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Medicinal Plant Abundance in Degraded and Reforested Sites in Northwest Pakistan

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Forest resources in northwest Pakistan are under severe threat, negatively affecting local people aiming to meet their subsistence needs through different types of forest use. In addition to uses such as fodder and fuelwood, medicinal

plants play an important role in the livelihoods of local people. To reduce pressure and dependency on remaining old-growth forests, some deforested and degraded sites have been reforested. The objectives of the present study were to (1) compare the abundance of medicinal plants on reforested and formerly forested degraded land and (2) assess the influence of reforested stand characteristics on the abundance of medicinal plants. Five plots were randomly selected per land use type. On these plots we analyzed the abundance and other variables of 10 herbal medicinal plants common and important for the rural human population. Frequencies,

densities, and cover of the 10 medicinal plants were significantly higher on reforested sites than on degraded sites. Frequencies of highly valuable species such as *Valeriana jatamansi*, *Bergenia ciliata*, and *Paeonia emodi* increased 16-, 8- and 6-fold on reforested sites, respectively. Moreover, density, cover and diversity of medicinal plants (in total) were 7, 5, and 2 times higher, respectively, and 3 species absent on degraded sites were encountered on reforested sites. On reforested plots, tree basal area was the most influential variable positively correlated with the abundance of the aforementioned species. Thus, our data suggest that reforestation of degraded sites can greatly increase the abundance of medicinal plants and may be an instrument for improving the livelihoods of local people and protecting remaining natural forest resources.

Keywords: Degraded land; tree basal area; livelihoods; medicinal plants; non-timber forest products (NTFPs); planted forest; Pakistan.

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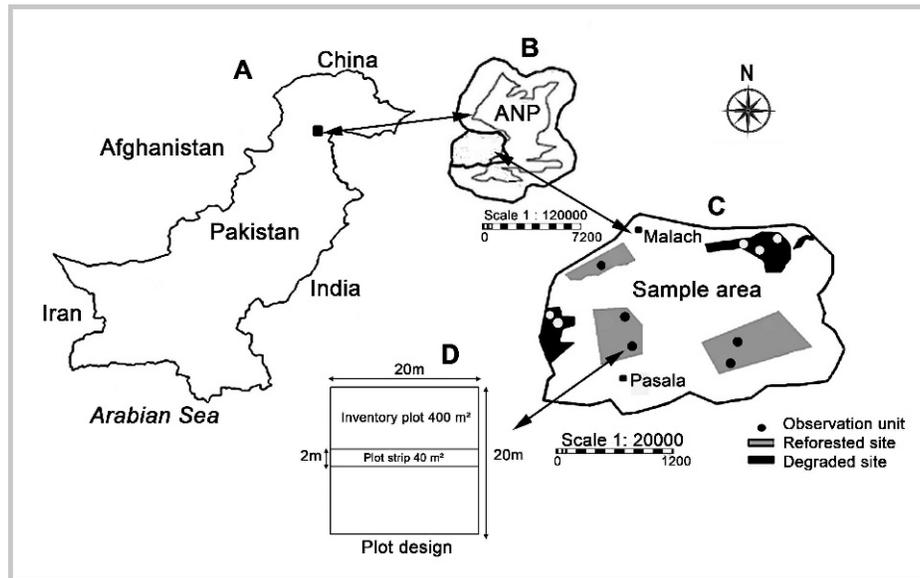
Introduction

Degradation of native old-growth forests and deforestation can have severe negative consequences for forest functions, such as conservation of biodiversity and provision of goods to rural communities. Reforestation can improve the conservation of native biodiversity, although negative effects have also been reported (Kanowski et al 2005; Lamb et al 2005; Carnus et al 2006; Brockerhoff et al 2008). Various factors may determine the efficiency of plantation in relation to biodiversity in a particular area. For example, it is essential to know about land use prior to plantation, the types of tree species involved, and how and for what purpose plantations are being managed (Brockerhoff et al 2008). Reforestation can accelerate forest succession on a previously deforested site by influencing the availability of light, understory microclimate, the structural complexity of vegetation, and the development of humus layers during the early years of plantation growth (Parrotta et al 1997; Parrotta 1999; Yirdaw 2001; Carnevale and Montagnini 2002). However, the role of plantation forestry must not be confined only to biodiversity conservation. People living in developing countries often struggle to meet their basic

food, health, and fuelwood needs, to which these plantations may contribute. Pakistan is an example, where the majority of rural people living in mountainous regions depend heavily on forest products (Adnan et al 2006).

Pakistan's forests cover 4.8% of the country's land area (Lubna 2001). The forest resources are under pressure from deforestation and subsequent land degradation (Ali and Tor 2004), and a deforestation rate of 1.5% per year has been indicated (FAO 2005). Forests in some highly diverse regions of northwest Pakistan have been classified as reserved forests and *guzara* forests (left for public use) (WWF-P 2004; Lodhi 2007). A part of the reserved forest was declared national park land in 1984 and named Ayubia National Park (ANP). Forests around the ANP are being cut ruthlessly, the impact of which is visible in the form of more open *guzara* forests (Aumeeruddy et al 2004). Moreover, the local community depends on non-timber forest products (NTFPs), mainly medicinal plants, which are also being overexploited (Aumeeruddy et al 2004). Such disturbances may result in dwindling renewable natural resources, including medicinal plants (Southworth and Tucker 2001). It has been argued that reforestation of degraded land could be a form of land rehabilitation that

FIGURE 1 Map of the study area and plot design. (A) Pakistan; (B) Ayubia National Park's (ANP) boundary (inside boundary) and its surrounding villages and forests (outside boundary); (C) randomly selected study plots comprising degraded and reforested sites that belong to the villages (note: The dark line around the sample area denotes the boundary around the 2 villages, while the white portion within the sample area indicates households, agricultural area, and part of *guzara* forest); (D) plot design. (Map by authors)



meets the demands of local people for fuelwood, timber, and NTFPs, thus protecting the remaining natural forests (Brown and Lugo 1994; Sedjo 1999).

The World Wide Fund for Nature, Pakistan (WWF-P) initiated reforestation on some degraded *guzara* forests near villages around the ANP, aiming to build capacity among local people to raise tree nurseries and plantations (Aumeeruddy et al 2004). It was assumed that reforestation of degraded land positively influences the ground flora, particularly the abundance of medicinal plants. However, little knowledge is available about the impact of reforestation on non-timber forest products, such as medicinal plants in mountain forests in Pakistan. The objectives of our study were to (1) compare the abundance of medicinal plants on reforested and degraded sites and (2) assess the influence of reforestation stand characteristics on the abundance of medicinal plants.

Material and methods

Study area

This study was carried out in the Northwest Frontier Province (NWFP) of Pakistan, which constitutes 40% of the country's forested area (Lubna 2001). The forests of the region stretch across the Himalayas, Hindu Kush, and Karakorum mountain ranges. The ANP, with an area of 3312 ha, is among the 21 national parks in Pakistan and is situated in the Gallis Forest Division of Abbottabad district, NWFP, between 33°01'N and 34°38'N latitude

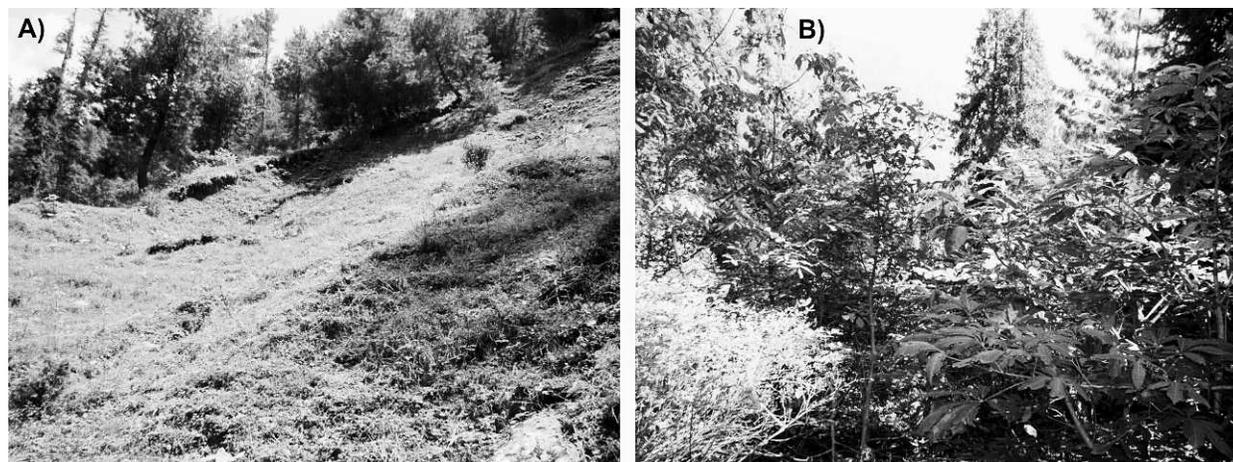
and 73°20'E to 73°30'E longitude (Figure 1B). The altitude ranges from 1220–2865 m, with Miranjani being the highest peak (Hussain 2003). The ANP and its surrounding areas are within the reach of the monsoon; a mean annual rainfall of 1500 mm, snowfall of 2.5 m, and temperature of 12°C have been measured at a nearby weather station (WWF-P 2004).

Soils are often shallow and loamy. The natural vegetation in this area is Himalayan moist forest, which is characterized by high plant species diversity (Aumeeruddy et al 2004). The dominant tree species are *Abies pindrow* Royle, *Cedrus deodara* G. Don, *Pinus roxburghii* Sargent, *Pinus wallichiana* A.B. Jacks, *Quercus incana* Roxb, and *Taxus wallichiana* Zacc (Shafiq 2003). About 50,000 people currently live in 12 villages around the ANP. The major ethnic group in the area is the Hazaary-wall, who speak Hindku and Potohari. Fuelwood consumption by each household in the study area has been estimated at 11,000 kg/year (Hussain 2003). Large amounts of fodder, mainly grasses and herbaceous species, are collected by women from May to November each year (Jabeen 1999; Rabia and Ashiq 2004). Annually, 13 tons of fodder are consumed per household (Rabia and Ashiq 2004).

Study sites and medicinal plants

The study sites were selected on areas included in the reforestation program initiated and supported by WWF-P (1999–2005) on degraded lands (*guzara* forests) surrounding the 2 villages of Mallach and Passala

FIGURE 2 (A) A degraded site near Ayubia National Park; (B) view of a reforested site with *Aesculus indica*, *Robinia pseudo-acacia*, and *Pinus wallichiana*. (Photos by Muhammad Adnan)



(Figure 1C), located near the ANP. “Degraded land” refers to formerly closed forest area that was deforested during the last 3 or 4 decades (Figure 2A), leaving only a few *Pinus wallichiana* trees. Land ownership of *guzara* forests is similar to communal land (Nafees et al 2009), but management is the responsibility of the Forest Department.

During reforestation of the degraded land (about 100 ha), 4 native tree species (*Robinia pseudo-acacia* L., *Aesculus indica* Colebr, *Populus ciliata* Wall. ex Royle, and *Salix tetrasperma* Roxb) were planted in combination with an initial spacing of 1 m² (WWF-P 2004; Figure 2B). The fieldwork was carried out between July and October 2008. At that time, these plantations had aged from 3 to 8 years. Data were collected from the reforested and degraded sites, both of which provided open access to grazing animals (goats and cows) and areas for fodder collection. However, 60% of the reforested area was protected during the initial planting period.

The altitude of the study sites ranged between 2100 m and 2200 m above sea level, where loamy soils and metamorphic rocks were encountered. Stratified random sampling was adopted by separating reforested area and degraded land on a map based on a geographical information system. Five random sample points (5 plots) each were allocated to the 2 land use types. In order to select random sample points on the map, we used the lengths of the *x*- and *y*-axis coordinates by applying specific software (ILWIS, version 3.4). Two random points, 1 at the *x* axis and 1 at the *y* axis, were selected and the point of their intersection taken as a sample point. Each sample point was considered to be the center of each plot and was located in the field by using global positioning system, compass, and other methods.

Ten medicinal plant species were selected as target species for this study. The selection criteria were high market value, relatively easy identification in the field,

and conservation concerns in the area. The selected plants are used locally and extensively as traditional medicines (Table 1). *Bergenia ciliata* (Haw) Stermb is used as a tonic and for the cure of various stomach diseases. *Bistorta amplexicaulis* (D. Don) Green is considered to purify blood (according to local traditional practitioners) and to cure ulcers. *Geranium wallichianum* D. Don is used mainly for the treatment of backache, *Paeonia emodi* Wall for back pain and as a tonic, *Swertia chirata* Buch. Ham. for stomachache and as a tonic, *Gallium aparine* L. for jaundice, *Podophyllum emodi* Wall for liver disorders and as a tonic, and *Plantago lanceolata* L. for diarrhea and stomach diseases. *Valeriana jatamansi* Jones and *Viola canescens* Wall ex Roxb are the 2 species with the highest market value for local people; they also provide adequate treatment for cholera and fever, respectively. Both species are shade-adapted and occur usually in association with trees (Adnan et al 2006; Sher and Khan 2006). Most of the above-mentioned plants can grow well under partially shady conditions, except *Plantago lanceolata*. The selected species are seen as moderately threatened by extinction, except *Bergenia ciliata* (highly vulnerable) and *Plantago lanceolata* (less vulnerable) (Sher and Hussain 2007).

Tree inventory and medicinal plant assessment

Each plot consists of a tree inventory plot of 20 m × 20 m = 400 m² and a long, horizontal plot strip of 20 m × 2 m = 40 m² enclosed in each inventory plot for the assessment of medicinal plants (Figure 1D). As plots lie on the contour line, we applied slope correction. Recorded tree variables on each inventory plot are diameter at breast height (Dbh), basal area, species richness, and stem density. A dimension of 2 cm Dbh for trees was the minimum measured. The Shannon-Wiener diversity index *H'* (Magurran 2004) of trees was calculated for each inventory plot. Hemispherical photographs were taken

TABLE 1 Target medicinal plant species (herbs) and their uses.

Botanical name	Family name	Local name(s) <i>Pashto/Hindko</i>	Part used	Uses	Light requirement/ habitat ^{a)}	Local prices (US\$/Kg)
<i>Bergenia ciliata</i> (Haw) Stermb	Saxifragaceae	<i>Gatpanra/ Zakhm-e-Hayat</i>	Rhizome/ leaves	Medicinal (stomach diseases), fodder, ethnoveterinary	Full shade to semi shade/near rocks, shady edges	2.50
<i>Bistorta amplexicaulis</i> (D. Don) Green	Polygonaceae	<i>Anjabar/Maslun</i>	Rhizome	Medicinal (ulcers), thatching, fodder, ethnoveterinary	Semi shade to full sun/partially moist, shady edges	1.50
<i>Podophyllum emodi</i> Wall.	Podophyllaceae	<i>Kakora/ BanKakri</i>	Fruit/ rhizome	Medicinal (liver disorders)	Full shade to semi shade/full-shade edges	1.25
<i>Geranium walli-chianum</i> D. Don	Geraniaceae	<i>Sra Zela/ RatanJot</i>	Rhizome	Medicinal (backache), ethnoveterinary	Semi shade to no shade/dappled-shade edges	2.00
<i>Paeonia emodi</i> Wall.	Ranunculaceae	<i>Mamekh</i>	Rhizome	Medicinal (backache and tonic), ethnoveterinary	Semi shade to no shade/sunny and shady edges	2.25
<i>Plantago lanceolata</i> L.	Plantaginaceae	<i>Jabai/ Chamchipatra</i>	Rhizome	Medicinal (diarrhea and stomach diseases)	Open areas, full sun/moist locations	1.25
<i>Swertia chirata</i> Buch. Ham.	Gentianaceae	<i>Cheratbotay/ Choraita</i>	Rhizome	Medicinal (stomach and tonic), ethnoveterinary	Semi shade/sunny and shady edges	1.50
<i>Gallium aparine</i> L.	Rubiaceae	<i>Gaya/Kachna</i>	Whole plant	Medicinal (jaundice), ethnoveterinary	Semi shade to no shade/shady edges, bushy habitat	1.25
<i>Valeriana jatamansi</i> Jones	Valerianaceae	<i>Mushkebala</i>	Rhizome	Medicinal (cholera)	Full shade/sunny edges	3.75
<i>Viola canescens</i> Wall ex Roxb	Violaceae	<i>Banafsha/ Savar Phal</i>	Leaves/ flower	Medicinal (purgative, antipyretic)	Full shade to semi shade/shady edges	8.75

^{a)} Sources: Larkcom 1997; Sher and Hussain 2007.

vertically along the middle horizontal line at 5-, 10-, and 15-m distances per plot with a high-resolution digital camera (Minolta Dimage Xt, Japan). The camera had a 185° fish-eye lens and was placed in a leveling device (Regent Instruments, Canada), which in turn was placed on a tripod. Images were analyzed for the forest cover and leaf area index with CanEye 5.0 (INRA 2007).

Variables of medicinal plants included the number of individuals (density), species richness, frequency, biomass, and cover. Each plot strip was then subdivided into 10 quadrates (subplots) of 4 m² each. Data on percentage cover of each medicinal plant species were collected through the visual estimation method in proportion (%) to the total plot strip area, which is covered by

TABLE 2 Tree and stand structural characteristics of reforested and degraded sites; $n = 5$ plots per land use type.

Type of sites	Stem density (n ha ⁻¹)	Diameter (cm)	Basal area (m ² ha ⁻¹)	Tree canopy cover (%)	Shannon diversity index H'
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Reforested sites					
Plot level	630 ± 74.68	14 ± 1.34	7.9 ± 0.85	36 ± 8.50	1.2 ± 0.09
Tree species					
<i>Aesculus indica</i>	140 ± 65.29	9 ± 1.79	1.2 ± 0.58	—	—
<i>Populus ciliata</i>	60 ± 42.48	8 ± 0.89	0.3 ± 0.18	—	—
<i>Robinia pseudo-acacia</i>	165 ± 52.77	8 ± 0.89	1.1 ± 0.40	—	—
<i>Salix tetrasperma</i>	230 ± 49.19	7 ± 0.89	1 ± 0.31	—	—
<i>Pinus wallichiana</i>	35 ± 9.84	40 ± 8.94	4.4 ± 2.77	—	—
Degraded sites					
Plot level (<i>Pinus wallichiana</i>)	50 ± 11.18	30 ± 4.47	2.9 ± 0.85	4 ± 3.58	0 ± 0

aboveground species in all parts. The density of each plant species was recorded by counting the number of individuals. Frequency was calculated as the percentage of subplots that include species. Estimations of frequency, cover, and density were carried out following the protocol outlined by Curtis and McIntosh (1951). Each variable conferred a single value per plot strip, that is, cover and density, which were estimated by adding up their respective 10 subplot values, while the frequency was calculated as the mean of the subplots.

Mean biomass of a particular plant species (fresh/dry, above/below, g/m²) per plot strip was estimated by randomly selecting 3 plants close to 3 randomly selected points along the middle line and then multiplying their average weight (above or below) by the total number of plants of these particular species. The plant species were dried in the shade for 15 to 30 days according to local methods, and dry biomass was then estimated. Similarly, single value per plot strip for species richness and Shannon-Wiener diversity index H' were derived for targeted medicinal plant species.

Statistical analysis

The Mann-Whitney test was applied to test differences in mean values ($n = 5$) of various variables of medicinal plants (frequency, density, biomass, cover, Shannon H', and richness) on the 2 land use types. Tests were performed at both plot level (a single value for all medicinal plants per plot strip) and treatment level (a single value for individual per plot strip) on the 2 sites. Statistical significance was accepted at $P < 0.05$. Detrended correspondence analysis (DCA) was applied to

identify the variables in forest stand structure (tree H', stem density, tree canopy cover, basal area, leaf area index) probably responsible for increasing the densities of medicinal plant species. DCA is based on the assumption of normally distributed data; therefore, data were logarithmically transformed to minimize the effect of zeros and achieve approximate normal distribution. DCA was carried out using PC-ORD 5.06 (McCune and Mefford 1999). Data compilation and Mann-Whitney analysis and Spearman correlation were carried out by using the Excel and SPSS programs (version 16.0), respectively.

Results

Forest stand structure

The observed mean tree basal area on reforestation plots (7.9 m² ha⁻¹) was approximately 2.5 times higher than on degraded plots (2.9 m² ha⁻¹). Planted trees accounted for 44% of the total basal area on reforested plots (Table 2). Mean tree canopy cover on reforested sites was 9 times higher than on degraded land. A mean tree H' of 1.2 was calculated for the reforested area and tree H' of 0 for the degraded sites. Mean stem density in the reforested area was about 13 times higher than on degraded sites.

Performance of medicinal plants on 2 land use types

In total (at plot level), medicinal plants showed significant differences between the 2 land use types included in this study (Table 3). Mean H' of medicinal plants was twice as high on reforested sites than on the degraded sites. Density and cover of medicinal plants were 7 times and 5.5 times higher on reforested sites than on degraded sites, respectively.

TABLE 3 Variation of studied medicinal plants between reforested and degraded sites ($n = 5$ plots per land use type). Small letters in superscript (^{a, b}) indicate significant differences at $P < 0.05$, Mann-Whitney test.

Medicinal plants variables	Reforested sites	Degraded sites
	Mean \pm SE	Mean \pm SE
Shannon index (H')	1.45 \pm 0.15 ^a	0.72 \pm 0.12 ^b
Dry weight above ground (g/m^2)	59.30 \pm 31.62 ^a	6 \pm 3.04 ^b
Dry weight below ground (g/m^2)	58.00 \pm 32.51 ^a	2 \pm 1.12 ^b
Density (n/m^2)	9.75 \pm 4.39 ^a	1.31 \pm 0.35 ^b
Cover % ($1 m^2$)	22 \pm 5.81 ^a	4 \pm 1.34 ^b

At the treatment level, frequencies and densities of 4 medicinal plants (*Geranium wallichianum*, *Paeonia emodi*, *Swertia chirata*, and *Gallium aparine*) were significantly higher on reforested sites than on degraded sites, while the frequency of *Plantago lanceolata* was significantly lower. *Bergenia ciliata*, *Bistorta amplexicaulis*, and *Valeriana jatamansi*, which were absent from degraded sites, were encountered on reforested sites (Figure 3A,B). The cover of medicinal plant species showed significant differences among 5 species. Cover percentage on reforested areas of *Gallium aparine* was 47-fold greater, *Swertia chirata* 18-fold, *Geranium wallichianum* 16-fold, and *Podophyllum emodi* 5-fold greater than on degraded land (Figure 3C).

Indicated by the DCA on the reforested stand, axis 1 (eigenvalue 0.35) of forest stand structural data was significantly correlated with basal area $r = 0.96$ ($P = 0.01$). The second axis (eigenvalue 0.13) did not show any significant correlation. This implies that tree basal area is the most important variable influencing the abundance of medicinal plants. Densities of *Bergenia ciliata* and *Valeriana jatamansi* increased greatly with increasing tree basal area, while *Bistorta amplexicaulis*, *Geranium wallichianum*, *Viola canescens*, and *Paeonia emodi* had less intense but positive relationships. On the other hand, densities of *Swertia chirata*, *Gallium aparine*, *Plantago lanceolata*, and *Podophyllum emodi* decreased with increasing tree basal area (Figure 4).

Discussion

Previous studies have already suggested that reforestation may be a source of improvement of ground vegetation (Islam et al 2001; Huy 2004). It has even been proposed that reforestation may have a catalytic effect on the regeneration of natural forest biodiversity (Parrotta 1995; Loumeto and Huttel 1997). In our study, all reforested sites were found to have higher density, diversity, biomass, and cover of medicinal plants than did degraded sites. Degraded sites studied were comparable to those subject to reforestation for 3 to 8 years prior to our field study. It

can be assumed that reforestation was the main reason for the great abundance of medicinal plants.

Comparison of individual medicinal plant frequencies on degraded and reforested sites indicates a relationship between frequency and reforestation. The reforested sites have a greater frequency of most of the target species, which can grow well under partial or full shade. On the

FIGURE 3 Species-specific frequencies (A), densities (B), and cover percentages (C) of the studied medicinal plants on reforested and degraded sites ($n = 5$ plots per land use type; * indicates significant differences at $P < 0.05$, Mann-Whitney test).

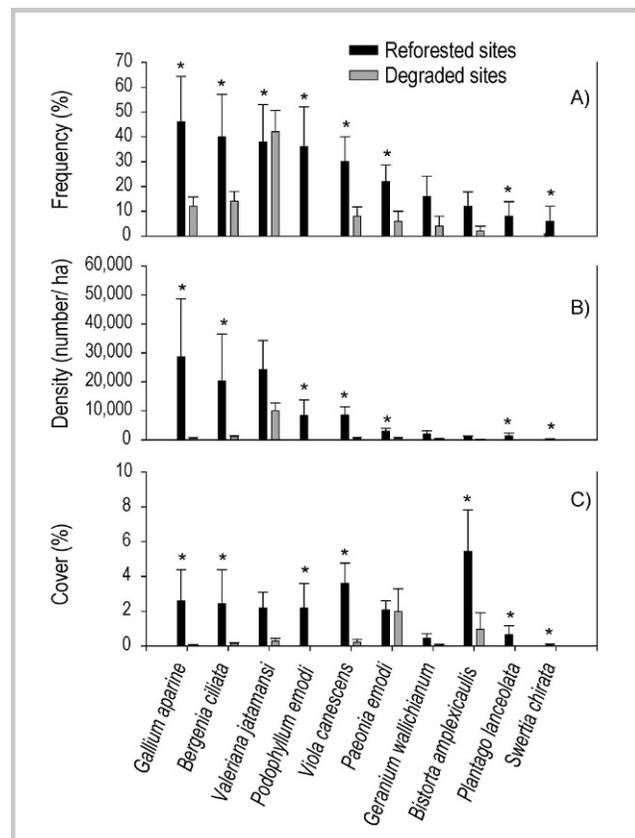
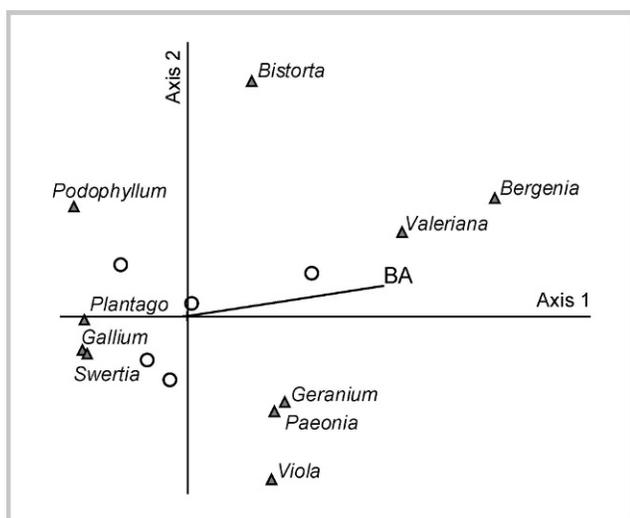


FIGURE 4 DCA for the response of individual medicinal plant densities to tree basal area on reforested sites. The matrix consists of 5 plots, 10 medicinal plant species, and basal area of trees. Axis 1: eigenvalue = 0.35, explained variance = 48%; axis 2: eigenvalue = 0.13, explained variance = 30%. Correlation threshold: $r^2 > 0.5$. Significant correlations (Pearson) at $P < 0.01$ were only observed for basal area ($r = 0.96$) with axis 1. BA indicates tree basal area, and round symbols represent plots. Refer to Table 1 for complete botanical names of medicinal plants.



other hand, frequency of *Plantago lanceolata* was observed less in reforested areas, which might have been due to better adaptation to growth conditions on open land. Partial-shade-adapted plants, such as *Gallium aparine*, *Swertia chirata*, and *Geranium wallichianum*, had low densities and high frequencies on degraded sites, which were observed more on reforested sites. Cover percentage of a particular medicinal plant species was usually associated with density. However, we observed an increase in the cover of *Paeonia emodi* despite insignificant differences in the density and frequency of both land use types. The reason could be enlargement in the surface area of leaves under partial-shade conditions on reforested sites.

Within the young reforestation stands of our study, higher tree basal area resulted in increased abundance of most medicinal plants, including 3 highly valuable species: *Valeriana jatamansi*, *Bergenia ciliata*, and *Paeonia emodi*. On the other hand, low tree basal area appeared to favor species such as *Plantago lanceolata*, *Swertia chirata*, and *Gallium aparine*. Basal area has been described as an approximation

of canopy cover and has been found to have a positive correlation with herb layer vegetation in forest stands (Mitchell and Popovich 1997). However, even at the studied growth stage of the reforestation stands, some of the species were correlated positively with basal area while the others were negatively correlated. According to Balandier et al (2006), abundant overstory (quantified through basal area, stem density, or light availability) can even suppress almost all understory species.

Our results suggest that open land species with high densities decreased, whereas shade-adapted species with low densities increased with increasing tree basal area on the reforested sites. We also assume that a high abundance of medicinal plants can be achieved in young tree stands with a certain balanced basal area, which probably involves partial-shade conditions. Hannerz and Hånell (1997) and Nagaike et al (2003) also mention that a great abundance of understory species can be found in young plantations. However, if the reforested stands are used for firewood collection, tree cutting, and replanting, they may develop into relatively young and open stands and could also provide good conditions for medicinal plant abundance in the long run.

Perhaps the most important result for local people is that the most valuable medicinal plant species (*Valeriana jatamansi*, *Bergenia ciliata*, and *Paeonia emodi*) were found to be much more abundant in reforested areas than in degraded areas. At the time of this study, local collectors could earn approximately US\$ 60 more per hectare on reforested sites. Thus, reforestation can contribute significantly not only to habitat restoration in the area but also to the livelihoods of local people who depend on medicinal plants. However, it has been observed that rural communities will not accept any approach unless they are involved in all development, management, and conservation interventions for the sustainability of forest resources, particularly medicinal plants.

In conclusion, our study indicates that in the mountain areas of northwest Pakistan, young reforestation stands have indeed increased the abundance of most of the medicinal plants studied, by comparison with deforested and degraded land. Therefore, we suggest the extension of reforestation to further areas of *guzara* forest and other mountainous areas of Pakistan, together with the active involvement of local people in management activities.

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