Article

Diversity of Medicinal Plants among Different Tree Canopies

Muhammad Zubair ^{1,*}, Akash Jamil ¹ , Syed Bilal Hussain ², Ahsan Ul Haq ³, Ahmad Hussain ⁴,
Din Muhammad Zahid ¹, Abeer Hashem ⁵, Abdulaziz A. Alqarawi ⁶ and Elsayed Fathi Abd_Allah ⁶

¹ Department of Forestry and Range Management, FAS&T, Bahauddin Zakariya University, Multan 60000, Pakistan; akashjamil2@live.com (A.J.); dmzahid@bzu.edu.pk (D.M.Z.)

² Institute of Molecular Biology and Biotechnology, Bahauddin Zakariya University, Multan 60000, Pakistan; drsbhussain@gmail.com

³ Department of Forestry and Range Management, University of Agriculture, Faisalabad 38040, Pakistan; ahsanmalik411@hotmail.com

⁴ Department of Forestry and Wildlife Management, University of Haripur, Haripur 22620, Pakistan; ahmad.hussain@uoh.edu.pk

⁵ Botany and Microbiology Department, College of Science, King Saud University, P.O. Box. 2460, Riyadh 11451, Saudi Arabia; habeer@ksu.edu.sa

⁶ Plant Production Department, College of Food and Agricultural Sciences, King Saud University, P.O. Box 2460, Riyadh 11451, Saudi Arabia; alqarawi@ksu.edu.sa (A.A.A.); eabdallah@ksu.edu.sa (E.F.A.)

* Correspondence: zubair.fast@bzu.edu.pk

Abstract: The moist temperate forests in Northern Pakistan are home to a variety of flora and fauna that are pivotal in sustaining the livelihoods of the local communities. In these forests, distribution and richness of vegetation, especially that of medicinal plants, is rarely reported. In this study, we carried out a vegetation survey in District Balakot, located in Northeastern Pakistan, to characterize the diversity of medicinal plants under different canopies of coniferous forest. The experimental site was divided into three major categories (viz., closed canopy, open spaces, and partial tree cover). A sampling plot of 100 m² was established on each site to measure species diversity, dominance, and evenness. To observe richness and abundance, the rarefaction and rank abundance curves were plotted. Results revealed that a total of 45 species representing 34 families were available in the study site. Medicinal plants were the most abundant (45%) followed by edible plants (26%). Tree canopy cover affected the overall growth of medicinal plants on the basis of abundance and richness. The site with partial canopy exhibited the highest diversity, dominance, and abundance compared to open spaces and closed canopy. These findings are instrumental in identifying the wealth of the medicinal floral diversity in the northeastern temperate forest of Balakot and the opportunity to sustain the livelihoods of local communities with the help of public/private partnership.

Keywords: biodiversity; biodiversity indices; non-wood forest products; medicinal plant inventory; forest canopies

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1. Introduction

Pakistan harbors a sizable range of lesser Himalayas, as they cover part of the northern province of the country. The mountain range harbors various biodiversity hotspots, including dense forests and extensive grasslands. This ecosystem has a majority of important flora and fauna endemic to this region [1,2]. The local inhabitants are directly or indirectly dependent upon resources from these forests, particularly non-wood forest products (NWFPs) [3,4]. NWFPs in any forest biome are categorized into edible, medicinal, and constructional products [5]. These products have particular roles in the lives of the local communities. Most important among these NWFPs are the medicinal plants, as the local people in the Himalayas use about 500 of these plant species in their traditional health care practices [6–11]. Pakistan has about 6000 plant species, of which about 33% are being used as NWFPs. Among these NWFPs, about 50% are extensively used as medicinal

plants [12–14]. The role of NWFPs in socioeconomics is well documented. Owing to the socioeconomic and environmental value of NWFPs in moist temperate forests of Pakistan, conservation of these resources is of vital importance [10–12].

Diversity of vegetation is known to have a direct effect on vegetation structure, ecosystem functions, and biogeochemical cycles of a specific ecosystem [15,16]. Measuring plant biodiversity in mountainous regions provides crucial knowledge regarding the suitability of the specific habitat, productivity of the ecosystem, and prediction of successional pathways [17–19].

Literature reveals that the Hindu Kush and Himalayan regions in Pakistan have approximately 4000 floral species, the majority of which are endemic [20,21]. These regions, due to frequent natural calamities and human interventions, are prone to habitat degradation and habitat loss that consequently leads to the extinction of crucial endemic species [22]. Recently, deforestation and natural disasters have triggered structural changes in the Himalayas' forests [23]. Recent earthquakes have jolted the Himalayan forests, causing havoc for the forest resources and the people dependent upon them [2,24]. Various studies have revealed that earthquakes in the Himalayan forests have caused swift deterioration in both the abundance and diversity of understory [25–27].

Forest canopies are known to be the engines and hotspots of plant diversity, biochemical processes, and interfaces between organisms and the atmosphere [28]. Canopy cover of the forest stand is implicated in maintaining the biodiversity and providing various ecosystem services [29,30]. Forest canopies support nearly 40% of world's existing species, among which about 10% are termed as canopy specialists [31]. Plant species directly or indirectly are dependent upon tree canopies for nutrients, sunlight, and reproduction aid [32,33]. Various authors have reported that the disturbance in the canopy has direct effects on the density and abundance of understory vegetation [34,35].

Medicinal plants have an integral representation in the understory vegetation of a forest [9,36]. Adnan and Holscher [20] compared the diversity and density of medicinal plants among the old growth forest and the degraded forest and showed that the density of medicinal plants was much higher in old growth forest as compared to the degraded forest. The amount of quantitative vegetation surveys in the Himalayas are quite limited and insufficient to visualize a clear picture of understory vegetation diversity [10,37]. It is important to document the diversity of vegetation, especially the status of medicinal plants in the region for policy development and sustainable management practices [10]. As a major proportion of the forest communities are dependent upon these resources for economics, edibles, constructional and medicinal purposes, and restoration of ecosystem services and biodiversity, it is necessary that these wild and precious resources be conserved [2,20,24]. Furthermore, there are very few investigations on the effects of different forest canopies on the diversity of medicinal plants [38–40]. The current study aims to depict the biodiversity of medicinal plants in the selected forest and displays the effect of canopies on the diversity and abundance of the medicinal plants. Even though numerous studies are available highlighting the significance and diversity of medicinal plants in this region, this study adds a new dimension of knowledge in terms of the role of various forest canopies influencing the diversity, distribution, and abundance of medicinal plants. The specific objectives of the research were firstly to find how much of NWFP biodiversity corresponds to medicinal plants and secondly to identify if the top story of the forest, i.e., the canopy of the trees, has a role in such diversity.

2. Methodology

2.1. Description of the Study Site

Naga Forest Reserve is located 30 km north of Balakot. It is situated at 34.6528° N, 73.3586° E (Figure 1). This is a protected moist temperate forest lying in the Himalayan mountain range, covering an area of 6254 hectares (ha). The study area was selected after discussion with forest department officials due to its accessibility and suitability for the objectives of this study. The vegetation in the forest includes relics of evergreen forests,

dominated by *Cedrus deodara* (Roxb. ex Lambert) G.Don, *Pinus wallichiana* A.B.Jacks, and *Abies pindrow* Royle. It also consists of patches of deciduous forests in which stands of *Juglans regia* L. prevail. The forest reserve experiences heavy rains throughout the summer. The rainfall becomes more frequent in the monsoon season, the average being 2500 mm. The maximum and minimum temperature is 43.5 °C and −3 °C respectively. The winters are characterized by heavy snow that starts from the latter half of November and continues to the end of March. The summers are very short, only lasting for about 4 months from May to August. Short summer periods provide very limited time for the growth of trees and understory vegetation. The average altitude of the forest is 2416 m. Owing to suitable weather and ease of access, we conducted this study in the summer season.

Figure 1. Study Site: Naga Forest Reserve, Balakot, KPK Punjab.

2.2. Sampling Methods and Instruments

The data were obtained using conventional techniques of vegetation inventory. In order to determine the biodiversity of the area, three nested sampling plots were established. The study sites were divided on the basis of canopy cover: closed canopy at the altitude of 2514 m, open space (grass land) at the altitude of 2648 m, and partial canopy at the altitude of 2450 m. Several instruments were used to collect field data: a 1 × 1 m quadrat, weight balance, GPS, measuring tape, clipper, pegs and field note book/range vegetation forms, map of the area, paper sacks, pencil, sharpeners, and erasers.

2.3. Data Collection

Each sampling plot was of 100 m² in which about 10 quadrates of 1 m² each were placed randomly at each site. A total of 30 quadrates were taken in between July and August 2018 from the selected sites (closed canopy, open space, and partial canopy) to reduce bias in the data. The vegetation inside the quadrat was taken out with the help of a

clipper affixed at 25 cm starting from the base of the plant. The clipped samples were placed in paper bags and were freshly weighted using a portable weight balance then placed in paper bags. These bags were then taken in the laboratory. These samples were then transferred into an oven and dried at 70 °C for 48 h until a constant weight was achieved. The samples were then weighed again for biomass determination of the vegetation. The rules for nomenclature as proposed by Peruzzi [41] were considered and vegetation data was quantitatively analyzed for frequency (F) and density (D). Plant species nomenclature follows terminology laid out by the Global Biodiversity Information Facility (gbif.org) [42] and family names follow the Angiosperm Phylogeny Group III classification [43].

2.4. Data Analyses

A detailed biodiversity analysis was performed. Basic quantitative analysis involving F, D, and abundances of vegetation was calculated using Curtis and McIntosh [44], distribution of species abundance was assessed following Miller and Wiegert [45], and to determine how dominant a species is in a given site, the important value index (IV) was used [46]. In order to determine species richness, dominance, heterogeneity, and evenness, various indices such as Margalef's, Simpson's, Shannon's, and Buzas and Gibson's index were calculated respectively [47–50]. The similarities in plant species composition among the various sampling sites were calculated using the Sørensen Dice Index [51]. Furthermore, the rank abundance curve was plotted in order to visualize species richness and evenness. Rank abundance curve is useful as it incapacitates the inadequacies of biodiversity indices, which are unable to display the relative part different variables played in their calculation [52,53]. In order to display the efficacy of sampling, true species richness in a specific habitat and the comparison of species richness among various habitats on an equal effort basis rarefaction curves were plotted [54,55].

3. Results

3.1. Vegetation Description of the Study Site

The study area exhibited a dense understory vegetation. The overall biodiversity of floral species in the area was considerable although the forest was partially open for the community in order to graze and collect plants. A total of 3200 plant individuals representing 45 species belonging to 34 families were identified from the understory vegetation of the study site. The plant species present mostly were indigenous in nature. About 70% of plants identified were herbs. The shrubs found in the site were 21% and only 9% of fern species were available in the study site. The forest surveyed showed that about 71% of plants found were being used for medicinal purposes by the local community. The data was taken from three different sites, viz., understory in a closed canopy site, vegetation from the open spaces, and sites partially covered with trees. It was noted that the observed species in partial and closed canopy sites were a little richer (23) as compared to open spaces (17) and closed canopy sites (16) (Tables 1–3).

3.2. Family Distribution of the Study Site

From the 34 plant families found, the most abundant and dense in the forest was Rosaceae. The family Fabaceae also existed as dominant, whereas the least dominant family was Urticaceae. The important value index (IV) showed that in a particular site the dominant species were not equally distributed. The highest IV value was of *Geranium wallichianum* D. Don ex Sweet, recorded at 0.84, and the majority of species had values in the range of 0.02–0.13. It was observed that in all 3 sites, only 3 species had values nearing the 0.8 range (Tables 1–3) namely *G. wallichianum*, *Valeriana wallichii* DC., and *Chrysopogon gryllus* (L.) Trin.

3.3. Medicinal Plant Cover and Abundance between the Various Forest Canopies

From the results of the comparison of the different forest canopies, we observed that the partial canopy had the maximum number of medicinal plants (65%), followed by the closed canopy (56%), and the open spaces (41%).

3.4. Closed Canopy

The F and D values when calculated among the categorized sampling sites gave different results. During the sampling in the closed canopy site, about 56% of plant species identified were classified as extremely important medicinal plants, in which the most dominant one was *V. wallichii* (F = 100%; D = 173). Another medicinal plant that was significantly present in the site was *Perilla frutescens* Britton. (F = 70%; D = 113). *G. wallichianum* (F = 60%; D = 56), an endangered and endemic medicinal plant of the Himalayas, was also present in the study site [37]. Rare medicinal plants were also present, the most treasured of which was *Podophyllum hexandrum* Royle (F = 10%; D = 1). There were quite a few edible plants (25%) also representing this site, the most prominent being *Potentilla indica* (Andrews) T. Wolf having the maximum F and D (F = 100%; D = 320). The others, such as *Dryopteris filix-mas* (L.) Schott (F = 20% D = 18) and *Viburnum grandiflorum* Wall. (F = 10% D = 2) were not quite as abundant but still were present in the site.

Table 1. Species Importance Index Values for the closed canopy plot in Naga forest (Rf: relative frequency, RD: relative density, C.P: Cover Percent, and IVI: Species Importance Value).

Species	Classification	R.F	R.D	C.P	R.C	I.V
<i>Geranium wallichianum</i> D. Don ex Sweet	Medicinal	0.11	0.06	0.07	0.03	0.84
<i>Valeriana wallichii</i> DC.	Medicinal	0.19	0.21	0.1	0.41	0.82
<i>Potentilla indica</i> (Andrews) T. Wolf	Fruit	0.19	0.39	0.3	0.20	0.79
<i>Perilla frutescens</i> Britton.	Medicinal	0.13	0.13	0.5	0.30	0.58
<i>Dryopteris filix-mas</i> (L.) Schott.	Vegetable	0.03	0.02	0.2	0.1	0.17
<i>Chrysopogon montanus</i> Trin.	Animal forage	0.01	0.02	0.18	0.10	0.14
<i>Dryopteris austriaca</i> Schinz & Thell.	Vegetable	0.05	0.04	0.04	0.02	0.13
<i>Adiantum stenochlamys</i> Baker	Medicinal	0.05	0.03	0.02	0.01	0.11
<i>Geranium nepalense</i> Sweet	Medicinal	0.03	0.01	0.03	0.02	0.07
<i>Chrysopogon gryllus</i> (L.) Trin.	Animal forage	0.01	0.004	0.07	0.03	0.06
<i>Viburnum grandiflorum</i> Wall.	Fruit	0.01	0.01	0.04	0.02	0.05
<i>Gentiana decumbens</i> L.f.	Medicinal	0.01	0.003	0.04	0.02	0.04
<i>Lavatera cachemiriana</i> Cambess.	Medicinal	0.01	0.001	0.003	0.02	0.04
<i>Sonchus asper</i> Hill	Animal forage	0.01	0.01	0.003	0.001	0.03
<i>Arisaema triphyllum</i> (L.) Schott	Medicinal	0.01	0.009	0.009	0.004	0.03
<i>Podophyllum hexandrum</i> Royle	Medicinal	0.01	0.001	0.009	0.004	0.02

3.5. Open Spaces

The F and D of the vegetation in the open spaces had little to no difference when compared to the closed canopy site. The only difference in the open spaces site was the representation of grasses and forage (47%) in the majority that were utilized by the grazing community. The most abundant of them were *C. gryllus* (F = 70%; D = 171), *Trifolium repens* L. (F = 60%; D = 185), *Gladiolus communis* L. (F = 50%; D = 37), *Primula denticulata* Sm. (F = 30%; D = 11), *Cyperus rotundus* L. (F = 30; D = 46). The plants displaying medicinal characteristics were also represented in this site, having about 41% of the species, the most prominent and important being *Hypericum perforatum* L. (F = 30%; D = 41), *Plantago ovata* Forssk. (F = 20% D = 21), and *Rumex nepalensis* Spreng (F = 20%; D = 13) while the others were quite rare, having minimum frequencies and densities. The edible plants in this site were not very dominant and hence were sparsely scattered in the sampled site. Among the edibles, only *P. indica* (F = 40% D = 56) had considerable representation.

Table 2. Species Importance Index Values for the open spaced plot in Naga forest (RF: relative frequency, RD: relative density, CP: Cover Percent, and IVI: Species Importance Value).

Species	Classification	R.F	R.D	C.P	R.C	I.V
<i>Trifolium repens</i> L.	Animal forage	0.14	0.22	0.58	0.23	0.59
<i>Gladiolus communis</i> L.	Aromatic	0.11	0.04	0.21	0.08	0.25
<i>Chrysopogon gryllus</i> (L.) Trin.	Animal forage	0.16	0.20	0.63	0.25	0.24
<i>Cyperus rotundus</i> L.	Animal forage	0.07	0.05	0.18	0.07	0.19
<i>Potentilla indica</i> (Andrews) T.Wolf	Fruit	0.09	0.25	0.13	0.05	0.1
<i>Hypericum perforatum</i> L.	Medicinal	0.04	0.02	0.13	0.04	0.12
<i>Plantago ovata</i> Forssk.	Medicinal	0.04	0.02	0.13	0.05	0.12
<i>Rumex nepalensis</i> Spreng.	Animal forage	0.04	0.01	0.06	0.02	0.12
<i>Primula denticulate</i> Sm.	Animal forage	0.07	0.02	0.024	0.009	0.10
<i>Hyoscyamus niger</i> L.	Medicinal	0.02	0.05	0.04	0.01	0.10
<i>Skimmia laureola</i> Siebold & Zucc. Ex Walp.	Medicinal	0.02	0.01	0.09	0.05	0.07
<i>Potentilla collettiana</i> Aitch. & Hemsl.	Fruit	0.02	0.009	0.10	0.04	0.07
<i>Artemisia absinthium</i> L.	Medicinal	0.02	0.009	0.10	0.043	0.07
<i>Cynodon dactylon</i> (L.) Pers.	Animal forage	0.02	0.01	0.04	0.01	0.05
<i>Rubus niveus</i> Thunb.	Fruit	0.02	0.007	0.02	0.009	0.03
<i>Adiantum stenochlamys</i> Baker	Medicinal	0.02	0.006	0.01	0.004	0.03

3.6. Partial Canopy

The third site, which had partial canopy cover, depicted a different trend when compared to the other two sites. This sampling area had the greatest number of species. Furthermore, this site had the maximum number of medicinal plants (65%), the most dominant species being the *Mentha spicata* L. (F = 50%; D = 41), *Polygonum amplexicula* D. Don (F = 30%; D = 55) and *Skimmia laureola* Siebold & Zucc. ex Walp. (F = 20%; D = 58), while the other 52% of the medicinal plants in this site were quite rare and were not uniformly distributed. Among the rare species, the most important medicinal plants present were *Paeonia emodi* Wall (F = 10%; D = 35) *Berberis lycium* Royle (F = 10%; D = 1), *Asparagus racemosus* Willd (F = 10%; D = 14), and *G. wallichianum* (F = 10%; D = 40). As compared to the closed canopy covered site, this area had quite a few varieties of grass species, the most dominant being the *C. gryllus* (F = 100%; D = 150) and *T. repens* L. (F = 40%; D = 244). In this site, a few edible species were represented. A quite popular edible plant, *P. indica* (F = 80%; D = 299), was in abundance when compared to other edible plants while other important edible plants such as *D. filix-mas* (F = 10%; D = 18), *Phyllanthus niruri* L. (F = 10%; D = 14), and *Solanum nigrum* L. (F = 10%; D = 16) were quite rare.

Table 3. Species Importance Index Values for the partial canopy plot in Naga forest (Rf: relative frequency, RD: relative density, CP: Cover Percent, and IVI: Species Importance Value).

Species	Classification	R.F	R.D	C.P	R.C	I.V
<i>Chrysopogon gryllus</i> (L.) Trin.	Animal Forage	0.2	0.09	0.82	0.41	0.83
<i>Potentilla indica</i> (Andrews) T.Wolf	Fruit	0.1	0.19	0.31	0.15	0.73
<i>Polygonum amplexicaule</i> D. Don	Medicinal	0.06	0.03	0.16	0.08	0.19
<i>Mentha spicata</i> L.	Medicinal	0.1	0.0	0.09	0.04	0.19
<i>Trifolium repens</i> L.	Animal forage	0.04	0.16	0.1	0.05	0.18
<i>Dryopteris filix-mas</i> (L.) Schott.	Vegetable	0.02	0.01	0.14	0.07	0.106
<i>Skimmia laureola</i> Siebold & Zucc. Ex Walp.	Medicinal	0.02	0.01	0.09	0.05	0.07
<i>Plantago major</i> L.	Medicinal	0.02	0.01	0.03	0.01	0.09
<i>Rumex nepalensis</i> Spreng.	Medicinal	0.04	0.03	0.044	0.02	0.07
<i>Asparagus racemosus</i> Willd.	Vegetable	0.02	0.009	0.02	0.01	0.04
<i>Miscanthus nepalensis</i> Hack.	Animal Forage	0.02	0.09	0.03	0.015	0.04
<i>Adiantum stenochlamys</i> Baker	Medicinal	0.02	0.01	0.02	0.01	0.04
<i>Arisaema triphyllum</i> (L.) Schott	Medicinal	0.02	0.005	0.03	0.015	0.03
<i>Dryopteris austriaca</i> Schinz & Thell.	Vegetable	0.02	0.0079	0.03	0.015	0.03
<i>Paeonia emodi</i> Wall.	Medicinal	0.02	0.02	0.004	0.002	0.03
<i>Geranium wallichianum</i> D.Don ex Sweet	Medicinal	0.02	0.08	0.01	0.005	0.02
<i>Berberis lyceum</i> Royle	Medicinal	0.02	0.006	0.01	0.005	0.02

3.7. Rank Abundance Curve and Rarefaction Analyses

In order to depict relative species abundance, species richness, and evenness, rank abundance curve was plotted. The X axis showed the abundance rank and the Y showed the relative abundance measured on a log scale. Figure 2 shows plant species data from closed canopy sites, open spaces, and partial covered tree sites. In this chart, the partial canopy site is dominated with very few species making up the bulk of the biomass while there is an extensive tail of relatively less abundant species. The curve of the open spaced site as shown in Figure 2 does not depict a steep slope, while the curve of the partial canopy site has a steep slope that indicates good evenness of species as compared to poor evenness in open spaces and closed canopy sites. The relative abundance of species in the closed canopy were quite low but the site displayed ample diversity in terms of the species variety. For the closed canopy site, the curve displayed a higher dominance value of a few species, but at the middle the curves fall sharply, then get stabled for an instance, and at the end fall again, depicting lower values of species abundance and rare species (Figure 2). Overall, the results demonstrate that the region has lower values of plant species cover and biomass that were mostly of functional equivalents of the dominant species but could differ with environmental requirement and tolerances.

Figure 2. Rank Abundance Curve.

Rarefaction curves are used in evaluating sampling efforts. It describes how many samples are required for the analysis of diversity in a population. The rarefaction curves depict the number of species in the X axis while the number of individuals found were placed in the Y axis (Figure 3). The curve of the closed canopy site reaches the asymptote after steeply going upwards which shows that there was a good effort in sampling (Figure 3). Conversely, the partially covered tree site curve shows that the area was full of other unique species which still could be found if more sampling would have been conducted.

Figure 3. Individual Rarefaction Curve.

3.8. Biodiversity Analyses

The diversity of the closed canopy sites, open spaces, and partial covered tree sites were determined using various biodiversity indices (Table 4). It was observed that the Shannon diversity index was at the maximum in the partial covered tree sites. This higher value characterizes the fact that this community is more diverse, incorporating high richness and evenness, while the site that had the lowest value of Shannon index was the area with closed canopy. Comparatively, this site was low in diversity and species richness among the other sites. In order to determine dominance and species abundance, Simpson's index was calculated from all the sites. The results showed that the partially covered tree sites were more dominant even in terms of understory vegetation. Similarly, the Simpson's index was at its minimum in the closed canopy sites. The Margalef index for species richness, and Buzas and Gibson's for species evenness, also had a similar result as compared to the other indices being used. The major outcome shows that the various indices and plots represent higher biodiversity in the partial canopy sites. The Sørensen index showed low compositional similarity among the closed canopy, open spaced, and partial canopy sites. The Sørensen Similarity coefficient index displayed similarity less than 50% (Table 5). The maximum similarity observed was of 35% in between site 1 and 3. Therefore it is inferred that there are less shared species among sites. This index tells that the endemic species in each of the site are rare.

Table 4. The average amount of indices and their comparisons in different sites.

Indices	Sites		
	Site 1(C.C)	Site 2(O.S)	Site 3(P.C)
Shannon H	1.87	2.19	2.60
Simpson_1-D	0.77	0.84	0.89
Margalef (Spp Richness)	2.23	2.36	3.00
Buzas and Gibson's evenness	0.40	0.43	0.52

Table 5. Sørensen coefficients showing similarity between different sites.

S _s Site 1&2	S _s Site 1&3	S _s Site 2&3
0.242(24%)	0.35(35%)	0.3(30%)

4. Discussion

Our study shows that the Naga Forest Reserve has an understory vegetation that is enriched with various NWFPs. These NWFPs are a key nexus with the forest community

and their livelihood, and they contribute to an appropriate ecosystem functioning in the forest [56]. Among the NWFPs that were found in the region, the most dominant were the medicinal plants. This is in agreement with the study conducted by Qasim et al. [57] in which he inferred that 100% of the respondents from his study in the Himalayas were possessing and using medicinal plants in abundance. High species density in this region is explained by the moist temperate climate of the area, which is a characteristic of the Himalayas in this part of the world, and creates certain biodiversity hotspots as well [58]. The study demonstrated a visible difference in the understory species composition among closed canopy, open spaces, and partial canopy sites. Our study further advances the fact that the structure and composition of the understory vegetation varies with canopy cover, as reported in other studies [25,59].

Findings of various studies showed the distribution of the understory vegetation is strongly affected by aspect, canopy cover, and elevation [60–62]. The maximum biodiversity, as shown by the Shannon, Simpson, and Margalef indices was found in the partial canopy site. It is explained by the fact that mostly the moderate canopy forests have high plant species, as they tend to support species from both closed as well as open canopy [63]. The partial canopy site was shown to have maximum abundance and species richness of both medicinal plants and grass species. It is because the moderate canopy forests have more availability of light, nutrients, and moisture [64]. As explained by Whitmore [65], canopy openings in the forest are likely to influence the establishment of species and help them grow in the environmental mosaic in a forest. A similar trend was observed by Sagar et al. [66], where the sites which exhibit intermediate levels of light intensity had the greatest herbaceous diversity.

The closed forest canopies in the present research exhibited a lower biodiversity as compared to the other sites. In evergreen forests, closed sites are usually less biodiverse, as showed by Mestre et al [67] in his experiment when they compared biodiversity in a deciduous forest and in evergreen dense forest. They inferred that the evergreen forest was least diverse. The authors concluded that upper story vegetation has a major effect on the richness and diversity of understory vegetation of mixed and pure forests. Open spaces showed a moderate amount of biodiversity when compared to other sites in the study. It could be because most herbs and shrubs do not grow in the high daylight environments that are created due to the canopy gaps [60]. Our study showed that the highest number of medicinal plants were available in the partial canopy sites, and the lowest in open spaces. It was in accordance with similar research conducted in Ayubia National Park KPK by Adnan and Hölscher [20], where it was concluded that the abundance of medicinal plants rises with the increased canopy cover while the density of grasses decreases with the increasing canopy cover. The low medicinal plant presence in open spaces can be explained due to the disturbed canopy cover. The disturbed cover story often leads to decline in medicinal plant diversity in the Himalayas [25].

All of the sites explored in this study displayed rich understory vegetation. The region exhibited many important medicinal plants that were endemic to this particular mountain system. There were quite a few medicinal plants such as *V. wallichii*, *P. frutescens* Britton, and *G. wallichianum* that had high F, and *M. spicata* that showed high F and D. However, other extremely valuable medicinal plants such as *P. hexandrum*, *H. perforatum*, *P. ovata*, *P. amplexicula*, *P. emodi*, and *B. lycium* were quite rare, having smaller frequencies and density. This is due to the increasing market awareness of the important medicinal plants and, consequently, the illegal and unsustainable collection and trading of these medicinal plants, thus resulting in a decreased population of this valuable asset [68,69]. There were quite a few edible NWFPs that were available in the study area. These plants were found to be of moderate abundance, having normal frequencies and densities. Similar results were observed previously, corroborating the fact that people were using wild foods only for their daily household use, thus avoiding the decline of population and diversity [70,71].

The most abundant edible NWFP in the study site was *P. indica*. It is a common fruiting plant producing berries that are significantly used by the forest communities as a wild

fruit. As this plant is available year-round, people heavily use it as a subsistence crop [72]. Just like the high diversity dominance and evenness observed in the partial canopy site, the rank abundance curve showed the abundance of this area to be highest as compared to other sites. These results were in accordance with Walker et al. [73], who showed low species abundance in the disturbed sites such as open spaces in the forest. In another study, it was concluded that the canopy gaps in the forest were responsible for a somewhat low abundance of understory vegetation. The undisturbed closed and partially closed forest canopies showed high species abundance [74]. The results were attained by obtaining the appropriate amount of samples as justified by the rarefaction curves. These curves were used in the data so that we could refrain from the pitfalls and hindrances that are often experienced while quantifying and comparing taxon richness [55].

5. Conclusions and Policy Implications

This study determined that the Naga Reserve Forest has a rich biodiversity of various highly important NWFPs. The most important and pivotal of them are the edible and medicinal plants. Furthermore, in our study, the closed canopy forest showed the lowest biodiversity, while the site with partial canopy showed the highest biodiversity of medicinal plants. It was seen that the areas such as open grasslands where grazing and human activities were routine had the least diversity of medicinal and edible plants.

Pakistan has a forest cover of more than 4.8% that is continuously undergoing deforestation at a rapid rate. The region has great diversity of vegetation, hosting about 6000 vascular plants in which about 400 species are endemic to Pakistan and about 80% of them are present in the northern and western mountains of the country. The current study has depicted that the few dense forests in the Pakistani Himalayas sustain a highly diverse medicinal flora. This high abundance of important and endemic plant species in the current study site have depicted an opportunity for providing diversification of products for not only the forest proximate communities but also enhancing the economy of the country.

Medicinal plants play an important role as a refuge for those jobless people who are vulnerable to extreme poverty. But the people involved in medicinal plant collection and trading are not earning what they deserve. It is due to managerial and organizational issues that the middleman in the business takes the lion's share, leaving these people in this vicious cycle of poverty. Our study recommends that the government take initiatives such as training people in the appropriate collection techniques for sustainable growth and production of medicinal flora. In order to increase more profitable employment opportunities in this business, the government must run programs under the umbrella of public and private partnerships incorporating production and processing technologies in the current scenario for accessing international trade markets. The current study has found out such biodiversity of medicinal plants in only one forest reserve. Further research in other forests and various ecosystems of the country will not only be able to provide diversification of floral products but also will add considerable value to the GDP of Pakistan.

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