while the rest 06 species were found in protected area only. Results of the present study revealed that the area under protection occupied highest herbs density and coverage than unprotected area, with 38 different species presents compared to 11 missing in unprotected region. The protected area, functioning as an ecological conservation park, has been cultivated with four different sapling and seedling tree species which have regenerated quickly (Fig.2).There was a fourfold difference between the tree species richness of the protected area (78.5%) and the unprotected area (19.15%) in terms of species richness (n 100 $m^{-2}$).A comparison of plant consumption as fodder by administrative status and land use was found to be insignificant (0.0%) in protected area and significantly higher (100%) in unprotected area (Table 1).

- **Tree variables and stands structural parameters of individual species on both land-use types.**

In both land-use types, only six of the ten listed tree species were found in both regions; the unprotected area was devoid of the remaining four species (Table 2). Tree species with significantly higher basal area i.e., *A. nilotica, A. modesta,* and *C. sinensis* were reported in the protected area in contrast to the unprotected area. Furthermore, *G. oppositifolia* and *S. mascatense* were the most prevalent tree species in the protected area (Table 3). On average, the basal area of protected plots (40.35 $m^2$ $ha^{-1}$) was nine times greater than the basal area of unprotected plots (2.95 $m^2$ $ha^{-1}$). Simpson and Shannon indices tended to be significantly higher in protected (0.98 ± 0.03) and (1.65 ± 0.25) than in unprotected (0.69 ± 0.02) and (1.50 ± 0.12), respectively. In addition, individuals were more uniformly distributed in the protected area. In the protected area, the stem density was the highest, reaching 163.49 ± 0.50, while the basal area was 40.35 $m^2$ $ha^{-1}$ and the density was 81.23 $ha^{-1}$(Table 2).

- **Species-specific densities of shrubs on both land-use types**

Based on the data provided, it appears that the average density of shrub species was much higher in the protected plots than in the unprotected area. In fact, it was found to be 4 times higher, with a mean density of 2628.8 ± 355.10 across both land use types. This difference was determined to be statistically significant, with a p-value of less than 0.01. The shrub species were therefore considered to be the dominant plants (30-41%) in the growing protected area.

Particularly, the densities of *R. stricta,* and *W. coagulans*, recorded with highestmean values of (175±18.8) and (173±17.5) respectively in the protected area. Similarly, the densities of *P. aphylla, C. procera, J. adhatoda, D. viscosa*, and *G. royleana*, were found to be the second under the protected area with mean values of 118 ± 7.7, 115.2±10.2, 111.36±6.7, 110.08±7.5, and 86.4±11.6 respectively (Table 4). These findings suggest that protecting areas from disturbances can have a significant impact on the density of shrub species.

- **Diversity of herbaceous vegetation and their canopy coverage**

A total of 39 species of vascular herbs were found in 50 quadrate plots in both types of land use. The mean densities of herb species (14.60 ± 1.89), particularly, *E. serrata*, *S. arvensis*, *P. harmala*, and *A. viridis* were significantly higher in the plots of protected area. The results indicate that the protected area has enhanced herb species abundance and diversity. The percentage of canopy coverage of the enumerated herbs was negligible for both land use types except for *P. hysterophorus* (16.96%) *E. serrata* (13.93%) *A. viridis* (10.07 %) in the protected area plots (Table 5).

- **Vulnerability Assessment and Conservation Status of aromatic and medicinal plant species**

Among the recorded 67 plants, twenty-two of the most important species were on the brink of extinction. As per IUCN red-list, *W. coagulans* and *G. royleana* with RVA scores of 18 and 19 were considered critically endangered and nearly endangered, while the remaining species were considered moderately vulnerable (Table 6). There was a relatively high number of vulnerable plant species among these species, with herbs accounting for 16.41%, followed by shrubs 9% and trees 6% respectively. Among the plants that were collected through various techniques, 60% were uprooted (herbs), 20% were cut (shrubs and trees) and 10% were miscellaneous. A comparison of the conservation status of reported plant species with those of national and international conservatories could give a reasonable explanation (Table 7). According to the current RVA, review table and online databases and organizations, such as IUCN's red list of endangered species, *W. coagulans* and *G. royleana* are critically endangered or nearly threatened, and the remaining species (at varying levels of vulnerability) are rapidly disappearing from an area outside the barbed fence.

- **Soil characteristics in both land-use types**

The soil samples were collected and analyzed to evaluate their profile, texture, and various organic and nutritional components across both land use-types. An analysis of the soil was performed at the Agricultural Research Institute, Tarnab Peshawar. In both land use-types, loamy soils were prevalent, exhibiting varying concentrations of organic compounds and nutrients. The protected area showed significantly higher values for nitrogen, zinc cation ($Zn^{+2}$), and iron ($Fe^{+2}$). At $p< 0.05$, the percent concentration of CaCO3, K and pH values in the unprotected area was significantly higher than that in the protected area (5.23). The soil characteristics of both types of land use were similar, including soil organic matter (SOM), electrical conductivity (EC), total soluble salts (TSS), and Phosphorus and Copernicium concentrations (Table 8).

## DISCUSSION

The study area contains various plant growth forms that are quite unique to both land-use types and have been described in the Ethnobotanical study of Kohat pass [10]. In the protected area, herb species diversity was observed to be the most dominant species followed by shrubs and trees. Accordingly, Gómez-Aparicio, Lorena *et al.* [24], found that herbs had a high population structure among all plant growth forms due to less heavy competition from shrubs and trees. In the protected area, high species diversity, particularly endemic plant species, ensures the sustainability of all life forms, whereas in the following study area virtually no such life forms can be found because natural vegetation has been overexploited. Plantation of seedlings and saplings, the control of soil erosion, and the control of invasive alien species may contribute to the stability of the ecological status of plant diversity in the protected area [25]. Anthropogenic practices exert a significant influence on indigenous plant diversity as well as the ecological complexity of an ecosystem [26]. Taking the data into consideration, it appears that over half of the unprotected area has lost approximately 35% of its indigenous plant species, and over a quarter has lost more than 47% of plant diversity.

This study aims to demonstrate both the status of flora and the extent of ecological and geological destruction as well as the socio-economic relationships of the area. Further, the findings indicated that the decline in stem density and species diversity correlated with the different activities carried out by the forest, including the cutting of wood for fuel and income, silage for livestock, timber, and various infrastructural activities in District Kohat. As well, grazing, browsing, deforestation, and soil erosion contributed to the above problems. Consequently, these recurrent anthropogenic practices have the potential to significantly affect forest structure and composition and induce gradual changes in tree density [27].

Our findings revealed that the diversity of plants, species richness and density, basal area of species, and diversity indices were significantly reduced in the unprotected area as compared to other sites located inside the fence. In addition, the current vegetation structure of the study area can be significantly disturbed by growing populations, infrastructure activities, and social awareness of traditional uses of plants [28]. The results of this study could be indicative of the status of medicinal and aromatic plants in terms of threats of extinction.

Based on our observations, we noticed that the concentration of tree stands structures; including basal area, stem density, shrubs and herbaceous understory was significantly higher in the protected area compared to the anthropogenically disturbed area. Upon conducting a thorough study, it was discovered that the density of tree species in the unprotected zone experienced a substantial decrease of approximately one-third, in contrast to the protected area. This finding strongly indicates that the protective measures implemented have been successful in conserving the tree species within the secure zone. It seems that the decline in the sapling and seedling densities of native plant species in the unprotected area with anthropogenic interruption levels is consistent with what was previously discovered by Adnan and Holscher in 2010 [9]. These disturbances can lead to a decrease in the number of trees, as well as a decrease in the size of the trees, resulting in a decrease in the basal area of tree species. This can be caused by overharvesting, deforestation, and firewood collection, as well as other activities that reduce the number of trees in each area. A study indicated that anthropogenically pressurized areas have significantly lower tree density than regenerated, protected, or minimally disturbed areas [29]. Our study also showed a higher species richness and density in the protected area. This was characterized by higher density of natural and planted seedlings and saplings. This regeneration of native plant species may initiate ecological restoration. Similarly, fencing of the protected area could be the source of an increase in species abundance and diversity.

Based on the calculated basal area values in the protected area (28.43 $m^2ha^{-1}$) and in the highly disturbed area (2.96 $m^2ha^{-1}$), it could be concluded that the unprotected area had poor vegetation status and canopy cover [30]. Similarly, the unprotected area showed a high density of small diameter (3.01 $m^2ha^{-1}$) trees, while the protected area had a higher density of large diameter (10.99 m2ha-1) trees, indicating a regeneration of the forest [31]. *O. ferruginea*, with the highest basal area of 14.2 $m^2ha^{-1}$, was the dominant species in the protected area, followed by *Z. nummularia* (6.022 $m^2ha^{-1}$), *A. nilotica* (5.92 $m^2ha^{-1}$) and A. modesta (5.76 $m^2ha^{-1}$). However, these same species were at risk in the disturbed area, as shown in (Table 2). This means that no laws or regulations were in place to protect trees from being cut down, leading to unregulated destruction of the environment. This destruction led to the degradation of the land, resulting in the menace seen today. An earlier study [32] also observed similar results due to the lack of conservation and restriction strategies.

It is reported that shrub cover growth in protected area (30-41% compared to 8-10% in disturbed areas) is much better than in unprotected area. The observations may be justified by a study based on shrub vegetation cover ranging from 15% to 30% under biotic and abiotic conditions [33]. A moderate diversity index was also found in the unprotected area, which was a result of the high resistance to grazing [34] but did not indicate the success of the strategy. Even though the protected area was highly endowed with shrub abundance and diversity, some shrub representatives were calculated equally on both land-use types that were not significant [35]. There seems to be a correlation between these results and the status of protection, which ensures shrub density indices within protected areas. Comparing the protected area with the degraded one, the present findings indicate a high density of *R. stricta, W. coagulans, P. aphylla C. procera,* and *D. viscosa.* Currently, the shrub density in the unprotected area is severely degraded due to anthropogenic practices. Therefore, the conservation of vegetation and systematic use of flora is necessary to reduce the loss of indigenous shrub density in the study area. This will help to preserve the habitats of the herb species that have been identified as having a higher mean density in the protected area plots.

In both the protected and unprotected areas, most herbs were found to be weeds. Sadly, anthropogenic activities such as browsing, chopping, grazing, and burying stones and sand in unprotected areas have severely limited herbaceous species [36]. The higher mean densities of herbs found in the protected area were likely due to the restriction of dangerous factors, such as agricultural activities, human interference, and overgrazing [37]. The effects of human activities and overgrazing on reproduction are likely to have detrimental effects on plant reproduction, such as flowering and seed production [38]. In addition to negatively affecting plant abundance and diversity, anthropogenic pressures alter soil fertility and precipitation gradients in the unprotected area [39], resulting in shallow floral coverage and herb diversity in the unprotected area.

The soil analysis of the study area has revealed a high degree of variability in soil potential regarding the life-supporting nutrients for plants. Despite their differences, both types of land-use are characterized by the same soil texture, namely silty loam. Nutrient-enriched soil may therefore contribute to the enlargement and development of plants. Some research studies have indicated that poor soils may contribute to the decline in plant stand characteristics [40], however controversial results have also been established, such as the finding that nutrient-poor ecosystems exhibit significantly higher species richness [41]. A substantial increase in CaCO3, potassium, and pH was observed in the unprotected area when compared to the protected area due to several human and livestock practices (trampling, consumption, excreta deposition, redistribution, etc.) that may positively affect soil nutrient behavior [42]. Even though it is difficult to determine an accurate description of soil organic matter and nutrient behavior [43], both land-use types showed no significant differences involving soil organic matter, phosphorus, Copernican, electrical conductivity, or total soluble salts. In unprotected areas, overgrazing, specifically trampling, can lead to soil erosion due to the excessive pressure exerted by the grazing animals. However, it is worth noting that the waste materials produced by these animals, such as excreta, play a vital role in maintaining the soil characteristics. Despite the negative impact of trampling, the presence of animal waste helps to keep the soil's properties relatively constant.

## Conclusions and Future Recommendations

In conclusion, there is a significant decline in native floral diversity in the studied area, as well as a reduction in tree stand structures, such as species richness, shrub density, and herbaceous cover, in response to increased anthropogenic activity. The protected area, however, shows an enormous growth of saplings and seedlings, which was deemed satisfactory indication of the restoration of the highly degraded area. Despite their fertile texture, the soils of the selected localities were highly deficient in essential macronutrients. The findings of this study provide a baseline for describing past, present, and future vegetative conditions in the study area. This study aimed to examine threats to plant diversity resulting from anthropogenic activities, and the restoration of that diversity in protected area. According to our findings, a degraded area may be protected and regenerated by allowing seedlings and saplings to grow and providing protection. Despite declining plant populations and ecosystems, we recommend that large-scale conservation programs can be beneficial in protecting them. As a result of various anthropogenic interactions, controversies arising from overgrazing of degraded areas can be easily resolved through protection management. As part of forest management practices, an awareness plan must be included in the formal and informal education system, to ensure that new generations and students are aware of the importance of plants. The community needs to be educated and motivated to collaborate more effectively. To address these issues, artificial regeneration of saplings and seedlings of native plant species would be helpful in restoring the ecosystem. For general conclusions, it is imperative to conduct eco- and conservational studies in other sites of the Kohat region. Furthermore, extensive ethnobotanical, pharmacological, and phytochemical studies should be conducted in the surrounding areas; considering both biotic and abiotic stresses that affect plant diversity and biochemistry.

## Declarations

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**Conflict of interest**

þIn this paper, the authors declare that they have no competing financial interests or personal relationships that might have influenced their work.

**Data availability**

**The data will be provided upon request by the corresponding author of this manuscript.**

**Author contribution statement**

Muhammad Zamin designed the study, conducted the field work and prepared the draft manuscript for publication. Shaheen Begum helped in data compilation and analysis. Muhammad Adnan and Waheed Murad supervised the study at all stages and contributed to the draft of the manuscript. Sardar Khan contributed to the development of the review table and reviewed the entire draft of manuscript for improvement. We are pleased to announce that the final manuscript has been read and approved by all authors.

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## Tables

**Table 1: General aspects of the two types of land-used in District Kohat and other particulars on the 25 plots per land-use type.**

| Attributes | Protected area | Un-protected Area |
|---|---|---|
| Total study area (ha) | 81.23 | > 81.23 |
| Fodder contribution to livestock (%) | 00.00 | 100.00 |
| Land use | Little or no human interference for 10 years | Extensive human pressure continues |
| Administrative status | Controlled area under the Kohat University of Science & Technology jurisdiction with barbed wire | Un-controlled area under public use with no protection |
| Slope (%) (mean) | 31 | 24 |
| Northern Aspect (%) | 45 | 38 |
| Distance (km) from highway | 1 | 1 |
| Distance (km) from nearest community | 0.5 | 0.5 |
| Distance (km) from security guards | 0-1 | No security |
| Total types of tree species (25 plots) | 10 (04) | 06 |
| Total types of shrub species (25 plots) | 18 | 12 |
| Total types of herbs species (25 plots) | 38 | 27 |
| Altitude of study plots (masl) (Range) | 558 | 504 |
| Total no. of tree species (25 plots) | 1132 | 204 |
| Total no. of shrub species (25 plots) | 2210 | 632 |
| Total no. of herb species (25 plots) | 3549 | 1496 |
| Total no. of saplings (25 plots) | 565 | 0.0 |
| Total no. of seedlings (25 plots) | 460 | 51 |

**Table 2: Tree and stand structural features of two land-use types. Mean and standard error, n = 25 plots per land-use type.**

| Parameters | Protected area Mean + SD | Unprotected Area Mean + SD | Mann-Whitney U test |
|---|---|---|---|
| Species Diversity (No. of Species) | 10 | 6 | — |
| Stem density (≥12 cm DBH) (n $ha^{-1}$) | 163.49 ± 0.50 | 30.70 ± 0.48 | $p$< 0.01 |
| Basal Area ($m^2$ $ha^{-1}$) | 10.52 ± 0.40 | 2.12 ± 1.00 | $p$< 0.01 |
| Tree species richness (n 100 $m^{-2}$) | 314.6 ± 53.49 | 76.6 ± 23.00 | $p$< 0.01 |
| Tree Simpson index (D) | 0.98 ± 0.03 | 0.99 ± 0.02 | NS |
| Tree Shannon index (H´) | 1.65 | 1.50 | $p$< 0.01 |
| Tree Shannon evenness ($E_H$) | 0.76 | 0.68 | NS |

**Table 3: Tree stands structural parameters of individual species on both land-use types. Mean and standard deviation, n = 25 plots per land-use type.**

| S. No. | Species Name/ Family | DBH (cm) Mean + SD | | | Basal Area ($m^2$/ha) Mean + SD | | | Stem Density (n/ha) Circumference ≥ 12.4 | | | Stem Density (n/ha) Circumference < 12.4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | PA | UA | MWU test | PA | UA | MWU test | PA | UA | MWU test | PA | UA | MWU test |
| 1. | *Acacia nilotica* (L.) Delile (*A. nilotica*)/ Fabaceae | 13.52 ±1.33 | 04.52 ±1.05 | $p < 0.05$ | 05.92 ±0.91 | 01.52 ± 0.96 | $p < 0.01$ | 15.68 ±1.82 | 3.84 ± 1.28 | $p < 0.01$ | 44.16 ± 2.41 | 15.52 ± 0.87 | $p < 0.01$ |
| 2. | *Acacia modesta* Wall. (*A. modesta*)/ Fabaceae | 13.72 ±1.43 | 04.04 ±1.34 | $p < 0.01$ | 05.76 ±1.16 | 0.44 ± 0.51 | $p < 0.01$ | 15.20 ±1.08 | 1.12 ± 0.53 | $p < 0.01$ | 47.36 ± 2.12 | 5.44 ± 0.58 | $p < 0.01$ |
| 3. | *Celtis sinensis* Pers. (*C. sinensis*)/ Cannabaceae | 12.60 ±1.47 | 02.32 ±1.07 | $p < 0.01$ | 01.16 ±0.85 | 0.08 ± 0.40 | $p < 0.01$ | 02.88 ±0.73 | 0.16 ± 0.37 | $p < 0.01$ | 4.64 ± 0.91 | 0.64 ± 0.49 | $p < 0.01$ |
| 4. | *Dalbergia sissoo* DC. (*D. sissoo*)/ Leguminosae | 12.40 ±1.87 | 0.04 ± 0.20 | $p < 0.01$ | 01.56 ±0.92 | 0 | $p < 0.01$ | 0.80 ±0.41 | 0 | NS | 19.04 ± 2.05 | 0 | $p < 0.01$ |
| 5. | *Eucalyptus camaldulensis* Dehnh. (*E. camaldulensis*)/Myrtaceae | 03.04 ±1.17 | 0.32 ± 0.48 | $p < 0.01$ | 01.52 ±0.96 | 0 | NS | 0.2 ± 0.41 | 0 | NS | 4.2 ± 1.00 | 0 | $p < 0.01$ |
| 6. | *Ficus drupacea* Thunb. (*F. drupacea*)/ Moraceae | 14.16 ±2.19 | 02.96 ±1.46 | $p < 0.01$ | 02.92 ±1.32 | 0.2 ± 0.50 | $p < 0.01$ | 0.64 ± 0.95 | 0 | NS | 1.4 ± 0.50 | 0 | $p < 0.01$ |
| 7. | *Grewia oppositifolia* Roxb. ex-DC. (*G. oppositifolia*)/Malvaceae | 05.76 ±1.39 | 01.12 ±0.97 | $p < 0.01$ | 06.04 ±0.93 | 0.52 ± 0.59 | NS | 4 ± 1.53 | 0 | $p < 0.01$ | 5.28 ± 0.61 | 0.32 ± 0.48 | $p < 0.01$ |
| 8. | *Olea ferruginea* Wall. ex Aitch. (*O. ferruginea*)/ Oleaceae | 12.48 ±2.33 | 02.92 ±1.55 | $p < 0.05$ | 01.36 ±0.91 | 0.16 ± 0.37 | $p < 0.01$ | 4.8 ± 0.91 | 0 | $p < 0.01$ | 6.28 ± 0.73 | 0.48 ± 0.51 | $p < 0.01$ |
| 9. | *Sideroxylon mascatense* (A. DC.) T.D. Penn (*S. mascatense*) / Sapotaceae | 10.44 ±2.02 | 01.64 ±0.99 | $p < 0.05$ | 02.36 ±1.11 | 0.20 ± 0.41 | $p < 0.01$ | 7.2 ± 1.71 | 0.8 ± 0.65 | $p < 0.01$ | 14.08 ± 0.81 | 1.12 ± 0.53 | $p < 0.01$ |
| 10. | *Ziziphus jujuba* Mill. (*Z. jujuba*)/ Rhamnaceae | 07.08 ±1.58 | 01.36 ±0.91 | $p < 0.05$ | 0 | 0 | 0 | 16.32± 1.03 | 1.6 ± 1.04 | $p < 0.01$ | 40.96 ± 0.68 | 11.36 ± 1.47 | $p < 0.01$ |

**Table 4: Species-specific densities of studied shrub plants on both land-use types Mean and standard deviation, n = 25 plots per land-use type**

| S. No. | Species Name/ Family Name | PA (n/ha) Mean ±SD | UA (n/ha) Mean ±SD | Mann-Whitney U test |
|---|---|---|---|---|
| 1. | *Abutilon grandifolium* (Willd.) Sweet (*A. grandifolium*)/ Malvaceae | 48.0 ±9.0 | 14.08±3.3 | P < 0.05 |
| 2. | *Buxus wallichiana* Baill. (*B. wallichiana*)/ Buxaceae | 32.0 ±4.8 | 12.0 ±1.7 | NS |
| 3. | *Calotropis procera* (Aiton) Dryand. (*C. procera*)/ Apocynaceae | 115.2±10.2 | 34.56±3.6 | P < 0.01 |
| 4. | *Erigeron canadensis* L. (*E. canadensis*)/ Compositae | 25.6±4.2 | 12.16±1.6 | NS |
| 5. | *Dodonaea viscosa* (L.) Jacq. (*D. viscisa*)/ Sapindaceae | 110.08±7.5 | 31.36±4.2 | P < 0.01 |
| 6. | *Drosera rotundifolia* L. (*D. rotundifolia*)/ Droseraceae | 28.16±3.8 | 7.68±1.3 | NS |
| 7. | *Gymnosporia royleana Wall. ex M.A.Lawson* (*G.royleana*)/ Celastraceae | 86.4±11.6 | 15±1.5 | P < 0.01 |
| 8. | *Indigofera heterantha* Brandis (*I. heterantha*)/ Leguminosae | 62.08±13.5 | 11.52±1.8 | P < 0.01 |
| 9. | *Justicia adhatoda* L. (*J. adhatoda*)/ Acanthaceae | 111.36±6.7 | 31.36±4.2 | P < 0.01 |
| 10. | *Nannorrhops ritchieana* (Griff.) Aitch. (*N. ritchieana*)/ Arecaceae | 13.4±2.9 | 7.68±1.3 | P < 0.05 |
| 11. | *Periploca aphylla* Decne. (*P. aphylla*)/ Apocynaceae | 34.0 ±3.2 | 14.72±1.5 | NS |
| 12. | *Prosopis cineraria* (L.) Druce (*P. cineraria*)/ Leguminosae | 35.0 ±4.5 | 17±1.5 | NS |
| 13. | *Rhazya stricta* Decne. (*R. stricta*)/ Apocynaceae | 175.0 ±18.8 | 43.5±2.3 | P < 0.01 |
| 14. | *Rydingia limbata* (Benth.) Scheen & V.A. Albert (*R. limbata*)/ Lamiaceae | 47.4±8.7 | 37.1±3.2 | P < 0.05 |
| 15. | *Sageretia thea* (Osbeck) M.C. Johnst. (*S. thea*)/ Rhamnaceae | 27±4.0 | 13±2.0 | NS |
| 16. | *Withania coagulans* (Stocks) Dunal (*W. coagulans*)/ Solanaceae | 173±17.5 | 19.2±2.1 | P < 0.01 |
| 17. | *Withania somnifera* (L.) Dunal (*W. somnifera*)/ Solanaceae | 51.8±5.4 | 16.6±1.9 | P < 0.05 |
| 18. | *Ziziphus nummularia* (Burm.f.) Wight & Arn (*Z. nummularia*)/ Rhamnaceae | 31±2.9 | 20±1.6 | P < 0.05 |

**Table 5: Diversity of herbaceous vegetation and their canopy coverage overall between land-use types, Mean and standard deviation, n = 25 plots per land-use type.**

| S. No. | Species Name/ Family Name | Herbs Density (n/6.25m$^2$) | | | Herbs Coverage (n/6.25m$^2$) | | |
|---|---|---|---|---|---|---|---|
| | | PA Mean ± SD | UA Mean ± SD | MWU test | PA Mean ± SD | UA Mean ± SD | MWU test |
| 1. | *Achyranthes aspera* L. (*A. aspera*)/ Amaranthaceae | 13.12 ± 1.74 | 5.44 ± 1.16 | NS | 4.48 ± 0.65 | 2.24 ± 0.72 | NS |
| 2. | *Aerva javanica* (Burm. f) Juss ex Shult (*A. javanica*)/ Amaranthaceae | 9.32 ± 1.07 | 4.48 ± 0.82 | NS | 3.04 ± 0.73 | 2.08 ± 0.70 | NS |
| 3. | *Amaranthus viridis* L. (*A. viridis*)/ Amaranthaceae | 28.32 ± 1.93 | 8.64 ± 0.86 | $P < 0.05$ | 10.08 ± 0.91 | 3.2 ± 0.91 | $P < 0.05$ |
| 4. | *Ammi majus* L. (*A. majus*)/ Apiaceae | 9.28 ± 0.98 | 5.92 ± 0.76 | NS | 3.36 ± 0.86 | 2.4 ± 0.87 | NS |
| 5. | *Ammophila arenaria* (L.) Link (*A. arenaria*)/ Poaceae | 6.72 ± 0.84 | 4.8 ± 0.82 | NS | 2.24 ± 0.66 | 1.6 ± 0.58 | NS |
| 6. | *Arabidopsis thaliana* (L.) Heynh. (*A. thaliana*)/ Brassicaceae | 14.4 ± 1.12 | 13.6 ± 1 | NS | 4.8 ± 0.65 | 3.88 ± 1.62 | NS |
| 7. | *Argemone mexicana* L. (*A. mexicana*)/ Papaveraceae | 6.08 ± 1.5 | 3.52 ± 0.87 | NS | 2.68 ± 0.80 | 0.76 ± 0.44 | NS |
| 8. | *Argyrolobium roseum (Cambess.) Jaub. & Spach* (*A. roseum*)/ Leguminosae | 6.56 ± 1.23 | 2.92 ± 0.7 | NS | 2.56 ± 0.58 | 1.36 ± 0.57 | NS |
| 9. | *Asparagus officinalis* L. (*A. officinalis*)/ Asparagaceae | 9.28 ± 1.06 | 4.2 ± 0.9 | NS | 3.56 ± 0.58 | 1.92 ± 0.64 | NS |
| 10. | *Cenchrus ciliaris* L. (*C. ciliaris*)/ Poaceae | 18.72 ± 1.28 | 8.96 ± 0.98 | NS | 6.6 ± 0.91 | 2.52 ± 0.82 | NS |
| 11. | *Cleome brachycarpa* (Forssk.) Vahl ex DC. (*C.brachycarpa*)/ Cleomaceae | 13.12 ± 1.3 | 6.2 ± 1.41 | NS | 4.64 ± 0.99 | 1.68 ± 0.63 | NS |
| 12. | *Convolvulus arvensis* L. (*C. arvensis*)/ Convolvulaceae | 7.36 ± 0.7 | 5.44 ± 0.71 | NS | 3.28 ± 1.1 | 1.72 ± 0.84 | NS |
| 13. | *Cymbopogon citratus* (DC.) Stapf (*C. citratus*)/ Poaceae | 21.12 ± 1.09 | 6.72 ± 1.28 | NS | 6.16 ± 1.10 | 2.08 ± 0.70 | NS |
| 14. | *Cymbopogon flexuosus* (Nees ex Steud.) W. Watson (*C. flexuosus*)/ Poaceae | 9.92 ± 1.04 | 4.36 ± 0.99 | NS | 4.68 ± 0.95 | 2.32 ± 0.75 | NS |
| 15. | *Cynodon dactylon* (L.) Pers. (*C. dactylon*)/ Poaceae | 31.84 ± 1.4 | 8.32 ± 0.75 | NS | 9.48 ± 1.98 | 2.76 ± 1.05 | NS |
| 16. | *Datura stramonium* L. (*D. stramonium*)/ Solanaceae | 11.84 ± 1.03 | 4.96 ± 0.88 | NS | 5.12 ± 1.01 | 2.08 ± 0.70 | NS |
| 17. | *Delphinium uncinatum* Hook. f. & Thomson (*D. uncinatum*)/ Ranunculaceae | 8.64 ± 0.99 | 4 ± 1.15 | NS | 2.88 ± 0.88 | 1.44 ± 0.51 | NS |
| 18. | *Dianthus anatolicus* Boiss. (*D. anatolicus*)/ Caryophyllaceae | 9.28 ± 1.4 | 4.32 ± 1.07 | NS | 2.88 ± 1.01 | 1.76 ± 0.66 | NS |
| 19. | *Dianthus deltoides* L. (*D. deltoides*)/ Caryophyllaceae | 8.16 ± 1.31 | 4.8 ± 1.16 | NS | 2.88 ± 0.73 | 1.76 ± 0.66 | NS |
| 20. | *Echinops echinatus* Roxb. (*E. echinatus*)/ Compositae | 7.04 ± 1.51 | 4.96 ± 0.79 | NS | 2.2 ± 0.65 | 1.76 ± 0.59 | NS |
| 21. | *Elymus repens* (L.) Gould (*E. repens*)/ Poaceae | 21.28 ± 1.82 | 3.04 ± 0.61 | NS | 6.56 ± 0.87 | 1.12 ± 0.67 | NS |
| 22. | *Euphorbia hirta* L. (*E. hirta*)/ Euphorbiaceae | 8.64 ± 0.49 | 5.76 ± 1 | NS | 3.28 ± 1.1 | 1.92 ± 0.64 | NS |
| 23. | *Euphorbia serrata* L. (*E. serrata*)/ Euphorbiaceae | 41.92 ± 1.32 | 7.36 ± 0.95 | $P < 0.01$ | 13.92 ± 0.90 | 2.16 ± 0.75 | $P < 0.01$ |
| 24. | *Fagonia indica* Burm.f. (*F. indica*)/ Zygophyllaceae | 6.56 ± 1.42 | 4.24 ± 0.83 | NS | 2.64 ± 0.7 | 1.92 ± 0.76 | NS |
| 25. | *Forsskaolea tenacissima* L. (*F. tenacissima*)/Urticaceae | 11.84 ± 1.34 | 3.2 ± 0.76 | NS | 4.76 ± 0.78 | 1.44 ± 0.58 | NS |
| 26. | *Gentiana olivieri* Griseb. (*G. olivieri*)/ Gentianaceae | 14.08 ± 0.76 | 0.64 ± 0.64 | NS | 4.64 ± 0.91 | 0.52 ± 0.51 | NS |

| S. No. | Species Name/ Family Name | Herbs Density (n/6.25m$^2$) | | | Herbs Coverage (n/6.25m$^2$) | | |
|---|---|---|---|---|---|---|---|
| | | PA Mean ± SD | UA Mean ± SD | MWU test | PA Mean ± SD | UA Mean ± SD | MWU test |
| 27. | *Himalaiella heteromalla* (D. Don) Raab-Straube (*H. heteromalla*)/ Compositae | 6.08 ± 1.15 | 2.24 ± 0.9 | NS | 1.6 ± 0.58 | 0.64 ± 0.49 | NS |
| 28. | *Inula britannica* L. (*I. britannica*) / Compositae | 5.12 ± 0.83 | 3.72 ± 0.98 | NS | 1.76 ± 0.66 | 0.12 ± 0.33 | NS |
| 29. | *Kickxia ramosissima* (Wall.) Janch. (*K. ramosissima*)/ Plantaginaceae | 4.8 ± 0.87 | 2.56 ± 0.82 | NS | 1.64 ± 0.57 | 0.72 ± 0.54 | NS |
| 30. | *Malva neglecta* Wallr. (*M. neglecta*)/ Malvaceae | 22.88 ± 1.3 | 9.12 ± 0.78 | NS | 7.96 ± 0.84 | 2.68 ± 0.69 | NS |
| 31. | *Parthenium hysterophorus* L. (*P. hysterophorus*)/ Compositae | 52.48 ± 2.85 | 22.08 ± 1.66 | P < 0.01 | 16.96 ± 1.21 | 8.48 ± 0.82 | NS |
| 32. | *Peganum harmala* L. (*P. harmala*)/ Nitrariaceae | 9.28 ± 1.9 | 6.88 ± 0.88 | P < 0.01 | 3.2 ± 1.04 | 2.56 ± 0.65 | NS |
| 33. | *Pennisetum alopecuroides* (L.) Spreng. (*P. alopecuroides*)/ Poaceae | 27.84 ± 1.72 | 4.8 ± 0.9 | NS | 9.6 ± 0.65 | 1.76 ± 0.72 | NS |
| 34. | *Plantago ovata* Forssk. (*P. ovata*)/ Plantaginaceae | 8.2 ± 0.7 | 3.2 ± 0.8 | NS | 4.84 ± 0.8 | 1.28 ± 0.61 | NS |
| 35. | *Pupalia lappacea* (L.) Juss. (*P. lappacea*)/ Amaranthaceae | 5.28 ± 0.79 | 2.72 ± 0.68 | NS | 2.08 ± 0.64 | 1.12 ± 0.73 | NS |
| 36. | *Rumex hastatus* D. Don/ (*R. hastatus*)Polygonaceae | 2.4 ± 0.6 | 1.6 ± 0.9 | NS | 2.12 ± 0.6 | 0.64 ± 0.49 | NS |
| 37. | *Sonchus arvensis* L. (*S. arvensis*)/ Compositae | 42.56 ± 1.36 | 11.84 ± 1.40 | P < 0.01 | 12.8 ± 1.98 | 2.96 ± 1.4 | NS |
| 38. | *Solanum americanum* Mill. (*S. americanum*)/ Solanaceae | 15.36 ± 0.81 | 3.4 ± 0.76 | NS | 5.44 ± 0.87 | 1.12 ± 0.78 | NS |
| 39. | *Silybum marianum* (L.) Gaertn. (*S. marianum*)/ Compositae | 18.4 ± 1.25 | 4.7 ± 0.8 | NS | 6.32 ± 1.11 | 1.48 ± 0.71 | NS |

**Keys:** PA (Protected area), UA (Unprotected Area), MWU test (Mann-Whitney U test), NS (Not Significant), L (Latin), $p < 0.01$ (Highly significant), $p < 0.05$ (Significant)

**Table 6: Rapid Vulnerability Assessment of the Studied Plant Species under both land-use types**

| S. No. | Botanical Name | Habit/ Life form | Habitat | Parts used | Use value | Population size | Regeneration rate | Season of Collection | Quantity collected (Kg/Year) | Threat status | Total score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | *A. aspera* | 1 | 5 | 3 | 2 | 5 | 1 | 2 | 4 | 2 | 25 |
| 2. | *A. arenaria* | 3 | 2 | 2 | 1 | 3 | 2 | 2 | 4 | 2 | 21 |
| 3. | *A. javanica* | 1 | 5 | 3 | 4 | 5 | 2 | 2 | 3 | 2 | 27 |
| 4. | *A. majus* | 3 | 5 | 1 | 2 | 1 | 1 | 1 | 3 | 1 | 18 |
| 5. | *A. mexicana* | 1 | 5 | 3 | 2 | 5 | 1 | 2 | 4 | 2 | 25 |
| 6. | *A. modesta* | 4 | 5 | 2 | 1 | 4 | 1 | 2 | 4 | 2 | 25 |
| 7. | *A. nilotica* | 4 | 5 | 2 | 1 | 3 | 1 | 2 | 5 | 2 | 25 |
| 8. | *A. officinalis* | 3 | 2 | 1 | 3 | 2 | 1 | 2 | 4 | 2 | 20 |
| 9. | *A. roseum* | 1 | 5 | 3 | 4 | 5 | 2 | 2 | 3 | 2 | 27 |
| 10. | *A. thaliana* | 3 | 5 | 4 | 3 | 4 | 2 | 1 | 2 | 1 | 25 |
| 11. | *A. viridis* | 3 | 2 | 1 | 3 | 2 | 1 | 2 | 4 | 2 | 20 |
| 12. | *A. grandifolium* | 5 | 5 | 3 | 2 | 4 | 1 | 2 | 5 | 2 | 29 |
| 13. | *B. wallichiana* | 1 | 3 | 4 | 3 | 3 | 2 | 2 | 5 | 1 | 24 |
| 14. | *C. arvensis* | 4 | 5 | 5 | 4 | 1 | 1 | 1 | 3 | 2 | 26 |
| 15. | *C. brachycarpa* | 5 | 5 | 1 | 2 | 4 | 1 | 2 | 5 | 2 | 27 |
| 16. | *C. ciliaris* | 3 | 5 | 4 | 3 | 4 | 2 | 1 | 2 | 1 | 25 |
| 17. | *C. citrates* | 5 | 1 | 2 | 2 | 1 | 2 | 2 | 5 | 2 | 22 |
| 18. | *C. dactylon* | 5 | 1 | 4 | 4 | 1 | 1 | 2 | 1 | 1 | 20 |
| 19. | *C. flexuosus* | 3 | 5 | 4 | 3 | 4 | 2 | 1 | 2 | 1 | 25 |
| 20. | *C. sinensis* | 4 | 2 | 1 | 3 | 2 | 1 | 2 | 5 | 2 | 22 |
| 21. | *C. procera* | 5 | 4 | 2 | 1 | 2 | 1 | 2 | 4 | 2 | 23 |
| 22. | *D. anatolicus* | 4 | 5 | 5 | 4 | 1 | 1 | 1 | 3 | 2 | 26 |
| 23. | *D. deltoids* | 3 | 5 | 4 | 3 | 4 | 2 | 1 | 2 | 1 | 25 |
| 24. | *D. rotundifolia* | 5 | 5 | 1 | 2 | 4 | 1 | 2 | 5 | 2 | 27 |
| 25. | *D. stramonium* | 3 | 5 | 4 | 3 | 4 | 2 | 1 | 2 | 1 | 25 |
| 26. | *D. sissoo* | 4 | 5 | 5 | 4 | 1 | 1 | 1 | 3 | 2 | 26 |
| 27. | *D. uncinatum* | 5 | 5 | 1 | 2 | 4 | 1 | 2 | 5 | 2 | 27 |
| 28. | *D. viscosa* | 1 | 1 | 3 | 4 | 3 | 2 | 1 | 5 | 1 | 21 |
| 29. | *E. camaldulensis* | 4 | 4 | 2 | 3 | 2 | 1 | 2 | 5 | 2 | 25 |
| 30. | *E. Canadensis* | 5 | 2 | 2 | 1 | 2 | 2 | 2 | 5 | 2 | 23 |
| 31. | *E. echinatus* | 5 | 5 | 3 | 5 | 3 | 2 | 2 | 5 | 2 | 32 |
| 32. | *E. hirta* | 4 | 5 | 3 | 1 | 2 | 1 | 2 | 3 | 2 | 23 |
| 33. | *E. repens* | 5 | 2 | 1 | 3 | 2 | 1 | 2 | 4 | 2 | 22 |
| 34. | *E. serrata* | 4 | 5 | 5 | 1 | 4 | 1 | 2 | 4 | 2 | 28 |
| 35. | *F. drupacea* | 2 | 4 | 5 | 3 | 5 | 2 | 2 | 5 | 2 | 30 |
| 36. | *F. indica* | 5 | 1 | 2 | 2 | 1 | 2 | 2 | 5 | 2 | 22 |
| 37. | *F. tenacissima* | 5 | 1 | 4 | 4 | 1 | 1 | 2 | 1 | 1 | 20 |
| 38. | *G.royleana* | 5 | 3 | 1 | 1 | 2 | 1 | 2 | 3 | 1 | 19 |
| 39. | *G. olivieri* | 2 | 4 | 5 | 3 | 5 | 2 | 2 | 5 | 2 | 30 |
| 40. | *G. oppositifolia* | 5 | 3 | 4 | 4 | 2 | 1 | 2 | 4 | 1 | 26 |

| S. No. | Botanical Name | Habit/ Life form | Habitat | Parts used | Use value | Population size | Regeneration rate | Season of Collection | Quantity collected (Kg/Year) | Threat status | Total score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 41. | *H. heteromalla* | 5 | 5 | 3 | 5 | 3 | 2 | 2 | 5 | 2 | 32 |
| 42. | *I.Britannica* | 4 | 5 | 3 | 1 | 2 | 1 | 2 | 3 | 2 | 23 |
| 43. | *I. heterantha* | 5 | 2 | 1 | 3 | 2 | 1 | 2 | 4 | 2 | 22 |
| 44. | *J. adhatoda* | 4 | 4 | 2 | 1 | 4 | 2 | 2 | 1 | 1 | 21 |
| 45. | *K. ramosissima* | 5 | 5 | 4 | 5 | 5 | 2 | 2 | 5 | 2 | 35 |
| 46. | *M. neglecta* | 5 | 2 | 1 | 3 | 2 | 1 | 2 | 5 | 1 | 22 |
| 47. | *N. ritchieana* | 5 | 5 | 2 | 4 | 5 | 2 | 1 | 4 | 2 | 30 |
| 48. | *O. ferruginea* | 4 | 5 | 3 | 1 | 2 | 1 | 2 | 3 | 2 | 23 |
| 49. | *P. alopecuroides* | 3 | 5 | 4 | 5 | 4 | 2 | 2 | 5 | 2 | 32 |
| 50. | *P. aphylla* | 2 | 4 | 5 | 3 | 5 | 2 | 2 | 5 | 2 | 30 |
| 51. | *P. cineraria* | 5 | 3 | 4 | 4 | 2 | 1 | 2 | 4 | 1 | 26 |
| 52. | *P. hysterophorus* | 3 | 4 | 1 | 1 | 3 | 1 | 2 | 4 | 2 | 21 |
| 53. | *P. harmala* | 1 | 3 | 3 | 4 | 2 | 2 | 2 | 3 | 2 | 22 |
| 54. | *P. lappacea* | 3 | 4 | 1 | 1 | 3 | 1 | 2 | 4 | 2 | 21 |
| 55. | *P. ovate* | 2 | 4 | 5 | 3 | 5 | 2 | 2 | 5 | 2 | 30 |
| 56. | *R. hastatus* | 5 | 3 | 4 | 4 | 2 | 1 | 2 | 4 | 1 | 26 |
| 57. | *R. limbata* | 3 | 4 | 1 | 1 | 3 | 1 | 2 | 4 | 2 | 21 |
| 58. | *R. stricta* | 3 | 5 | 4 | 3 | 5 | 2 | 2 | 4 | 1 | 29 |
| 59. | *S. americanum* | 1 | 3 | 3 | 4 | 2 | 2 | 2 | 3 | 2 | 22 |
| 60. | *S. arvensis* | 3 | 4 | 1 | 1 | 3 | 1 | 2 | 4 | 2 | 21 |
| 61. | *S. marianum* | 2 | 4 | 5 | 3 | 5 | 2 | 2 | 5 | 2 | 30 |
| 62. | *S. mascatense* | 3 | 4 | 1 | 1 | 3 | 1 | 2 | 4 | 2 | 21 |
| 63. | *S. thea* | 1 | 3 | 3 | 4 | 2 | 2 | 2 | 3 | 2 | 22 |
| 64. | *W. coagulans* | 3 | 4 | 1 | 1 | 2 | 1 | 2 | 3 | 1 | 18 |
| 65. | *W. somnifera* | 2 | 4 | 5 | 3 | 5 | 2 | 2 | 5 | 2 | 30 |
| 66. | *Z. jujube* | 1 | 3 | 3 | 4 | 2 | 2 | 2 | 3 | 2 | 22 |
| 67. | *Z. nummularia* | 3 | 4 | 1 | 1 | 3 | 1 | 2 | 4 | 2 | 21 |

**Table 7: National and International Conservation status of the Studied Plant Species**

| Botanical Name | Locality (Area/ Country) | Conservation Status (Present study) | Reason | Recommendation for improvement | Conservation Status<br><br>(Red List) | Remarks | Citation(s) |
|---|---|---|---|---|---|---|---|
| *A. modesta* | Malakand/ Pakistan | Endangered (EN) | Improper way of collection, Unwanted incidental fire,<br><br>Unsustainable and unscientific utilization | In-situ conservation,<br><br>Sustainable utilization | Not Evaluated (NE) | Not Available (NA) | Muhamma Zahir, *et al* 2018 [44] |
| | Chamla Valley/ Pakistan | Near Threatened (NT) | Excessive utilization,<br><br>Climate change, Overpopulation,<br><br>Market pressure, Deforestation. | Government and NGOs need to implement strong programs with the participation of local people, for conservation and plantation of<br><br>1. *modesta* | | Not Available (NA) | Khan, Khalid, *et a* 2019 [45] |
| | **Takht Bhai, Mardan/ Pakistan** | Endangered (EN) | Urbanization, Agricultural,<br><br>Collection for medicinal purposes | Govt. must take steps to control the conversion of non-cultivable area from urbanization and agriculture | | Not Available (NA) | Khan, Musharaf, Shahana Musharaf 2015 [27] |
| | Mohmand Agency / Pakistan | Vulnerable (VU) | Anthropogenic disturbances and overgrazing | Not Available (NA) | | Not Available (NA) | Shah Khal & Syed Zal Shah 2016 [46] |
| *A. nilotica* | Malakand/ Pakistan | Endangered (EN) | Improper way of collection, Unwanted incidental fire,<br><br>Unsustainable and unscientific utilization | In-situ conservation,<br><br>Sustainable utilization | Least Concern (LC) | Not Available (NA) | Muhamma Zahir, *et al* 2018 [44] |
| | Shangla/ Pakistan | Endangered (EN) | Grazing,<br><br>Land utilization,<br><br>Deforestation,<br><br>Rapid human population growth | ex-situ conservation<br><br>(Establishment of nurseries and botanical garden) in-situ conservation (Local community awareness and involvement in protection) | Least Concern (LC) | Not Available (NA) | Mohib Sha & Farrukh Hussain 2012<br><br>[47] |
| | Southern Pakistan | Critically Endangered (CR) | Habitat destruction,<br><br>Soil erosion,<br><br>Grazing,<br><br>Invasive species | Minimize the anthropogenic activities, Introduction in botanic gardens for public display, Preservation of seeds in local seed banks, Alternate means of energy | | Not Available<br><br>(NA) | Abbas, Haider, *et a* 2013 [48] |
| *A. bracteosa* | Muzaffarabad (AJK), Pakistan | Near Threatened (NT) | Agricultural expansion, Collection for medicinal purposes | Sustainable collection and propagation of important medicinal plants | Not Evaluated (NE) | Not Available<br><br>(NA) | Ishtiaq, Muhamma *et al.*, 2012 [49] |
| | Neelum Valley, Azad Jammu and Kashmir/ Pakistan | Vulnerable (VU) | Unwise collection for medicinal uses,<br><br>overgrazing and deforestation, | Appropriate training of the local people about the conservation and sustainable | | Not Available<br><br>(NA) | Ahmad, Khawaja Shafique, *e al.*, 2012 [50] |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | utilization of medicinally important flora, overgrazing and deforestation should be abridged, promote forest management practices; awareness programs at grass root level should be introduced. | | | |
| | Himalaya/ Pakistan | Critically Endangered (CR) | Remarkable medicinal potential and commercialization, | Conservation practices and management techniques should be carried out to protect this important species from extinction. | | Not Available (NA) | Hussain, Mubashir, *al.*, 2016 [51] |
| | Hindu Kush Mountain/ Pakistan | Vulnerable (VU) | Overexploitation, Soil erosion, Climatic changes | Appropriate strategies are required for conservation. | | Not Available (NA) | Abdullah, Abdullah, *al.*, 2021 [52] |
| *A. thaliana* | Valencia/ Spain; Norwich/UK Halle/ Germany; Oulu/ Finland | Vulnerable (VU) | Climate change | Adaptational lag in banked seeds considers the most important strategy for managing longer-lived species, as well as for attempts to conserve threatened populations through ex situ preservation. | Not Evaluated (NE) | Not Available (NA) | Wilczek, Amity M., *al.*, 2014 [53] |
| *A. javanica* | United Arab Emirates (UAE) | Endangered (EN) | Overexploited due to their relatively higher medicinal importance | Cultivation of medicinal plants, ex-situ and in-situ conservation | Not Evaluated (NE) | In addition to medicinal uses, the *A. javanica* is used for fuel and fodder as well. | Sakkir, Sabitha, Maher Kabshawi, and Mohamed Mehairbi 2012 [54] |
| *A. officinalis* | Islamabad/ Pakistan | Vulnerable (VU) | Due to the parts used, growth rate, quantity of consumption and pressures like grazing and erosion. | To be conserved by domestication and regeneration techniques. | Least Concern (LC) | Not Available (NA) | Muhamma Ibrar Shinwari & Mir Ajab Khan 200 [55] |
| | Kurram Valley, Parachinar / Pakistan | Critically Endangered (CR) | Unwise collection for culinary and medicinal purposes, Overgrazing. | Not Available (NA) | | Shaghai, Lakhtukai | Hussain, Wahid, *et a* 2012 [56] |
| *B. wallichiana* | Rajouri-Poonch Uttarakhand/ India | Near Threatened (NT) | Overexploitation, Anthropogenic habitat destruction | Long term conservation and management | Least Concern (LC) | Shamshad | Wani, Zishan Ahmad, *et al.,* 2022 [57] |
| | Jammu and Kashmir region/ India | Vulnerable (VU) | Overexploitation, Anthropogenic habitat destruction | Alternative methods for propagating such high value multipurpose tree species, Conventional nursery raising, in-vitro protection | | Not Available (NA) | Pant, Shreekar, and Virbal Sharma Pant, 2011 [58] |
| | Chamla Valley/ Pakistan | Near Threatened (NT) | Excessive and unwise utilization, over grazing, | Government and NGOs need to implement strong | | Not Available (NA) | Khan, Khalid, *et a* 2019 [45] |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | climate change, increase in population,<br>Poor method of collection,<br>Market pressure, Deforestation. | programs with the participation of local people, for conservation and plantation of<br>*B. wallichiana.* | | | |
| *C. procera* | Bannu/Pakistan | Vulnerable (VU) | Land degradation, livestock grazing,<br>Collection for medicinal purposes, Urbanization, Agriculture | Proper collection of plants, Pasture management,<br>Conservation of medicinally important plant species | Least Concern (LC) | Not Available<br>(NA) | Khalil, Muhamma (2020) [59] |
| *E. echinatus* | Bannu/ Pakistan | Endangered (EN) | urbanization and agriculture | To stop the collection of whole plants | Not Evaluated (NE) | Not Available<br>(NA) | Khalil, Muhamma (2020) [59] |
| | Maharashtra/ India | Vulnerable (VU) | Road widening in Ghats and construction activities on forts | Awareness among the common populace regarding its importance | | Least Concern (LC)<br>IUCN (2019) | More, S., Conti, F., & Bhosale, H S. 2020 [60] |
| *F. cretica* | Saharo-Macaronesian and Southern-Mediterranean/ Italy | Critically Endangered (CR) | Changes in land uses due to urban expansion and reforestation with exotic plants | Conservation measures, Establishment of a micro-reserve. Inclusion of *F. cretica* in the lists of protected plant species at regional (Calabria) and country scales in Italy. | Not Evaluated (NE) | IUCN criteria (IUCN, 2012) | Spampina Giovanni, *e al.,* 2018 [6] |
| *G. royleana* | Karak/Pakistan | Vulnerable (VU) | Stone excavation Road construction<br>Gully erosion<br>Overgrazing<br>Deforestation<br>invasion of invasive species | Hybridization and Grafting should be introduced for the conservation and expansion of many species. | Near Threatened (NT) | Formerly known as *Maytenus* royleana | Khan, Musharaf, Zabta Kha Shinwari, and Shahana Musharaf. 2011 [62] |
| | Malakand/ Pakistan | Vulnerable (VU) | Extensive harvesting, Deforestation, Land sliding | In-situ conservation,<br>Sustainable utilization | | Not Available<br>(NA) | Muhamma Zahir, *et al* 2018 [44] |
| | Mwingi/Kenya | Near Threatened (NT) | Ethnoveterinary medicinal uses,<br>Fodder etc. | Requires conservation measures,<br>capacity building and awareness | | Unfortunately, the bulk of the people seem to be unaware of the great threat facing *G. royleana* in the wild. | Njoroge, G N. 2010 [63] |
| *I. heterantha* | Dachigam Kashmir Himalaya/ India | Vulnerable (VU) | Grazing,<br>Human activities (fuel, and fodder collection, harvesting of medicinal herbs, burning of ground vegetation) | Improve the vegetation cover,<br>Regular monitoring of livestock grazing,<br>Protection, Regeneration | Least Concern (LC) | Not Available<br>(NA) | Arif Yaqoo *et al.,* 2014 [64] |
| | Malam<br>Jabba, Swat/ Pakistan | Near Threatened<br>(NT) | Unsustainable mode of collection,<br>Conversion of natural habitat into agricultural land,<br>Overgrazing, | Careful conservation,<br>Monitoring of restoration programs | | Not Available<br>(NA) | Rashid, Abdur, *et a* 2011 [65] |

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|---|---|---|---|---|---|---|---|
| *J. adhatoda* | Malakand/ Pakistan | Endangered (EN) | Improper way of collection, Unwanted incidental fire, Unsustainable and unscientific utilization | In-situ conservation,<br><br>Sustainable utilization | Least Concern (LC) | Not Available<br><br>(NA) | Muhamma Zahir, *et al* 2018 [44] |
| | Manipur/India | Endangered (EN) | Extensively used as ethno-medicine as well as food. | Careful collection for medicinal and fodder purposes | | Also known as *Adhatoda vasica* | Khuraijam Jibankuma Singh & Deepak Huidrom 2013 [66] |
| | Himalayas/ India | Vulnerable (VU) | Establishment of a forest watershed,<br><br>Allelopathic effects of *Lantana camara* and *Murraya koenigii* | Eradication / replacement of *Lantana* species through the plantation of native plants | | Represented by its formerly known name: *Adhatoda vasica* | Pawan Sharma *et al.,* 2009 [67] |
| | Dayalbagh Educational Institute, Agra/ India | Critically Endangered (CR) | Population growth, high rates of habitat modification, deforestation, climate change, pollution, the spread of invasive alien species and over-exploitation | Not Available<br><br>(NA) | | Represented by its formerly known name: *Adhatoda vasica* | Gautam, Monika, ar Sharmita Gupta, 201 [68] |
| *N. ritchieana* | Khyber Pakhtunkhwa / Pakistan | Endangered (EN) | Collection in huge amount for domestic and commercial uses,<br><br>Porcupine grazes the roots and leaves | Conservation of *N. ritchieana* in its natural geographical range.<br><br>Cultivation of the *N. ritchieana* should be encouraged under the Billion Tree Afforestation Program (BTAP). | Least Concern (LC) | NA | Abdullah, Haq, Z. U., Khan, S. M 2019 [69] |
| | Mohmand Agency/ Pakistan | Endangered (EN) | The plant is locally used for making various handicrafts (mats, caps, utensils etc.) | There is an urgent need for increased local awareness of the importance and conservation of this species. | | Mazarai | Shah Khal & Syed Zal Shah 2016 [46] |
| | Hindu Kush Mountain/ Pakistan | Vulnerable (VU) | Overexploitation,<br><br>Soil erosion,<br><br>Climatic changes | Appropriate strategies are required for conservation. | | NA | Abdullah, Abdullah, *e al.,* 2021 [52] |
| *O. europaea* | Shangla/ Pakistan | Endangered (EN) | Grazing,<br><br>Land utilization,<br><br>Deforestation,<br><br>Rapid human population growth | Regeneration of woody tree species, Distribution of saplings by the Government among the citizens Establishment of nurseries | Data Deficient<br><br>(DD) | In paper *O. europaea* mentioned by its formerly known name *Olea ferruginea* | Mohib Sha & Farrukh Hussain 2012 [47] |
| | KozAbakhel (Swat)/ Pakistan | Vulnerable (VU) | Use of timber and wood for fuel, Unsustainable collection,<br><br>Over exploitation | Imparting knowledge regarding genetic diversity and its distribution in the genotypes of *O. europaea* is necessary for its protection and use. | | Threats, Conservation status and Genetic diversity of *Olea ferruginea* Royle (Mentioned in paper) | Muhamma Noor, *et al.* 2019 [70] |
| *P. aphylla* | Lehri/Jindi Reserved Forest, Jehlum, Pakistan | Endangered (EN) | Human and livestock activities Habitat destruction | Fencing, conservation, | Least Concern (LC) | Not Available | Nawaz, Tahira, *et a* 2012 [71] |

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|---|---|---|---|---|---|---|---|
| | Bahadur Khel Karak/ Pakistan | Vulnerable (VU) | Collection for medicinal purposes,<br><br>Overgrazing, browsing pressure. Trampling of the animals makes the soil compact and seed germination is retarded. | Restoration and improvement of the original vegetation. | | Not Available<br><br>(NA) | Rashid, A. U. R., & Marwat, S. K. (2006). |
| *R. stricta* | Kohat Plateau/ Pakistan | Near Threatened (NT) | Local population fragmentation,<br><br>Rapid fragmentation is habitat destruction | Conservation intervention for the habitat and species types is required | Not Evaluated (NE) | Not Available<br><br>(NA) | Gilani, Sye Abdullah, *e al.,* 2014 [72] |
| *S. restrictum* | Central Argentina | Endangered (EN) | Afforestation in the area using exotic timber species | creation of a reserve (the local flora) | Least Concern (LC) | Synonym | Vischi., *et* 2004 [73] |
| *S. mascatense* | Karak/Pakistan | Vulnerable (VU) | Stone excavation Road construction<br><br>Gully erosion<br><br>Overgrazing<br><br>Deforestation | Hybridization and Grafting should be introduced for the conservation and expansion of many species. | Least Concern (LC) | Formerly known as *Monotheca buxifolia* (falk) A. DC. | Khan, M., Shinwari, Z.K. and Musharaf, S., 2011 [62] |
| | Western Hajar Mountains (Samali Gap to Jebel Sarah)/ Oman | Near Threatened (NT) | Habitat destruction<br><br>Climate change, human encroachment, grazing pressure by domesticated and feral animals. | Recruitment of seedlings and saplings thereby preserving the fragile ecosystem, | | Not Available<br><br>(NA) | Hopkins, E Al-Yahyai, & Lupton, I 2021 [74] |
| | Mohmand Agency/ Pakistan | Vulnerable (VU) | Anthropogenic disturbances and overgrazing | Not Available<br><br>(NA) | | *Monotheca buxifolia* | Shah Khal & Syed Za Shah 2016 [46] |
| *W. coagulans* | Pakistani-Afghan borders | Endangered (EN) | Unsustainable collection for medicinal uses,<br><br>Grazing, | Conservation strategies should be adopted for the protection of medicinal plants | Critically Endangered (CR) | *W. coagulans* sometimes along with *W. chevalieri* may be investigated | Hussain, Wahid, *et* 2018 [75] |
| | Jaipur/India | Critically Endangered (CR) | Collection for medicinal uses | In-vitro conservation | | Not Available<br><br>(NA) | Jain, R., Kachhwah S., & Kotha S. L. 2012 |
| | United Arab Emirates (UAE) | Near Threatened (NT) | Overexploited due to their relatively higher medicinal importance | Cultivation of medicinal plants,<br><br>ex-situ and in-situ conservation | | Not Available<br><br>(NA) | Sakkir, S., Kabshawi, M., & Mehairbi, M 2012 [54] |
| | Dir Kohistan/ Pakistan | Critically Endangered (CR) | Clearing of wilderness or cleanliness derived bulldozing, cutting, burning of wild plants | All these activities should be stopped forthwith to save the remaining plant species | | Not Available<br><br>(NA) | Hazrat, Ali, Muhamma Wahab. 2011 [77] |
| *Z. nummularia* | Malakand/ Pakistan | Vulnerable (VU) | Overgrazing, Excessive collection, Burning and other anthropogenic activities | In-situ conservation policy, Sustainable utilization | Not Evaluated (NE) | Karkana is the most delicious fruit locally used | Muhamma Zahir, *et al* 2018 [44] |

**Table 8: Soil Analysis in both Land-use types**

| Parameters | Protected area (Mean ± SD) | Unprotected area (Mean ± SD) | Mean-Whitney U-test |
|---|---|---|---|
| Soil Texture | Silt Loam | Silt Loam | ---- |
| Calcium carbonate ($CaCO_3$) (%) | 05.23 ± 0.07 | 5.92 ± 0.18 | $p< 0.01$ |
| Soil Organic Matter (SOM) (%) | 00.14 ± 0.03 | 0.25 ± 0.05 | NS |
| Nitrogen (ppm) | 00.13 ± 0.07 | 0.02 ± 0.01 | $p< 0.05$ |
| Phosphorus (ppm) | 07.02 ± 0.24 | 6.56 ± 0.62 | NS |
| Potassium (ppm) | 99.88 ± 3.80 | 112.40±5.59 | $p< 0.01$ |
| Zinc (II) ion (ppm) | 16.24 ± 2.48 | 17.70 ± 2.26 | $p< 0.05$ |
| Copernicium ($Cn^{++}$) (ppm) | 50.46 ± 3.94 | 49.82 ± 2.44 | NS |
| Iron (II) ion (ppm) | 36.52 ± 1.65 | 31.60 ± 1.75 | $p< 0.01$ |
| pH | 07.27 ± 0.62 | 8.62 ± 0.77 | $p< 0.05$ |
| Electric Conductivity (dS/m) | 00.11 ± 0.03 | 0.31 ± 0.33 | NS |
| T.S.S (Total Suspended Solids) (%) | 0.04 ± 0.005 | 0.03 ± 0.01 | NS |

**Keys:** pH (Potential of Hydrogen), % (Percentage), ppm (Part per Million), dS/m (deciSiemens per meter), NS (Not Significant), $p< 0.01$ (statistically highly significant), $p< 0.05$ (statistically significant), ± (Statistical Margin of Error), SD (Standard Deviation)

## Figures

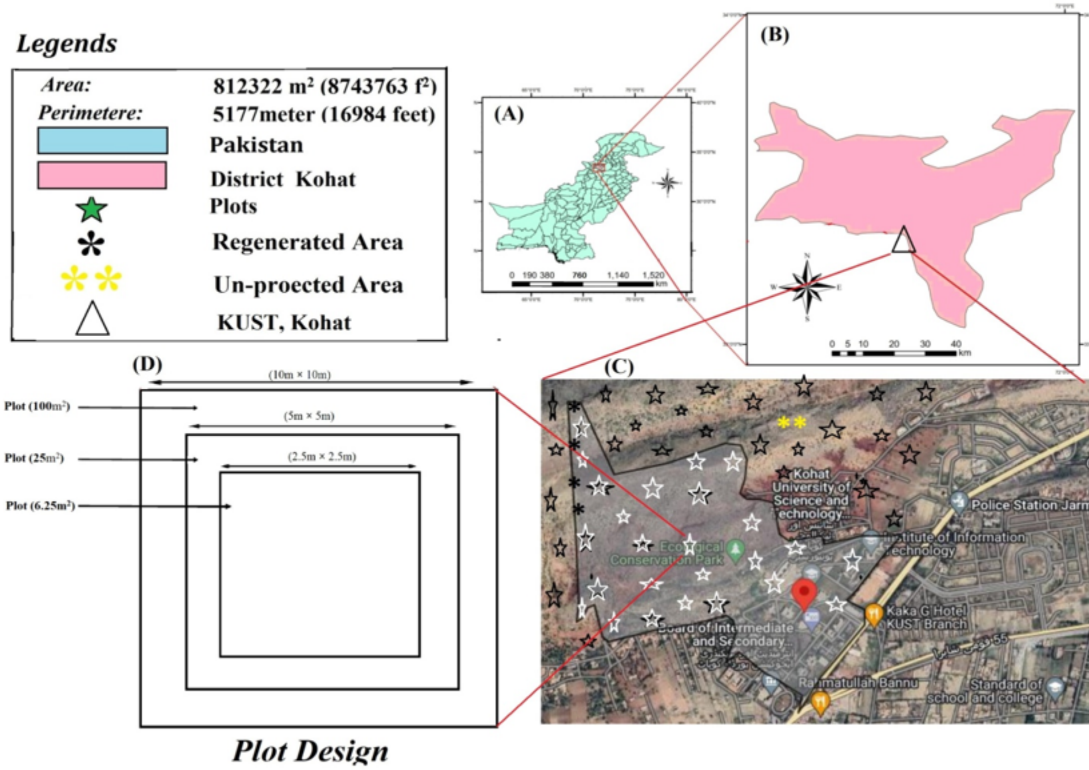


Figure 1

**Showing the map of the study area and plot design** (A) Pakistan and location of study region (B) District Kohat (C) Protected area with perimeter of KUST, adjoining degraded area outside the fence and randomly selected plots from both types of land use. (D) Plot design; includes inventory plot for trees ($100m^2$), plot for shrub density ($25m^2$) and for herbs density and coverage ($6.25m^2$).

Figure 2

Showing the protected and unprotected land-use types of study area.