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Full Length Article

Medicinal Plants after Forest Disturbance, Restoration and Cultivation in Pakistani Himalaya

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Abstract

Himalayan forests of Pakistan are subjected to various anthropogenic pressures, which have resulted in the extinction of several medicinal plants important for rural livelihood as food, healthcare and income. The study was carried out at Ayubia National Park with the objectives (i) to assess the abundance of selected medicinal plant species in disturbed, undisturbed and restored forests, and (ii) to evaluate the cultivation potential of highly valuable medicinal plant species. In the first step, 15 plots were randomly assigned each to three forest types, in which the abundance of five medicinal herbs was assessed. Secondly, five locally valuable species were cultivated each in three replications of 1 m^2 area in agroforest. Density of medicinal plants such as *Bergenia ciliata* was the highest in undisturbed forest (4.3 m^{-2}), intermediate under restored forest (1.8 m^{-2}) and the lowest under disturbed forest (01 m^{-2}). *Podophyllum emodi* and *Paeonia emodi* were found absent from the disturbed forest, while encountered in restored forest. Species such as *B. ciliata* showed higher production and economic gains (18 US$) on agroforest plot (1 m^2). In conclusion, forest restoration has the potential to recover extinct medicinal plant species and can provide local support for forest expansion in the region. In addition, introduction of medicinal plants cultivation into the agricultural system may represent an opportunity for the conservation of such species in the wild and improving rural livelihood. Above all, the application of present study on a wider scale may help in mitigating the adverse effects of climate change on food security and may also ensure their sustained supply.

Keywords: Herbs; Forest types; Density; Agricultural production; Livelihood

Introduction

Himalayan forests have played a key role in the rural livelihood of both mountains and lowland communities by supplying diversity of valuable forest products for food and medicine (Kala, 2004). The age-old traditional values attached with non timber forest products (NTFPs) such as medicinal plants have gained a tremendous importance in this century (Jabbar *et al*., 2006). Medicinal plants are an important source of income for the underprivileged communities apart from their contribution in food and health care system (Bussmann and Sharon, 2006).

The forest area of Pakistan is comprised of 4.8% of the total geographical area having a deforestation rate of 1.5% per year (FAO, 2005). Forest degradation and deforestation during the recent decades has changed the structure of undisturbed old growth forests to various kinds of degraded forests particularly in the country's northwest region. Lack of alternatives for resources such as fodder, fuel-wood, timber and medicinal plants are the possible factors of forests degradation (WWF-P, 2004). Humans are the agent behind such factors that affecting water supply, food supply, pollution, extinction of species and climate change (Pokhriyal *et al*., 2012); while their negative impact on medicinal flora has already been identified (Mishra *et al*., 2004). Hence, conserving the remaining forests and their biodiversity is the demand of today. Forest restoration is probably be the only solution that will be effective in order to meet the increasing demands for ecosystem services such as particular medicinal plants (Lamb *et al*., 2005). Ecological restoration could therefore be an important practice to increase the levels of biodiversity in human-altered ecosystems (Brudvig, 2011) and may mitigate the impact of climate change (Harris, 2009). However, to ensure forest restoration, the community may be mobilized towards other alternatives such as cultivation of wild medicinal plant species. Cultivation of medicinal plants is an effective measure of sustainable use of valuable species (Hamilton, 2004) that will not only expand the trade of such resources and high returns to the farmers but will also contribute in the continuous supply as industrial raw material. However, in many countries medicinal plants cultivation did not get much attention (Rao *et al*., 2004).

The present study was carried out in the Ayubia National Park, where large numbers of people is dependent on medicinal plant resources. This study will identify the

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role of forest restoration in reclaiming the abundance of medicinal plants and can also show how effectively such plants can be cultivated for a continuous food supply, economic gains and mitigating the effects of climate change. The objectives of this study are (i) to assess the abundance of selected medicinal plant species in disturbed, undisturbed and restored forests, and (ii) to evaluate the cultivation potential of some highly valuable medicinal plant species.

Materials and Methods

Study Area

The study was carried out in Ayubia National Park (ANP) and surrounding forest situated in the Gallis Forest Division of Abbottabad district, Khyber Pakhtunkhwa, Pakistan (Fig. 1 A, B). The altitude ranges from 1220–2865 m (Hussain, 2003). ANP has a mean annual rainfall of 1500 mm, snowfall of 2.5 m, and temperature of 12^{o}C (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. The dominant tree species are *Abies pindrow*, *Pinus roxburghii* and *P. wallichiana*. About 50,000 people currently live in 12 villages around the ANP. Women usually collect medicinal plants. Annual fuel-wood and fodder consumption by each household in the study area was about 12 tons and 13 tons, respectively (Hussain, 2003).

Medicinal Plant Selection through Direct Matrix Ranking

Direct matrix ranking (DMR) was used to check the use diversity of multipurpose medicinal plants as described by Cotton (1996). It involved 15 (10 men and 5 women) key informants. Participants for this exercise were selected based on their long years of experience as traditional herbal medicine practitioners.

Data on 124 medicinal plants (herbs) of the study area was collected from the available literature (Adnan *et al*., 2012) and were subjected to DMR method, from which we selected five high ranked medicinal plant species. The selected species have high market value, multipurpose uses, relatively easy identification in the field, and conservation concerns in the area. The selected plants are used locally and extensively as traditional medicines. *Bergenia ciliata* (Haw) Sternb is used against stomach, intestine and fever diseases, and having high marketable species (2.6 US$ kg^{-1}). *Paeonia emodi* Wall (3.1 US$ kg^{-1}) is used for back pain and as a tonic, and *Podophyllum emodi* Wall (5.2 US$ kg^{-1}) for liver, stomach, intestinal disorders and tonic. *Valeriana jatamansi* Jones (4.6 US$ kg^{-1}) and *Viola canescens* Wall ex Roxb (12.6 US$ kg^{-1}) provide adequate treatment for cholera and fever, respectively. All species are adapted to deep shady and partial shaded conditions and occur in association with trees (Adnan *et al*., 2012).

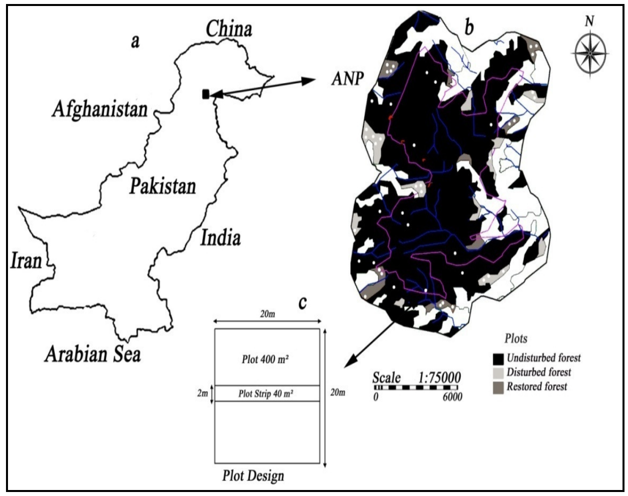

Fig. 1: Map of the study area and plot design. (a) Pakistan, (b) Ayubia National Park (ANP; inside boundary) and its surrounding with random plots in three forest types, (c) Plot design

Sampling, Plot and Estimation Designs for Tree Inventory and Medicinal Plants

Data on medicinal plants abundance was collected from July 2012 to August 2012 in three forest types. Undisturbed forest refers to the forest type with slight or no human interventions with high level of protection from resource exploitation. Disturbed forest refers to areas where grazing, logging, fodder collection and medicinal plants collection are common practices. Restored forests are currently regenerating after disturbance. Fifteen random sample points (15 plots) each were allocated to the 3 forest 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). Each sample point was considered to be the center of each plot and was located in the field by using global positioning system and compass. Each plot consisted of a tree inventory plot of 20 m × 20 m = 400 m^2 and a long, horizontal plot strip of 20 m × 2 m = 40 m^2 enclosed in each inventory plot for the assessment of medicinal plants (Fig. 1C) (Adnan and Hölscher, 2011). Estimated tree variables were basal area, stem density and canopy cover. Moreover, Shannon-Wiener diversity index $H^{/}$(Magurran, 2004) of trees was calculated for each inventory plot. Tree canopy cover was photographed by using hemispherical camera (Minolta Dimage Xt, Japan). Variables of medicinal plants included density of selected medicinal. Estimation of species density was carried out following the protocol outlined by Curtis and McIntosh (1951).

Cultivation of Medicinal Plants in Agroforest

Total of 75 seedlings (2 cm height) of each selected medicinal plant species were collected from the medicinal plant nurseries of WWF-Pakistan. Three replications of 1 m^{-2} plots were laid for each species in three different agroforest locations under the cultivation of crops, vegetables and fruit trees. Each replica was cultivated with 25 seedlings of a plant species by keeping row to row and plant to plant distance of 20 cm (WWF-P, 2004). Cultivation was carried out in May 2012, while harvesting in October 2012. Two to three irrigations and other agronomic practices were done during the seedling stage. Data on various parameters i.e., plant height, root collar diameter, dry biomass above ground and dry biomass below ground were measured. Plant height was measured using measuring tape while root collar diameter with the help of Vernier Caliper. Dry biomass of each species above and below was measured after 15 days shade drying using electric balance. The prices (US$) of species were estimated by multiplying its local market prices (part use) with its production in 1 m^2.

Statistical Analysis

Kruskal–Wallis test was applied to test differences in mean values of medicinal plants density between three forest-use types. Detrended Correspondence Analysis (DCA) was used to identify variables of forest tree stand structure related to densities of medicinal plant. DCA was carried out using PC-ORD 5.06 (McCune and Mefford, 1999). Data on cultivation in 3 replications were subjected to mean and standard error. Data compilation, Kruskal-Wallis test, DMR and Shannon index were carried out using Microsoft Excel and SPSS version 16.0 (SPSS Inc., 2007).

Results

Five medicinal plant species, selected on the basis of DMR, were *P. emodi* and *Pa. emodi* (ranked first and were the most threatened species), *B. ciliata* and *V. canescens* (both ranked second) and *V. jatamansi* (ranked third) (Table 1). Results indicated that the selected multipurpose medicinal plant species were exploited for medicinal, fodder and ethnoveterinary purposes (Table 1). Medicinally, these species were mostly used against stomach, intestinal and chest related infections, and have higher market prices.

Densities of all the medicinal plants species have shown significant difference ($p < 0.01$) between the forest types. Density of *B. ciliata* was highest in undisturbed forest (4.3 m^{-2}) followed by in restored forest (1.8 m^{-2}) as compared to disturbed forest (01 m^{-2}). Similar trends were showed by other studied medicinal plants. *P. emodi* and *Pa. emodi* were found absent from the disturbed forest (Fig. 2). DCA has shown significant correlation of axis 1 with tree basal area ($r= -0.41$, $p \leq 0.01$), density of *Pa. emodi* ($r = 0.65$, $p \leq 0.01$) and density of *P. emodi* ($r = 0.39$, $p \leq 0.01$) (Fig. 3).

Results on cultivation showed that *P. emodi* attained maximum height (24 cm), while *B. ciliata* highest root

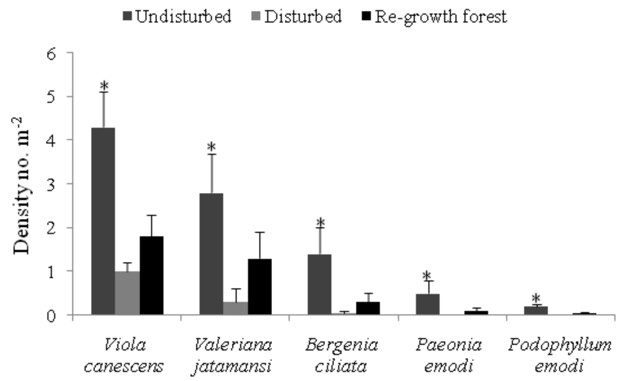

Fig. 2: Density of selected medicinal plants among three forest-use types. * represents significant difference ($p < 0.01$; Kruskal-Wallis test)

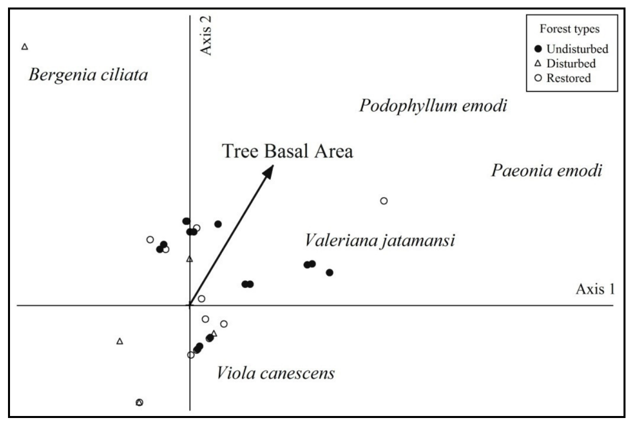

Fig. 3: Detrended correspondence analysis (DCA) for the response of medicinal plant densities to tree basal area. Axis 1: eigen value = 0.3, explained variance = 43%. Significant correlations were observed for basal area, *P. emodi* and *Pa. emodi*

collar diameter (18 cm) among all the species. *B. ciliata* was also found with more above ground biomass (1.14 kg m^{-2}) and below ground biomass (0.82 kg m^{-2}) of worth 18 US$ extracted from 1 m^2. Moreover, *P. emodi* and *Pa. emodi* also showed good production (Table 2).

Discussion

Our study indicated that densities of *B. ciliata*, *P. emodi*, *Pa. emodi*, *V. canescens* and *V. jatamansi* were highest in undisturbed forest. This might be due to the high level of protection and closed canopy cover of this forest type, which may have provided suitable deep and partial shady condition to the studied medicinal plants. Other studies in the Himalayan region have reported higher densities and ground flora richness under undisturbed sites than highly disturbed sites (Uniyal *et al*., 2010). In undisturbed forest the density of these medicinal plants has very much reduced

Table 1: Average direct matrix ranking (DMR) score of fifteen key informants for five medicinal plants species

Use diversity	*Bergenia ciliata*	*Paeonia emodi*	*Podophyllum emodi*	*Valeriana jatamansi*	*Viola canescens*	Total	Rank
Fodder	5	4	4	5	5	23	1
Fuel	2	2	3	2	2	11	4
Ethnoveterinary	4	5	4	2	2	17	2
Medicinal	5	5	5	4	4	23	1
Vegetable	2	4	4	2	5	17	3
Total	18	20	20	15	18		
Rank	2	1	1	3	2		

Table 2: Cultivation potential of medicinal plants

Species	Height (cm)	Root collar diameter (cm)	Dry biomass above ground (kg m^{-2})	Dry biomass below ground (kg m^{-2})	Income (US$ m^{-2})
Viola canescens	9.7±0.7	3.4±0.2	0.14±0.05	0.07±0.03	2
Valeriana jatamansi	9.9±1.2	6.1±0.6	0.27±0.06	0.10±0.06	3
Podophyllum emodi	24.3±3.5	5.2±0.4	0.41±0.05	0.33±0.04	7
Paeonia emodi	20.3±2.0	4.6±0.4	0.40±0.1	0.26±0.1	6
Bergenia ciliata	15.4±1.7	18.0±2.0	1.14±0.2	0.82±0.1	18

due to certain anthropogenic activities such as grazing and over collection of such species for medicinal and vegetable purposes. Such activities have resulted in the extinction of *P. emodi* and *Pa. emodi* from the disturbed landscapes. Mishra *et al*. (2004) has reported that that human disturbance is the main reason for declining medicinal plants abundance in forests. They further augmented that disturbance may consequently result in the extinction certain species that are adapted to a particular ecological condition, however may also favor invasive species.

In restored forest the density of medicinal plants was found highest as compared to undisturbed forest. Moreover, highly vulnerable species such as *Pa. emodi* and *P. emodi* were encountered in this forest type. DCA results have also confirmed a direct relation between the tree basal area and the densities of these medicinal plants. These species are well adapted to deep and partial shady environment, therefore their abundance increases as the basal area increases. Other studies have confirmed that if a forest is allowed to regenerate and is protected, the understory species that had once disappeared from it also regenerate (Parrotta *et al*., 1997; Islam *et al*., 2001). Forest re-growth alters conditions for the ground vegetation, such as soil fertility, light, temperature and moisture (Barbier *et al*., 2008); all of which affect competition dynamics at ground level.

The relationship of tree basal area is not only confined to the density of medicinal plants but also to the climate change due to global warming. Forest ecosystems are the major carbon sinks that are taking up carbon from the atmosphere and thus have an important role in mitigating climate change. Reducing tree basal area can limit the deposition of CO_2 in trees, which may increase CO_2 concentration in the atmosphere and raise the temperature (Zilberman and Sunding, 1999; FAO, 2005). The consequence would likely be on the understory medicinal plants, which may result in challenges for the security of medicinal food in the world's poorest areas. Therefore, cultivation of medicinal plants would be a good strategy to face such challenges.

Cultivation of medicinal plants has shown encouraging results in this study. *B. ciliata* showed highest production followed by *P. emodi* and *Pa. emodi*. The increased production of such species might be due to the presence of modified canopy cover to provide suitable shady conditions for such species under agroforest. Local farmers can earn 18 US$ from a 1 m^2 plot in agroforest from *B. ciliata*. These species are also very important from market point of view and have high demand in pharmaceutical industries. Hence, cultivation of medicinal plants appears to be an important strategy for meeting the growing demand and reducing harvest pressure on wild populations (Hamilton, 2004).

In conclusion, high utilization has drastically decreased the abundance of medicinal plants under disturbed forest as compared to undisturbed forest. Restored forest has recovered medicinal plants that were observed absent from the disturbed forest. Moreover, cultivation of medicinal plants has shown good potential under agroforest. Therefore, forest protection and restoration, and cultivation of medicinal plants can mitigate the adverse anthropogenic pressure and climate change on the vegetation and may ensure medicinal food security in the region.

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