

# **EXPLORING PATTERNS OF PHYTODIVERSITY, ETHNOBOTANY, PLANT GEOGRAPHY AND VEGETATION IN THE MOUNTAINS OF MIANDAM, SWAT, NORTHERN PAKISTAN**

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ETHNOBOTANY, PLANT GEOGRAPHY AND  
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aus

Swat, Khyber Pakhtunkhwa, Pakistan

Göttingen, 2014

WHEN WE ARE FIVE AND THE APPLES ARE FOUR MY MOTHER  
SAYS "I DO NOT LIKE APPLES"

DEDICATED

TO

*My Mother*

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## Table of Contents

Acknowledgements .....	8
Zusammenfassung .....	10
Summary .....	12
CHAPTER 1 .....	14
INTRODUCTION.....	14
Do mountains account for plant species diversity?.....	14
Phytodiversity in Himalayan perspective.....	14
Computer based multivariate analyses of vegetation .....	15
Ethnobotanical work in Pakistan.....	15
Phytodiversity and vegetation analyses in Pakistan.....	16
Study area.....	17
Geology of Swat .....	17
Miandam .....	19
Basis of objectives of the present project.....	20
Objectives.....	20
References .....	21
CHAPTER 2.....	26
DIVERSITY AND USE OF ETHNO-MEDICINAL PLANTS IN THE REGION OF SWAT, NORTH PAKISTAN .....	26
Abstract .....	27
Introduction.....	28
Study area.....	29
Methods.....	29
Results and discussion.....	30
Plant diversity, use and applications.....	30
Habitats and conservation of ethno-medicinal plants .....	32
Conclusion .....	33
References.....	44

CHAPTER 3.....	49
VEGETATION PATTERNS AND HUMAN IMPACT ALONG AN ELEVATION GRADIENT IN THE MOUNTAINS OF SWAT, NORTHERN PAKISTAN .....	49
Abstract .....	50
Introduction.....	51
Study Area.....	52
Materials and methods .....	53
Data collection.....	53
Data analysis.....	54
Results.....	56
Diversity, classification and description of vegetation .....	56
(1) Subalpine scrub of <i>Betula utilis</i> .....	56
(2) Laurophyllous <i>Quercus semecarpifolia</i> forest .....	60
(3) Subalpine <i>Betula-Viburnum</i> treeline scrub .....	60
(4) Alpine turf of <i>Sibbaldia cuneata</i> with <i>Juniperus</i> patches .....	60
(5) Coniferous forest of <i>Abies pindrow</i> and <i>Geranium wallichianum</i> .....	61
(6) <i>Picea smithiana</i> mixed coniferous forest .....	61
(7) Woodland of <i>Abies pindrow</i> and <i>Viburnum grandiflorum</i> .....	62
(8) Subtropical groves of <i>Ailanthus altissima</i> .....	62
(9) Mixed forest of <i>Quercus floribunda</i> and <i>Pinus wallichiana</i> .....	63
(10) Woodland of <i>Abies pindrow</i> and <i>Indigofera heterantha</i> .....	63
(11) Woodland of <i>Pinus wallichiana</i> with <i>Sorbaria tomentosa</i> shrubbery .....	64
(12) Woodland of <i>Pinus wallichiana</i> with <i>Indigofera heterantha</i> scrub .....	64
Gradient analysis and altitudinal zonation .....	65
Discussion .....	69
Comparison with other studies in wider surroundings .....	69
Human impact.....	72
References.....	75

CHAPTER 4.....	79
SPECIES RICHNESS, ALPHA AND BETA DIVERSITY OF TREES, SHRUBS AND HERBACEOUS PLANTS IN THE WOODLANDS OF SWAT, PAKISTAN .....	79
Abstract .....	80
Introduction.....	81
Materials and Methods.....	82
Study area .....	82
Field sampling.....	82
Data analysis .....	84
Results.....	84
Species richness in relation to elevation .....	84
Alpha diversity in relation to elevation.....	86
Beta diversity in relation to elevation .....	87
Discussion .....	88
Variation in species richness.....	88
Variation in $\alpha$ -diversity.....	89
Variation in $\beta$ -diversity .....	89
Conclusion .....	89
References .....	90
CHAPTER 5.....	94
SYNTHESIS .....	94
Ethnobotanical findings .....	94
Phytosociological and phytogeographical aspect.....	95
Measurements of species diversity.....	96
Major contributions of the present project .....	97
Recommendations .....	97
References.....	98
Declaration of originality and certificate of ownership.....	101

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## Zusammenfassung

Das Miandam-Untersuchungsgebiet (35° 1' - 5' N, 72° 30' - 37' E) liegt in der Swat-Region der Provinz Khyber Pakhtunkhwa (ehemals North West Frontier Province) im nördlichen Pakistan. Die vorliegende Arbeit berücksichtigt sowohl ethnobotanische und pflanzensoziologische Aspekte als auch die Pflanzenartendiversität innerhalb des Gebietes.

Aufgrund der hohen Habitatvielfalt weist das Miandam-Gebiet einen großen Reichtum von Medizinalpflanzen auf. Die im Rahmen der Arbeit durchgeführte ethnobotanische Studie dokumentiert das Vorkommen der Medizinalpflanzen sowie deren Nutzung in der Region. Weiterhin wurden die durch Sammlerpräferierten Lebensräume bestimmt und evaluiert inwiefern die Heilpflanzen durch Sammlung und Habitatzerstörung bedroht werden. Insgesamt wurden 106 traditionelle Heilpflanzen aus 54 Pflanzenfamilien verzeichnet. Zu den am häufigsten gefundenen Wuchsformen zählten mehrjährige (43%) und kurzlebige Kräuter (23%), Sträucher (16%) und Bäume (15%). Ein Großteil der untersuchten Heilpflanzen und ihrer Produkte wird zur Behandlung von Magen-Darm-Erkrankungen eingesetzt. Die Produkte werden vorrangig als Sud oder Pulver zubereitet und oral angewendet. Achtzig der 106 traditionellen Heilpflanzen gehören der Gruppe der einheimischen Arten an. Fast 50% der Pflanzenarten treten dabei in synanthroper Vegetation auf, während der Rest in naturnaher Umgebung (z.B. extensiv beweidete Wald- und Graslandbereiche) vorgefunden werden kann. Wälder sind der Ursprung der meisten nicht synanthropen einheimischen Medizinalpflanzen. Drei Arten (*Aconitum violaceum*, *Colchicum luteum*, *Jasminum humile*) können als Folge intensiven Sammelns als bedroht eingestuft werden.

Um die pflanzensoziologischen und phytogeografischen Aspekte des Projektes abzudecken wurde die Vegetation des Miandam-Gebietes mit einem Fokus auf Wäldern, Gebüschern und anderen Formationen untersucht. Die Ergebnisse der Vegetationserhebungen wurden mit denen anderer Studien in der weiteren Umgebung des Hindukush-Himalayas verglichen. Weiterhin wurde untersucht inwiefern die Waldökosysteme durch anthropogene Aktivitäten im Untersuchungsgebiet bedroht sind. Die im Gebiet verzeichneten Gefäßpflanzenarten umfassen insgesamt 33 Bäume, 52 Sträucher, 305 Kräuter und 11 Lianen. Basierend auf einer multivariaten Analyse konnten 12 Pflanzengesellschaften identifiziert werden. Die Spanne dieser Gesellschaften reichte von subtropischen semiariden Wäldern mit *Ailanthus altissima* im Tiefland zu alpinen Rasen von *Sibbaldia cuneata* durchsetzt mit *Juniperus*. Die dominierende Vegetation des Untersuchungsgebietes besteht aus von *Abies pindrow* und *Viburnum grandiflorum* Wäldern. Eine georeferenzierte Karte der Vegetation erleichtert die Lokalisierung der ökologisch interessanten Vegetation.

Artenreichtum und –diversität wurden entlang eines Höhengradienten untersucht. Dazu wurde die Alpha- sowie Beta-Diversität verschiedener Wuchsformtypen bestimmt. Der Artenreichtum aller Gefäßpflanzenarten erreichte sein Maximum zwischen 2200-2500 m. Dagegen zeigte der Artenreichtum der Sträucher einen glockenkurvenartigen Verlauf mit einem Maximum zwischen 2000 und 2200 m. Die höchste Alpha-Diversität der Gefäßpflanzenarten wurde in den tieferen Lagen des Untersuchungsgebietes verzeichnet. Die Beta-Diversität aller Wuchsformtypen zeigte entlang des gesamten Höhengradienten hohe Werte und somit einen starken Artenwechsel. Die Beta-Diversität der Straucharten fluktuiert entlang des Höhengradienten und zeigt damit ein einzigartiges Muster.

## Summary

The study area of Miandam (35° 1' - 5' N, 72°30'-37' E) is located in the District of Swat in the Province of Khyber Pakhtunkhwa (formerly North West Frontier Province) in the North of Pakistan. The present project is a combination of three different studies that consist of ethnobotanical, phytosociological and phytodiversity aspects.

Due to its geographical and habitat conditions, the area of Miandam harbors a wealth of medicinal plants. The ethnobotanical study was carried out to document which medicinal plant species and which plant parts are used in the region. It was also observed which habitat is frequented by collectors and to which extent medicinal plants are vulnerable due to collection and habitat destruction. A total of 106 ethno-medicinal plant species belonging to 54 plant families were recorded. The most common growth forms were perennial (43%) and short-lived herbs (23%), shrubs (16%), and trees (15%). Most frequently used plant parts were leaves (24%), fruits (18%) and subterranean parts (15%). A considerable proportion of the ethno-medicinal plant species and remedies concerns gastro-intestinal disorders. The remedies were mostly prepared in the form of decoction or powder and were mainly taken orally. Eighty out of 106 ethno-medicinal plants were indigenous. Almost 50% of the plants occurred in synanthropic vegetation while slightly more than 50% were found in semi-natural, though extensively grazed, woodland and grassland vegetation. Woodlands are the main source for non-synanthropic indigenous medicinal plants. Three species (*Aconitum violaceum*, *Colchicum luteum*, *Jasminum humile*) must be considered vulnerable due to excessive collection.

To cover the phytosociological and phytogeographical aspect of the present project, vegetation of Miandam area was thoroughly investigated with particular focus on woodlands, shrublands and other formations. The findings of the vegetation study were compared with other studies in the wider surroundings of Hindukush-Himalaya. It was also assessed to what extant forest ecosystem is threatened by different anthropogenic activities. The vascular plant species found comprise 33 trees, 52 shrubs, 305 herbs and 11 climbers. Based on multivariate analysis twelve plant communities were established from Sub-tropical semiarid groves of *Ailanthus altissima* in the lowland to Alpine turf of *Sibbaldia cuneata* with *Juniperus* patches. Woodland of *Abies pindrow* and *Viburnum grandiflorum* is the dominant woodland vegetation in the area. A georeferenced map of the vegetation is presented that will help researchers in spotting vegetation of ecological interest.

Patterns of species richness and diversity were also evaluated along an elevation gradient. Alpha and beta diversities of different growth forms were determined. Species richness of all the vascular plants was highest between 2200-2500 m. A hump shaped relationship was found between shrub richness and elevation with maximum species richness of shrubs between 2000 and 2200 m. For all the

vascular plants Alpha diversity was high in the lower zone of the elevation gradient. Beta diversity of all the growth forms was quite high along the entire gradient reflecting high species turnover. A unique pattern of beta diversity of shrub species was observed which fluctuated along the elevation gradient giving rise to a unimodal pattern.

# CHAPTER 1

## INTRODUCTION

### **Do mountains account for plant species diversity?**

Approximately 25% of the land surface of the Earth is covered by mountains, which host at least a third of terrestrial plant species diversity (Barthlott, 1996). As one ascends a mountain, environmental conditions change, and one finds organisms that are commonly well adapted to the local conditions along an altitudinal transect, thus offering ideal conditions for exploring evolutionary adaptation over short spatial distances. However, the interpretation of results obtained from such works becomes difficult when the gradients selected include environmental changes that reflect local or regional peculiarities, such as fire (Hemp, 2005), land use (Spehn *et al.* 2006) or drought (Marshall and Zhang, 1994), not generally associated with altitude above sea level. Since many conspicuous changes of community composition and richness are related to differences in elevation, altitudinal gradients have become increasingly popular for investigating diversity patterns (Grytnes and McCain, 2007; Rahbek, 1995; 2005). One of the analytical advantages of elevational gradients is that they are replicated across the globe, allowing contrasting gradients under different climatic, edaphic, or topographic situations (Lomolino, 2001; McCain, 2009). The relationship between species richness and elevation is complex, depending on the taxonomic group and the gradient considered, with hump-shaped (Bhattarai *et al.* 2004; Brehm *et al.* 2007; Kluge *et al.* 2006; Oommen and Shanker, 2005) and monotonically decreasing (for e.g., Patterson *et al.* 1998) patterns being the most common (Kessler *et al.* 2009; McCain, 2009; Rahbek, 1995; 2005).

### **Phytodiversity in Himalayan perspective**

The Himalayas include the highest mountains in the world with the greatest ecological amplitude (Dobremez and Jest, 1976). Himalayan vegetation is diverse and ranges from tropical evergreen species in the south east to thorn steppe and alpine species in the north-western parts (Behera and Kushwaha, 2007). Himalayas affect global climate by bringing changes in temperature and precipitation. Within a relatively short horizontal distance, one can find large environmental variation from humid lowland forests to the glaciated and snowbound upper regions. This mountain range is therefore an excellent place for studying species richness patterns (Körner, 2000) and for testing various biogeographical hypotheses (Carpenter, 2005). Species richness patterns along the Himalayan

elevational gradient have been analyzed for: flowering plants (Bhattarai and Vetaas, 2003; Carpenter, 2005; Grytnes and Vetaas, 2002; Vetaas and Grytnes, 2002; Wang *et al.* 2006; 2007), ferns (Bhattarai *et al.* 2004), liverworts and mosses (Grau *et al.* 2007), lichens (Baniya *et al.* 2010) and birds and mammals (Hunter and Yonzon, 1993). In addition to high species richness, the central and eastern Himalaya also supports many endemic plant species (Singh, 2001; Vetaas and Grytnes, 2002). These species have a special value in nature conservation because they are restricted to a small geographical region and are vulnerable to extinction from habitat loss, forest destruction and degradation (Rajbhandari *et al.* 2000; Winkel, 2006). The identification of elevational zones with high numbers of endemic species is valuable for strategic conservation plans in the light of land-use pressures and climate change (Körner, 2000; Klanderud and Birks, 2003). However, regional patterns in total richness may not correspond to endemic richness (Vetaas and Grytnes, 2002). In the Himalayan region, it is proposed that maximum endemic richness occurs at high elevations (Shrestha and Joshi, 1997), possibly caused by evolutionary drivers such as polyploidy and allopatric speciation by means of isolation mechanisms. Consistent with this, Vetaas and Grytnes (2002) found maximum richness of plant species endemic to Nepal in an elevational zone between 3800 and 4200 m, whereas maximum species richness occurred between 1500 and 2500 m .

### **Computer based multivariate analyses of vegetation**

There are many advantages in using new approaches in multivariate analyses of data. Ecologists get help from computer based statistical and multivariate analytical programs to discover structure in the data set and to analyze the effects of environmental factors on whole group of species. Now computation is cheap and fast (Diaconis and Efron, 1983). Different softwares developed for vegetation science are used for broad understanding, concepts and methods of descriptive analysis of plant community data. Methods of vegetation science include vegetation sampling, classification, and gradient analysis, and exploration of the relationship of species distributions to their environment. For the analyses of my data I used Turboveg (Hennekens and Schaminée, 2001), JUICE (Tichý, 2002), Canoco (Ter Braak and Šmilauer, 2002), PC-Ord (McCune *et al.* 2002), R (R Core Team, 2014), Arc GIS (ESRI, 2011) and Excel (Microsoft Word) etc.

### **Ethnobotanical work in Pakistan**

Ethnobotanical work in Pakistan is not old. But in the last decade the ethnobotanical work has multiplied. Lot of work related to ethnobotany and medicinal plants usage has been carried out in different parts of Pakistan. It includes studies from D.I.Khan (Marwat *et al.* 2011), Hazar nao,

Malakand (Murad *et al.* 2011), Noorpur thal, Khushab (Shaheen *et al.* 2012b), Gujranwala (Mahmood *et al.* 2013), Kalat and Khuzdar (Tareen *et al.* 2010), Hub, Baluchistan (Qasim *et al.* 2010), Khirthar National Park (Panhwar and Abro, 2007), Nara desert (Qureshi and Raza Bhatti, 2008) and Skardu (Bano *et al.* 2014). Most of the work is in documentation phase. Universities are involved in research related to ethnobotany. It will provide baseline data but still there is need of phytochemical screening and pharmacological testing. Some research institutes like PCSIR (Pakistan Council of Scientific and Industrial Reserch) and HEJ (Hussain Ebrahim Jamal) Karachi are involved in phytochemical screening and pharmacological research. Some famous industries like Hamdard, Qarshi, are actively involved in the production of plant products. It is now essential to develop a liaison among universities, research organizations and industries.

### **Phytodiversity and vegetation analyses in Pakistan.**

Phytosociological work in Pakistan has some tradition but is still at the very beginning and both local studies and comprehensive surveys are scarce or missing. Studies such as Chaudhri and Qadir (1958), Qadir *et al.*(1966), Shaukat and Qadir (1971) and Hussain *et al.*(1981) represent pioneer works on vegetation analysis but relatively few studies have been added since (recently, e.g., Siddiqui *et al.*(2010);Shaheen *et al.*(2012a) Khan *et al.*(2013). A total of 1,572 genera and 5,521 species of flowering plants have been documented for Pakistan (Ali and Qaiser, 2011), including many endemic plants. To date 5 monotypic genera (*Douepia*, *Sulaimania*, *Kurramiana*, *Wendelboa* and *Spiroseris*) and c. 400 species belonging to c. 169 genera and 45 families are endemic in Pakistan. About 80% of endemic flowering plants are confined to the northern and western mountains of Pakistan (Ali, 2008). Most recently computer based multivariate vegetation analyses have been produced, chiefly thanks to HEC (Higher education commission) initiatives to send Pakistani students and teachers abroad to learn advanced computer skills, or to hire foreign scientists for teaching and research in various universities and research organizations in Pakistan.

## Study area

### Geology of Swat

The Swat valley and adjoining parts of NW Pakistan consist of rock units representing the Kohistan Arc sequence. The Kohistan arc terrane in north Pakistan is widely regarded as one of the most completely exposed sections from the deep root to the volcanic edifice of an island arc (Searle *et al.* 1999). The Kohistan arc sequence constitutes the hanging wall of the main mantle thrust and essentially consists of late Jurassic-Cretaceous and Tertiary plutonic, meta-plutonic, meta-volcanic, and meta sedimentary rocks (Figure 2). From south to north, the Kohistan Arc sequence consists of the (i) Jijal Complex, (ii) Kamila Amphibolites, (iii) Chilas Complex, (iv) Kohistan Batholith and Gilgit gneisses, (v) Chalt-Ghizar, Sharman and Utror volcanics and (vi) Yasin metasediments. The ultramafic-mafic Jijal Complex represents the upper mantle to lower crust transition (Arif *et al.* 2011).



Figure 1. Miandam Mountains though looking lush green but affected by logging and habitat deterioration.

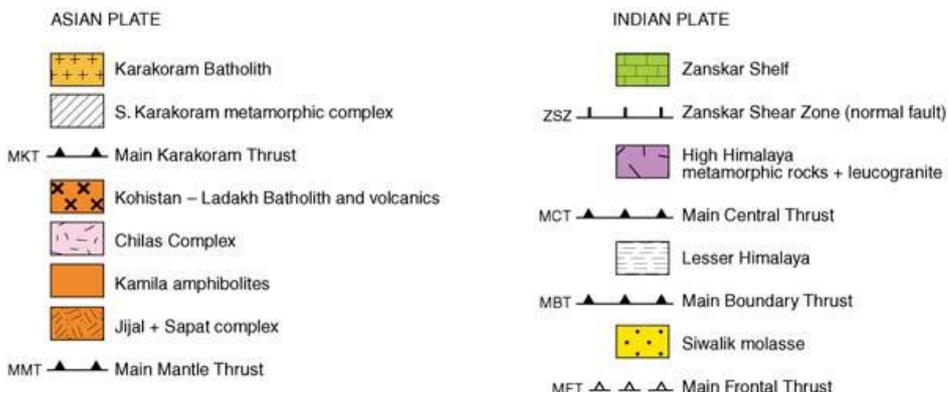
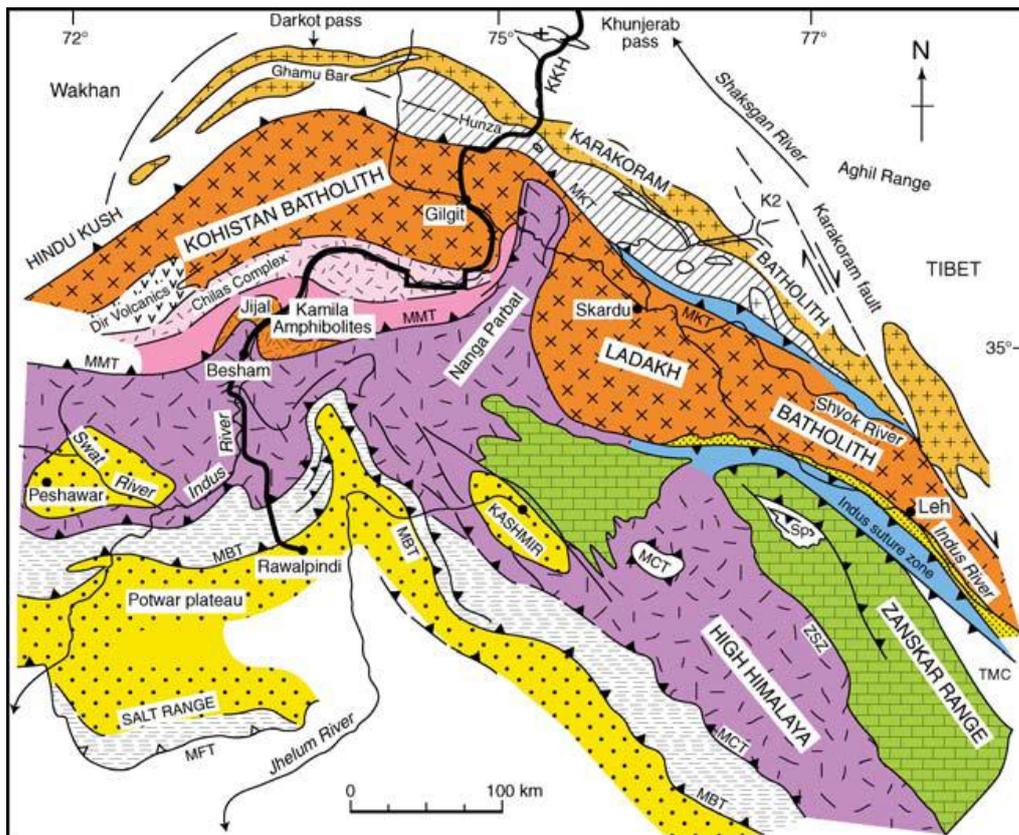


Figure 2. Geological map of the western Himalaya, Kohistan and Karakoram (after Searle *et al.* 1999).

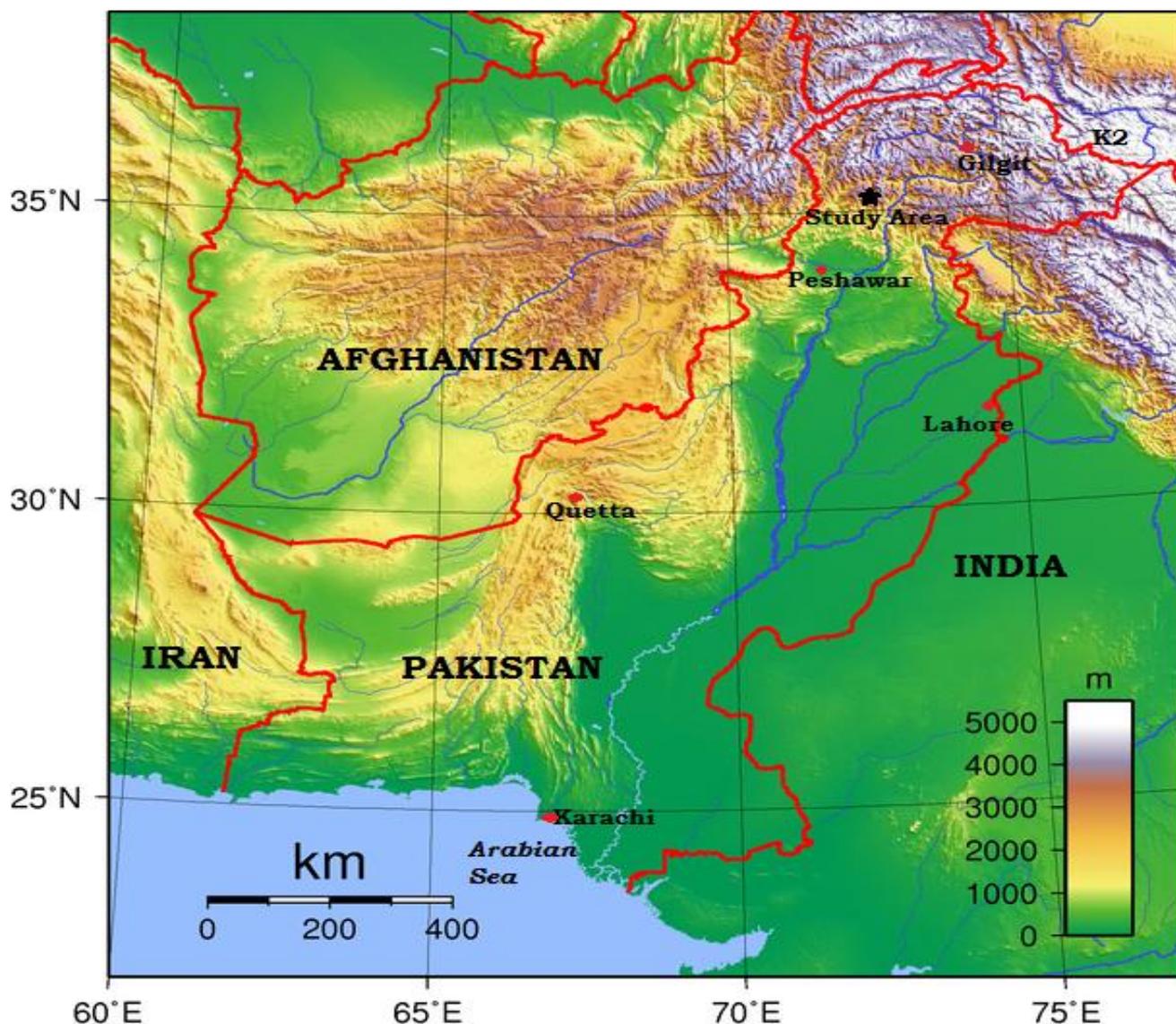


Figure 3. Topographic map of Pakistan showing location of the study area between Gilgit and Peshawar, (Sadalmelik, 2007).

### **Miandam**

The study area (Figure 1) of Miandam ( $35^{\circ} 4' N$ ,  $72^{\circ} 29-32' E$ ) is located in the District of Swat in the Province of Khyber Pakhtunkhwa (formerly North West Frontier Province). The province is located on both banks of the river Indus and is bounded by the Himalaya, Karakoram and Hindukush Mountains in the north and Afghanistan in the north-west. The District of Swat is located in the north of Khyber Pakhtunkhwa. Miandam lies about 50 km northeast of Saidu Sharif, district capital of Swat, and 21 km from Khwazakhela, administrative centre of the surrounding villages. Its western boundary is the river Swat. A topographic map of Pakistan showing the study area is presented in Figure 3.

## **Basis of objectives of the present project**

Plant collections in the Indian sub-continent started as early as 1820-1822 by W. Moorcroft who collected in Ladakh and Kashmir, followed by V. Jacquemont in 1828-1832 in Punjab and Kashmir. J. F. Royle (1832-1834) also collected in Kashmir. N. Vicary was the first to collect in Sindh in 1838; he also collected in Salt Range, Punjab and the Khyber Pakhtunkhwa region. William Griffith was the first collector in Baluchistan and Khyber Pass area in 1838. R.R. Stewart (1890-1993) collected plants from all over Pakistan (Ali, 2008).

Ecosystems in high mountain regions are intricate and significant. Cost and time factors are involved in their study, particularly where they are remote. Conserving plant biodiversity requires consistent and sound qualitative as well as quantitative records of botanical data on a regular basis (Clubbe *et al.* 2010) and subtle phytosociological and other ecological sampling techniques are essential to achieve this. Ethnobotanical methods can be linked to this, to describe and evaluate the nature and value of the ecosystem services that plant communities provide for local people. Data obtained through a combination of these techniques provides basic knowledge for conservation managers and biodiversity planners to evaluate the services provided by mountain ecosystems and to formulate sustainable management. Surveying the enormous diversity of the world's vegetation is one of the basic tasks of vegetation science. In recent decades the demand for vegetation survey data has been steadily increasing particularly in applied fields such as biodiversity conservation and environmental monitoring. Vegetation survey and classification are also very important in basic ecological and biodiversity research. Interpretations of biodiversity patterns and their underlying mechanisms strongly depend on the definitions and delimitations of the studied systems. In this context, survey and classification provide essential tools for defining vegetation or ecosystem types and a framework for understanding differences among them (Chytrý *et al.* 2011)

Keeping in view the above aspects of biodiversity research the present project was initiated in the mountains of the region of Miandam, Swat, Northern Pakistan, to achieve the objectives outlined below.

## **Objectives**

The objectives of the dissertation project are described in the context of the three result chapters. Chapter (2) deals with traditional knowledge about plants, an important asset for the people of the area. This knowledge passes from generation to generation and can be lost if not documented. One of the objectives was to document the empirical knowledge about medicinal plants of the area. The aim

was to gather and document baseline information regarding medicinal plants that can be further used for future phytochemical and pharmacological studies. Moreover, the target was to classify medicinal plants according to biological and distributional properties as well as ecological preference. It was also focused that where and in which habitat ethno-medicinal plants occur; as such knowledge is a prerequisite to identify vulnerable plant species susceptible to collecting or habitat change.

In chapter (3), among other objectives one aim was to survey woodlands, shrublands and other widespread formations in the research area to describe the vegetation zones along elevation. Our next objective was revealing similarities and dissimilarities of plant communities with plant communities described in literature from the wider area of Hindukush-Himalaya. With logging and grazing occurring largely uncontrolled, a focus was on human impact, to provide a risk assessment for the plant communities in the forest ecosystem. Quantitative analysis of vegetation of the study area was also planned and achieved by combining multivariate classification and ordination techniques.

Chapter (4) deals with the study of variation in species richness and diversity along elevation in the region. As patterns of diversity on different mountains are different, species richness and diversity of different growth forms were statistically determined along elevation gradient based on regression modeling. The focus was on the following two research questions: (1) Do species richness and diversity vary among different growth forms along the elevation gradient studied? (2) Are variations along the elevation gradient monotonic, unimodal, or otherwise? To my knowledge this is the first study for Pakistan Himalaya in which the diversity patterns of different growth forms of plants have been tested along an elevation gradient.

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## CHAPTER 2

# DIVERSITY AND USE OF ETHNO-MEDICINAL PLANTS IN THE REGION OF SWAT, NORTH PAKISTAN

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## Abstract

**Background:** Due to its diverse geographical and habitat conditions, northern Pakistan harbors a wealth of medicinal plants. The plants and their traditional use are part of the natural and cultural heritage of the region. This study was carried out to document which medicinal plant species and which plant parts are used in the region of Swat, which syndrome categories are particularly concerned, and which habitat spectrum is frequented by collectors. Finally, we assessed to which extent medicinal plants are vulnerable due to collection and habitat destruction.

**Methods:** An ethnobotanical survey was undertaken in the Miandam area of Swat, North Pakistan. Data were collected through field assessment as well as from traditional healers and locals by means of personal interviews and semi-structured questionnaires.

**Results:** A total of 106 ethno-medicinal plant species belonging to 54 plant families were recorded. The most common growth forms were perennial (43%) and short-lived herbs (23%), shrubs (16%), and trees (15%). Most frequently used plant parts were leaves (24%), fruits (18%) and subterranean parts (15%). A considerable proportion of the ethno-medicinal plant species and remedies concerns gastro-intestinal disorders. The remedies were mostly prepared in the form of decoction or powder and were mainly taken orally. Eighty out of 106 ethno-medicinal plants were indigenous. Almost 50% of the plants occurred in synanthropic vegetation while slightly more than 50% were found in semi-natural, though extensively grazed, woodland and grassland vegetation. Three species (*Aconitum violaceum*, *Colchicum luteum*, *Jasminum humile*) must be considered vulnerable due to excessive collection. Woodlands are the main source for non-synanthropic indigenous medicinal plants. The latter include many range-restricted taxa and plants of which rhizomes and other subterranean parts are dug out for further processing as medicine.

**Conclusion:** Medicinal plants are still widely used for treatment in the area of Swat. Some species of woodlands seem to be adapted to wood-pasture, but vulnerable to overcollecting, and in particular to deforestation. It is suggested to implement local small-scaled agroforestry systems to cultivate vulnerable and commercially valuable ethno-medicinal woodland plants under local self-government responsibility.

**Keywords:** Ecosystem services, Ethnobotany, Medicinal plants, Miandam, Phytomedicine, Plant applications, Plant conservation, Vernacular plant names

## Introduction

Plants are an important source of traditional medicine for the treatment of various diseases (Bako *et al.* 2005). It has been estimated that herbal medicines are used by more than 80% of the world's population in developing countries to meet their primary healthcare needs (World Health Organization, 2002). In Pakistan, the available modern healthcare services are either insufficient or inaccessible and unaffordable to the majority of people. In addition, due to illiteracy and poverty most of the population is dependent on traditional phytomedicine to cure various ailments. As the country has diverse socio-economic, ethnic, linguistic and cultural areas, as well as unique biodiversity, copious knowledge of indigenous medicinal plants and their use in treating human ailments might reasonably be expected. More than 10% of the national flora of Pakistan (600-700 plant species) are used for medicinal purposes (Shinwari, 2010). Phytomedicinal research in Pakistan is a recent activity and the documentation of ethnomedicinal plant knowledge and its applications are ongoing (Shinwari, 2010; Abbasi *et al.* 2011; Sher *et al.* 2011; Shinwari *et al.* 2006). The loss of precious medicinal plant wealth due to overgrazing, agricultural expansion, environmental degradation, acculturation and deforestation, enhanced by population pressure and poverty, has been reported by various researchers (Shinwari, 2010; Hussain *et al.* 2007; Ibrar *et al.* 2007; Khan and Khatoun, 2008; Sher and Hussain, 2007) but information on which medicinal plant species in particular are vulnerable, and why, is lacking.

Traditional resources of medicinal plants from Chitral, North Pakistan, have been evaluated (Hussain *et al.* 2007; Ali and Qaiser, 2009). Several studies exist on the ethnomedicinal use of plants in different regions of Swat, North Pakistan (Ibrar *et al.* 2007; Hamayun *et al.* 2006; Hussain *et al.* 2005; Sher and Hussain, 2009; Shinwari and Gilani, 2003). In an ethno-medicinal study from the valley of Miandam, Swat, a total of 179 plant species have been listed (Adnan *et al.* 2006), with medicinal use reported for 27 plants, but without reference to local names, habitats, and which parts of these plants are used. Recording the indigenous knowledge of medicinal plants is an urgent task. Traditional knowledge is usually passed verbally from generation to generation, and valuable information about medicinal plants is easily lost if not preserved in written form. The main objective of the present study was therefore to survey and to document the scattered indigenous knowledge of medicinal plants of the Miandam valley as basis for future phytochemical and pharmacological studies. Moreover, and for the first time in any region of Pakistan, the medicinal plants of the study area are classified according to biological and distributional properties as well as ecological preference. It is essential to know where and in which habitats ethno-medicinal plants occur; as such knowledge is a prerequisite to identify vulnerable plant species susceptible to collecting or habitat change.

## Study area

The valley of Miandam, Swat, is a well-known summer resort in northern Pakistan. Located about 50 km northeast of Saidu Sharif, the valley lies between 35° 1' - 5' N, 72° 30' - 37' E in the mountain range of Hindu Raj (Porter, 1970). The study area ranges between 1400 to 3500 m a.s.l. It is a narrow valley with a number of gorges, bounded on the north, east and south by high mountains. Its western boundary is the river Swat. Gujars (Indian Aryans) and Yousafzai (Pakhtoon) are the two main tribes residing in the area. Their main source of income is agriculture (nearly 41%) (Rashid, 1999) and most of the population of the study area is directly or indirectly engaged in it. Miandam is a mountainous region and the cultivated land is insufficient for subsistence. Additional sources of income are daily wages and salaries (20%), foreign and domestic remittances (17%), forest products including medicinal plants (12%) and other professions (10%). Findings from (Rabbi *et al.* 2010) reveal that 59% of the households in north-western Pakistan derive their income from the forests.

Due to its considerable variation in altitude, temperature, topography, soil type and moisture, the vegetation of Miandam Valley can be classified into a series of altitudinal belts, namely dominated by *Olea ferruginea* and *Quercus oblongata* (submontane), *Pinus wallichiana*, *Abies pindrow*, *Picea smithiana* and *Quercus semecarpifolia* (montane), and alpine-subalpine flora, respectively (Adnan *et al.* 2006). See also the vegetation maps of the northern Pakistan regions of Chitral and Hunza (Nüsser and Dickoré, 2002; Eberhardt *et al.* 2007).

## Methods

Regular field surveys were carried out in the Miandam valley from September 2010 through July 2011 in order to document the habitats and indigenous uses of ethno-medicinal plants of the valley. The surveys were carried out at different seasons so as to obtain identifiable plants and multiple information and also to cross-check the information provided by the local informants during earlier visits. We interviewed a small group of chiefly elder people of both Gujars and Yousufzai tribes who were highly esteemed in their societies due to their sound knowledge of medicinal plants. Structured questionnaires, formal and informal interviews and participatory observations were used to inquire about vernacular names, used plant parts and the process of remedy preparation. We did not encounter controversial issues among the informants but commonly received complementary information. Moreover, for each plant species growth forms (tree, shrub, woody climber, perennial herb, annual or biennial herb), plant status (indigenous, established alien, cultivated), abundance in the area (common, scattered, rare) and habitat preferences (arable fields, ruderal sites, wetland, woodland, mountain grassland) were recorded. Voucher specimens were identified using relevant standard literature (Nasir and Ali, 1970; Nasir and Ali, 1982; Nasir *et al.* 1972; Ali and Qaiser, 1993) and submitted to the Herbarium PUP at the Department of Botany, University of Peshawar. Plant nomenclature was

updated using the World Checklist of Selected Plant Families (<http://apps.kew.org/wcsp/home.do>) and The Plant List ([www.theplantlist.org/](http://www.theplantlist.org/)). Family assignment in this paper follows the Flora of Pakistan (Ali and Qaiser, 1993).

## Results and discussion

### Plant diversity, use and applications

A total of 106 ethno-medicinal plant species belonging to 96 genera and 54 plant families were recorded. The plants have been used to treat a wide range of diseases from simple headache to complex disorders of kidney and liver. The results are presented in Table 1 with family names in alphabetical order, taxon name, local name, parts used, medicinal use, growth form, plant status, frequency and habitat preference. Perennial herbs were the most common growth form (Figure 2) among medicinal plants (43%), followed by annuals and biennials (23%), shrubs (16%) and trees (15%). As far as documented the use of herbs for remedy preparation in the study area is in consistence with other studies (Ali and Qaiser, 2009; Abbasi *et al.* 2009; Adnan and Hölscher, 2010; Ali *et al.* 2011; Awan *et al.* 2011; Badshah and Hussain, 2011; Hazrat *et al.* 2010; Iqbal and Sher, 2011; Jabeen *et al.* 2009; Jan *et al.* 2011; Khan *et al.* 2011a; Mahmood *et al.* 2011; Razaq *et al.* 2010; Pieroni *et al.* 2008; Teklehaymanot and Giday, 2007; Yineger *et al.* 2008).

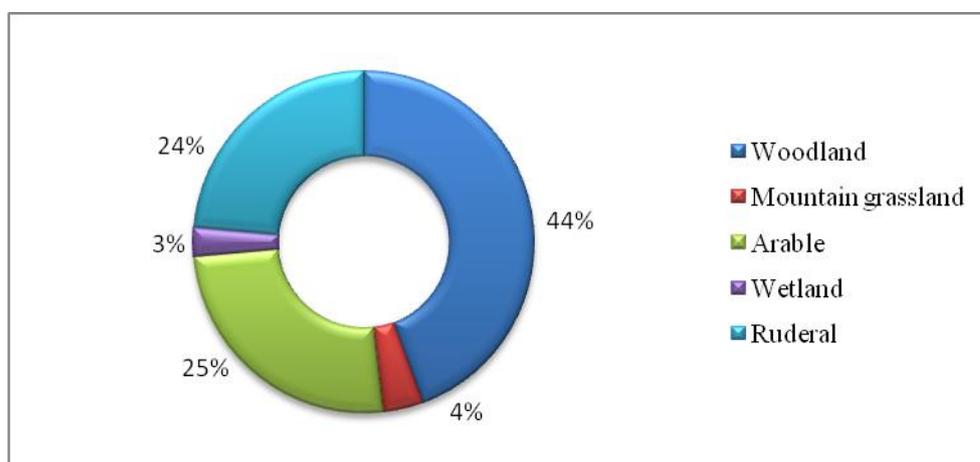


Figure 1. Habitat types of medicinal plants.

Ninety-nine of the species (93%) are used for human ailments, three species (3%) for livestock cure and four (4%) to treat both human and livestock ailments. No less than 44 plant species were used to treat gastro-intestinal disorders such as dyspepsia, dysentery and stomach-ache followed by the treatment of dermatological diseases with more than 25 herbal remedies. Ten species were used against skeleto-muscular complaints like rheumatism, backache and muscular pain. Sixteen species were used to cure respiratory problems such as cough and asthma, fourteen for urinary complaints, twelve for cardio-vascular complaints and circulatory diseases, twelve to treat fever and headache,

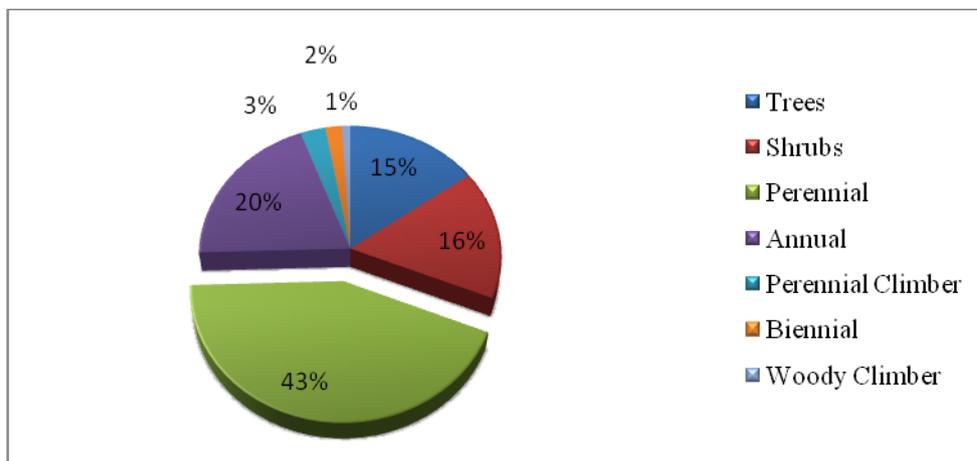


Figure 2. Growth forms of medicinal plants.

eleven for genital and sexual diseases, six for dental problems, six for ear, nose, throat (ENT) and eyes diseases, two for nerve disorders, one species (*Spiraea sp.*) was used to ease childbirth, and eighteen species for other purposes (wounds, cuts, narcotic, tonic, anticancer and tumor) (Table 2). The leaves of *Skimmia laureola* are used for spiritual purposes.

A single plant species may be used to cure several human ailments (Table 2). Some of the remedies

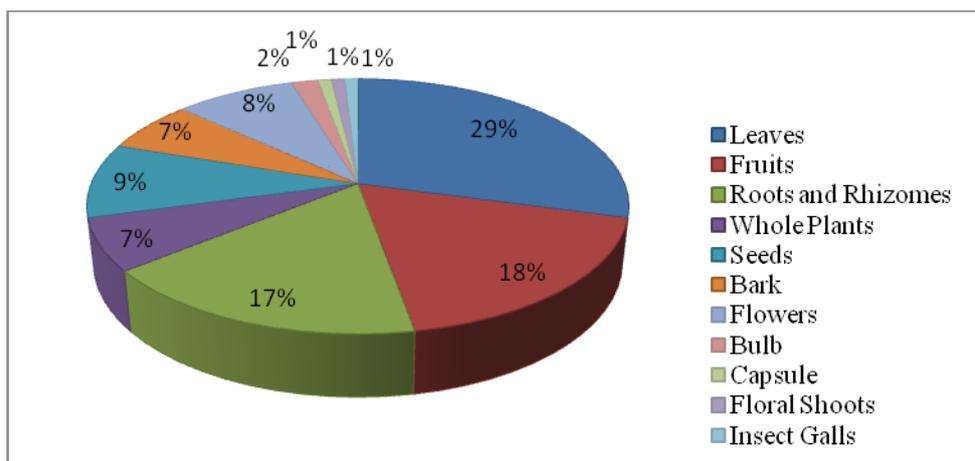


Figure 3. Use of different plant parts in the preparation of remedies in the research area.

were prepared by combining different plants such as the powdered rhizome of *Dioscorea deltoidea* mixed with powdered root of *Berberis lycium* for the treatment of jaundice and ulcers. Similarly, root decoction of *Geranium wallichianum* with pods of *Pistacia chinensis* was used for curing urinary complaints, cough and fever. According to traditional healers, complex medicines of two or more plant species are more potent than those prepared with single species. This has been attributed to interactive effects of the plants (Okello and Ssegawa, 2007). The most common medicinal recipe preparation was in powder form followed by decoction, infusion, juices, poultice and paste. The traditional healers and local herbalists of the region usually utilize every part of the plant. However, the use of a particular plant part depends on the plant habit and user's needs. The most frequently used plant parts (Figure 3) in the preparation of herbal remedies were leaves (29%), followed by fruit (18%), roots and rhizomes

(17%), and whole plants (7%). Seeds (9%), flowers (8%), bark (7%), bulbs (2%), capsules, floral shoots and insect galls (1% each) have also been used. The use of specific plant parts suggests that these parts have strongest medicinal properties but it needs biochemical analysis and pharmaceutical screening to cross-check the local information. Our findings of the frequent use of green leaves in the preparation of remedies corroborate the results of (Kala, 2005; Muthu *et al.* 2006; Murad *et al.* 2011; Adnan *et al.* 2012; Bhat *et al.* 2013).

Different liquids such as water, juices, sugar, tea, honey, mustard oil, *desi ghee* (butter) and milk are mixed with plants or plant parts during the preparation of the remedies. The prepared remedies are mostly administered orally (77%), less frequently dermally (10%) or both orally and dermally (12%). Only 1% is administered through ears or eyes.

#### **Habitats and conservation of ethno-medicinal plants**

Eighty out of 106 medicinal plants are indigenous to the area while the others are cultivated (20) or established alien plants (6). The latter groups are of no conservation concern as they are common (20) or scattered (7) in the study area. Also among the indigenous medicinal plants the majority of species is common (61%) or scattered (33%) in the area, thus neither of immediate conservation concern. Only five medicinal plant species (6%) are rare in the study area: *Aconitum violaceum*, *Colchicum luteum*, *Elaeagnus umbellata*, *Jasminum humile* and *Sambucus wightiana*. *Sambucus* and *Elaeagnus* are woodland shrubs of which leaves and fruits or leaves and flowers, respectively, are collected for medicinal purposes. Since this kind of harvesting is non-destructive, the rarity of the shrub species is apparently not caused by overcollection. In contrast, populations of *Aconitum violaceum*, *Colchicum luteum* and *Jasminum humile* may be harmed since rhizomes, corms or whole plants are collected, respectively. In these cases, plant populations should be monitored to avoid overcollection.

The synanthropic flora (i.e., occurring in arable fields or ruderal sites) contains a high proportion of the ethno-medicinal plants. Slightly under 50% (51) out of the 106 ethno-medicinal plant species occur in man-made habitats (in arable fields 27 species, most of which being cultivated; another 24 in ruderal sites). Since they can be expected to grow abundantly in or near settlements, or are even cultivated and harvested, they may be collected without much effort, and in suitable quantities. Slightly more than 50% (55) of the ethno-medicinal plant species encountered in the study area occur in semi-natural habitats (though extensively grazed or otherwise used). Most species of the latter group (47) occurred in different kinds of woodland (Figure 1), while only few occur in wetlands (4) and mountain grasslands (4). Mountain grassland medicinal plants known in the Miandam valley comprise *Colchicum luteum*, *Corydalis stewartii*, *Nepeta cataria* and *Thymus linearis*. Since Himalayan mountain floras are rich (Adnan *et al.* 2012; Bhat *et al.* 2013; Khan *et al.* 2013b) and the local almost certainly contains more species of pharmaceutical value, we assume that the habitat is too

remote and too difficult to access to be of much interest as a “medicinal plant hunting area” for the people in the Miandam valley.

Woodlands are the main source for non-synanthropic indigenous medicinal plants. They comprise 21 woody plants (apart from the climber *Hedera nepalensis*, seven trees and thirteen shrubs), two short-lived and 24 perennial herbs. Almost half of the perennial herbs are dug to collect the stem base (*Primula denticulata*) or chiefly the rhizomes (*Aconitum violaceum*, *Arisaema jacquemontii*, *Bergenia stracheyi*, *Delphinium denudatum*, *Dioscorea deltoidea*, *Paeonia emodi*, *Podophyllum hexandrum*, *Polygonatum multiflorum*, *Polygonatum verticillatum*). Except the latter two, these species are range-restricted taxa of Himalayan or narrower distribution. Due to their biochemical components they are largely unpalatable for livestock, hence fairly resistant under the widespread practice of wood-pasture, but may be vulnerable to overcollecting for medicinal purposes, although so far only *Aconitum violaceum* is considered rare in the study area. A currently more serious threat to the ethno-medicinal plant wealth of the woodlands as well as to the social and economic basis of the rural population in northern Pakistan is excessive timber exploitation leading to deforestation and habitat destruction.

### **Conclusion**

The Miandam valley in northern Pakistan is very rich in commercially and pharmaceutically important ethno-medicinal plant species. The locals, in particular traditional healers, have centuries-old knowledge regarding the uses of the plants, and the locals use these species in a traditional way for curing a wide spectrum of diseases. Few species were found to be vulnerable probably due to overcollection. Especially perennial woodland herbs with rhizomes are of conservation concern. The local inhabitants depend on plants for the treatment of diseases but not all are familiar with the proper collection, parts to be used, preservation and storage. In contrast, local traditional healers are familiar with proper collection and use of medicinal plants, and they should be involved in efforts of conservation and sustainable use of ethno-medicinal plant resources. In view of the outstanding importance of woodlands and forests in northern Pakistan the currently widespread and uncontrolled deforestation is a serious threat both to ecological and social sustainability as well as to the long-term economic basis of the local population (Rabbi *et al.* 2010). It is also a threat to the ethno-medicinal plant wealth. For purposes of plant conservation and to increase the locals' income we suggest to cultivate vulnerable woodland medicinal plants of commercial value in newly designed and locally administered self-government agroforestry systems. Due to the specific habitat demands of many woodland plant species better results may be obtained through well managed agroforestry systems than in ex-situ sites (Sher *et al.* 2010).

Table 1. Medicinal plants of the Miandam area with their medicinal properties, and biological, ecological and chorological characteristics.

Plant family	Taxon name	Local name	Parts used	Medicinal uses, remedies	Growth form	Plant status	Frequency	Habitat
Amaranthaceae	<i>Amaranthus viridis</i>	Chalvaray	Leaves	Leaf extract is emollient, also used for curing cough and asthma.	Annual	Indigenous	Common	Ruderal
Anacardiaceae	<i>Pistacia chinensis</i>	Shnai	Insect galls, leaves and bark	Powdered insect galls, bark and leaves are topical antiseptic, also for curing jaundice and liver diseases.	Tree	Established alien	Scattered	Woodland
Apiaceae	<i>Bupleurum longicaule</i>	Gillo	Whole plant	Powdered plant is mixed with milk and used as laxative	Perennial	Indigenous	Common	Woodland
Apiaceae	<i>Coriandrum sativum</i>	Dhanyal	Whole plant	Stimulant and carminative	Annual	Cultivated	Common	Arable
Apiaceae	<i>Foeniculum vulgare</i>	Kaga vanalay	Fruit	Powdered fruit is mixed with sugar, taken with a cup of milk for curing urinary problems (dysuria); dry fruits are carminative and laxative	Annual	Cultivated	Common	Arable
Apiaceae	<i>Pimpinella diversifolia</i>	Watani kaga	Fruit	Powdered fruits are carminative	Perennial	Indigenous	Scattered	Woodland
Apiaceae	<i>Heracleum candicans</i>	Kadu panra	Root	Decoction of root against colic and asthma	Perennial	Indigenous	Scattered	Wetland
Araceae	<i>Arisaema jacquemontii</i>	Marjarai	Rhizome	Rhizome bolus is given orally to livestock for respiratory problems	Perennial	Indigenous	Scattered	Woodland
Araliaceae	<i>Hedera nepalensis</i>	Prewata	Leaves	Juice from leaves for curing diabetes, also considered as blood purifier	Woody climber	Indigenous	Common	Woodland
Asclepiadaceae	<i>Periploca aphylla</i>	Barara	Stem, fruits	Milky juice of stem and fruit applied to swellings; stem latex as antimycotic for curing dermatitis in livestock	Shrub	Indigenous	Common	Ruderal
Asteraceae	<i>Artemisia scoparia</i>	Jaukay	Shoot and seeds	Respiratory stimulant, anthelmintic, purgative and against earache	Biennial	Indigenous	Common	Woodland
Asteraceae	<i>Cichorium intybus</i>	Han	Root	Decoction of fresh root for treatment of fever	Perennial	Indigenous	Common	Ruderal
Asteraceae	<i>Echinops echinatus</i>	Ghwand Saray Ghanowala	Root	Powdered root applied to wounds of cattle for killing maggots; also to kill lice	Perennial	Indigenous	Scattered	Wetland
Asteraceae	<i>Launaea procumbens</i>	Shaуда pai	Leaves	Mixture of powdered leaves with sugar to enhance lactation in livestock	Perennial	Indigenous	Common	Ruderal
Asteraceae	<i>Sonchus asper</i>	Shaуда pai	Shoot	Shoots fed to livestock for enhancing lactation	Annual	Indigenous	Common	Ruderal
Asteraceae	<i>Taraxacum</i> sp.	Ziar gulai	Leaves and	Grinded leaves are tonic, root decoction	Perennial	Indigenous	Common	Ruderal

Plant family	Taxon name	Local name	Parts used	Medicinal uses, remedies	Growth form	Plant status	Frequency	Habitat
Asteraceae	<i>Xanthium strumarium</i>	Ghishkay	roots Leaves	against kidney and liver disorders Leaf decoction recommended in malarial fever	Annual	Indigenous	Common	Ruderal
Berberidaceae	<i>Berberis lycium</i>	Kwaray	Root bark	Dried root bark given orally as body tonic	Shrub	Indigenous	Scattered	Woodland
Berberidaceae	<i>Podophyllum hexandrum</i>	Kakora	Rhizome	Powdered rhizome used to cure liver diseases	Perennial	Indigenous	Scattered	Woodland
Boraginaceae	<i>Cynoglossum lanceolatum</i>	Gat gul	Whole plant	Powdered plant taken with a decoction of <i>Coriandrum sativum</i> fruits as laxative	Perennial	Indigenous	Common	Woodland
Boraginaceae	<i>Onosma hispida</i>	Khwaga abai	Root	Used to color mustard oil which is applied for smoothing hair	Perennial	Indigenous	Common	Ruderal
Brassicaceae	<i>Brassica campestris</i>	Sharshum	Seeds	Oil, extracted from seeds, is used as ointment, for massage of body and hair	Annual	Cultivated	Common	Arable
Brassicaceae	<i>Brassica campestris</i> var. <i>rapa</i>	Tepar	Leaves, roots	Against stomachache and ulcer problems	Annual	Cultivated	Common	Arable
Brassicaceae	<i>Capsella bursa-pastoris</i>	Bambesa	Leaves and seeds	Paste of fresh leaves with milk for curing diarrhea; seeds are stimulant and diuretic	Annual	Indigenous	Common	Ruderal
Brassicaceae	<i>Nasturtium officinale</i>	Talmera	Young shoot	Young shoot against constipation and stomachache	Perennial	Indigenous	Common	Wetland
Buxaceae	<i>Sarcococca saligna</i>	Ladanr	Leaves	Heated in mustard oil and applied to muscular pain; infusion of leaves orally for rheumatism	Perennial	Indigenous	Common	Woodland
Cannabaceae	<i>Cannabis sativa</i>	Bang	Leaves	Leaves in bandage for wound healing; powdered leaves as anodyne, sedative, tonic and narcotic; juice added with milk and nuts as a cold drink ("Tandai") generating a pleasant excitement; "Charas" is also prepared from it	Annual	Indigenous	Common	Arable
Caprifoliaceae	<i>Sambucus wightiana</i>	Benakai	Leaves, fruits and flowers	Poultice from leaves and flowers to treat burns and rheumatism; berries are purgative and used in dropsy	Shrub	Indigenous	Rare	Woodland
Caprifoliaceae	<i>Viburnum grandiflorum</i>	Ghuz meva	fruit	Fresh fruit is eaten to cure stomach problems	Shrub	Indigenous	Common	Woodland
Caryophyllaceae	<i>Arenaria griffithii</i>	Kinar	Shoots	Dried shoot powder with honey after meal as antispasmodic	Perennial	Indigenous	Common	Woodland
Caryophyllaceae	<i>Silene vulgaris</i>	Matorangay	Shoot	Shoot against stomachache and as emollient	Perennial	Indigenous	Common	Woodland

Plant family	Taxon name	Local name	Parts used	Medicinal uses, remedies	Growth form	Plant status	Frequency	Habitat
Caryophyllaceae	<i>Stellaria media</i>	Oulalai	Whole plant	Decoction is considered as purgative	Annual	Indigenous	Common	Arable
Chenopodiaceae	<i>Chenopodium album</i>	Sarmay	Whole plant	Dried powdered plant considered as carminative and diuretic agent	Annual	Indigenous	Common	Ruderal
Clusiaceae	<i>Hypericum perforatum</i>	Shin chai	Shoot	Used as diuretic and its tea is stimulant and analgesic	Perennial	Indigenous	Scattered	Woodland
Convolvulaceae	<i>Convolvulus arvensis</i>	Prewatai	Whole plant	Purgative, also applied in skin disorders	Perennial, climber	Indigenous	Common	Arable
Cuscutaceae	<i>Cuscuta reflexa</i>	Zelai	Whole plant	Decoction for urine control, diabetes and blood purification; plant extract used as anti-lice	Perennial, climber	Established alien	Scattered	Arable
Dioscoreaceae	<i>Dioscorea deltoidea</i>	Kanis zelai	Rhizome	Powdered rhizome mixed with powdered root of <i>Berberis lycium</i> , the mixture is used for treatment of jaundice and ulcers	Perennial, climber	Indigenous	Scattered	Woodland
Ebenaceae	<i>Diospyros kaki</i>	Sur amlok	Ripe fruits	Laxative	Tree	Cultivated	Common	Arable
Ebenaceae	<i>Diospyros lotus</i>	Tour amlok	Dried ripe fruits	Carminative, purgative and causing flatulence; boiled in milk and taken against constipation and dysentery	Tree	Cultivated	Common	Arable
Elaeagnaceae	<i>Elaeagnus umbellata</i>	Ghanum ranga	Flowers, leaves	Decoction of flowers used twice a day to cure heart diseases; decoction of leaves against cough; mature raw seeds eaten as vitamin C source	Shrub	Indigenous	Rare	Woodland
Euphorbiaceae	<i>Euphorbia wallichii</i>	Shangla	Whole plant	Dried leaves and seeds given to children in bowel complains; plant juice against ringworm	Perennial	Indigenous	Common	Woodland
Euphorbiaceae	<i>Ricinus communis</i>	Harhanda	Seeds	Seed oil demulcent and to evacuate bowels in children	Shrub	Established alien	Scattered	Ruderal
Fabaceae	<i>Indigofera heterantha</i>	Ghwarija	Root and leaves	Dried powdered root taken with glass of water against scabies; leaves against stomach problems	Shrub	Indigenous	Common	Woodland
Fabaceae	<i>Lathyrus aphaca</i>	Korkamanai	Seed	Decoction of the seed 3 times a day for wound healing	Annual	Indigenous	Scattered	Arable
Fabaceae	<i>Lotus corniculatus</i>	Fateh khana	Whole plant	Decoction of dried powdered plant with ghee or boiled water against sexual debility and backache	Perennial	Indigenous	Scattered	Woodland
Fagaceae	<i>Quercus oblongata</i>	Banj	Fruit	Powdered fruits in urinary infection	Tree	Indigenous	Common	Woodland
Fagaceae	<i>Quercus floribunda</i>	Tour banj	Fruit	Powdered fruits for treating gonorrhoea and urinary disease	Tree	Indigenous	Common	Woodland

Plant family	Taxon name	Local name	Parts used	Medicinal uses, remedies	Growth form	Plant status	Frequency	Habitat
Fumariaceae	<i>Corydalis stewartii</i>	Mamera	Floral shoot	Decoction of floral shoot to cure eye diseases	Biennial	Indigenous	Scattered	Mountain grassland
Geraniaceae	<i>Geranium wallichianum</i>	Srazela	Root	Root decoction with pods of <i>Pistacia chinensis</i> to treat cough and fever and urinary complaints	Perennial	Indigenous	Common	woodland
Hippocastanaceae	<i>Aesculus indica</i>	Jawaz	Seeds and bark	Fruits are anthelmintic and given to horses in colic; plant oil externally used against rheumatism; nuts against colic and to cure chest diseases in horses, donkeys and mules	Tree	Indigenous	Scattered	Woodland
Juglandaceae	<i>Juglans regia</i>	Ghwaz	Fruit, bark, leaves	Dried fruit mixed with coconut and honey used as tonic; bark (locally called Dandasa) for cleaning and sparkling of teeth; decoction of leaves against eczema and intestinal worms	Tree	Cultivated	Common	Arable
Lamiaceae	<i>Ajuga bracteosa</i>	Booti	Whole plant	Locally, decoction of the plant or its powder swallowed with water before breakfast for the treatment of throat sore, internal colic, purifying blood and epilepsy; decoction for curing jaundice and hypertension	Perennial	Indigenous	Common	Ruderal
Lamiaceae	<i>Mentha spicata</i>	Podina	Leaves and stem	Carminative	Perennial	Cultivated	Common	Arable
Lamiaceae	<i>Mentha royleana</i>	Valenay	whole plant	Decoction of leaves for treatment of diarrhea in children; powdered plant mixed with sugar for prevention of vomiting and dyspepsia	Perennial	Indigenous	Common	Ruderal
Lamiaceae	<i>Nepeta cataria</i>	Pisho botai	Flowers and leaves	Dried leaves and flowering tops	Perennial	Indigenous	Scattered	Mountain grassland
Lamiaceae	<i>Otostegia limbata</i>	Spin azghai	Whole plant	Juice of leaves applied to gums for treatment of gum problem in children; dried powder of plant is used in jaundice	Perennial	Indigenous	Common	Woodland
Lamiaceae	<i>Isodon rugosus</i>	Spearkai	Leaves	Dried leaves put in mouth as remedy for toothache	Shrub	Indigenous	Common	Woodland
Lamiaceae	<i>Origanum vulgare</i>	Shamakay	Whole plant	Diuretic and against toothache and earache	Perennial	Indigenous	Common	Woodland
Lamiaceae	<i>Salvia lanata</i>	Spera botai	Leaves	Paste of leaves applied to toes laceration	Perennial	Indigenous	Scattered	Woodland

Plant family	Taxon name	Local name	Parts used	Medicinal uses, remedies	Growth form	Plant status	Frequency	Habitat
Lamiaceae	<i>Salvia moorcroftiana</i>	Kherghwag	Leaves	in hot and moist season <i>Brassica campestris</i> oil applied to fresh leaves tied round for healing of wounds	Perennial	Indigenous	Common	Ruderal
Lamiaceae	<i>Thymus linearis</i>	Chi botai	Shoots	Tea of shoots advised for treating pain and fever	Perennial	Indigenous	Common	Mountain grassland
Liliaceae	<i>Allium sativum</i>	Ouga	Bulb and leaves	Boiled and the cooled extract administered against diarrhea, dysentery and for lowering blood pressure; bulbs stimulant; leaves diuretic, aphrodisiac and expectorant; antiseptic; juice applied to soothe irritation caused by scorpion and hornet stings	Perennial	Cultivated	Common	Arable
Liliaceae	<i>Allium cepa</i>	Piaz	Bulb and leaves	Bulbs stimulant; leaves diuretic, aphrodisiac and expectorant; also antiseptic and juice applied to soothe irritation caused by scorpion and hornet sting; Mountaineers have it with them while crossing high altitude passes as it enhances the intake of oxygen	Perennial	Cultivated	Common	Arable
Liliaceae	<i>Colchicum luteum</i>	Qaimat guallay	Whole plant	Blood purifier, laxative and aphrodisiac; fried corms are used for joints pain	Perennial	Indigenous	Rare	Mountain grassland
Liliaceae	<i>Polygonatum multiflorum</i>	Noorealam	Rhizome	Rhizome infusion against dysentery; referred aphrodisiac	Perennial	Indigenous	Scattered	Woodland
Liliaceae	<i>Polygonatum verticillatum</i>	Noorealam	Rhizome	Against rheumatism and as aphrodisiac	Perennial	Indigenous	Scattered	Woodland
Malvaceae	<i>Abelmoschus esculentus</i>	Bhindi	Fruits	Emollient, demulcent and diuretic	Annual	Cultivated	Scattered	Arable
Meliaceae	<i>Melia azedarach</i>	Tora bakyana, shandai	Fruits, shoots, bark, leaves	Dried, crushed fruits against gastric trouble, fever and cough; dry leaves mixed with wheat flour used as anthelmintic in livestock; decoction of the bark considered anti-allergic; extraction of leaves used by women against head lice; leaves, young branches or fermented fruits are given as carminative to cattle, when belly is swollen through gas accumulation due to	Tree	Established alien	Scattered	Woodland

Plant family	Taxon name	Local name	Parts used	Medicinal uses, remedies	Growth form	Plant status	Frequency	Habitat
Moraceae	<i>Ficus palmata</i>	Inzer	Flowers and fruits	overeating Fresh floral parts as demulcent; juice extracted from fruit as expectorant	Tree	Cultivated	Common	Arable
Moraceae	<i>Morus alba</i>	Toot	Fruit	Fruit to treat constipation and cough	Tree	Indigenous	Common	Arable
Oleaceae	<i>Jasminum humile</i>	Rambil chambil	Roots and flowers	Powdered roots as anthelmintic and diuretic; juice extracted from flowers against skin diseases, headache and mouth rash	Shrub	Indigenous	Rare	Woodland
Oleaceae	<i>Olea europaea</i>	Khona	Leaves	Decoction of leaves as gargle considered as remedy for toothache, mouth and gum diseases	Tree	Cultivated	Scattered	Arable
Oxalidaceae	<i>Oxalis corniculata</i>	Tarukey	Whole plant	Decoction of plant to enhance digestion	Annual	Indigenous	Common	Ruderal
Paeoniaceae	<i>Paeonia emodi</i>	Mamekh	Rhizome	Powdered rhizome with milk to cure backache and general weakness	Perennial	Indigenous	Scattered	Woodland
Papaveraceae	<i>Papaver somniferum</i>	Qashqash	Capsule, seeds	Capsules and seeds as narcotic; dried capsule to make tea for cough and fever	Annual	Indigenous	Scattered	Arable
Plantaginaceae	<i>Plantago lanceolata</i>	Jabai	Leaves	Leaves applied to treat bedsores, inflamed surfaces and candidiasis	Perennial	Indigenous	Scattered	Ruderal
Plantaginaceae	<i>Plantago major</i>	Ghwa jabai	Seeds, leaves	Leaves applied to treat bedsores and candidiasis	Perennial	Indigenous	Scattered	Ruderal
Platanaceae	<i>Platanus orientalis</i>	Chinar	Bark	Powdered bark taken orally to control diarrhea	Tree	Indigenous	Scattered	Woodland
Poaceae	<i>Avena sativa</i>	Jamdaray	Fruit	Fried in ghee and milk, the paste is considered as general body tonic and aphrodisiac	Annual	Cultivated	Common	Arable
Poaceae	<i>Cynodon dactylon</i>	Kabal	Whole plant	Decoction as blood purifier and to control nose bleed; chewed and placed on wound to stop bleeding and as topical anti-septic	Perennial	Indigenous	Common	Ruderal
Polygonaceae	<i>Rumex dentatus</i>	Shalkhay	Rhizome, leaves	Rhizome and leaves as poultice for wound healing	Annual	Indigenous	Common	Ruderal
Portulacaceae	<i>Portulaca oleracea</i> s.l.	Warkharae	Shoot	Shoot decoction against liver and kidney diseases	Annual	Cultivated	Common	Arable
Primulaceae	<i>Primula denticulata</i>	Mamera	Stem base	Infusion of young stem base ophthalmic	Perennial	Indigenous	Common	Woodland
Punicaceae	<i>Punica granatum</i>	Nangoray, Anar	Fruit	Dried fruit in bolus form for removal of intestinal helminths	Shrub	Cultivated	Scattered	Arable
Ranunculaceae	<i>Aconitum violaceum</i>	Zaharmora,	Rhizome	Rhizomes, wrapped in sheep or goat	Perennial	Indigenous	Rare	Woodland

Plant family	Taxon name	Local name	Parts used	Medicinal uses, remedies	Growth form	Plant status	Frequency	Habitat
		Da Ghra Zahar		intestine and thoroughly boiled in milk; milk discarded and rhizomes crushed into powder, taken against rheumatism and arthritis; administering as such may cause death or mental problems if overdosed				
Ranunculaceae	<i>Caltha alba</i>	Makan path	Leaves	Leaves laxative in nature	Perennial	Indigenous	Scattered	Wetland
Ranunculaceae	<i>Delphinium denudatum</i>	Jadwar	Rhizome	Rhizome powder with water to cure cough and fever	Perennial	Indigenous	Scattered	Woodland
Rosaceae	<i>Fragaria bucharica</i>	Da zmake toot	Root, fruit	Powdered root useful in disease of urinary tract; fruits carminative and laxative	Perennial	Indigenous	Common	Woodland
Rosaceae	<i>Prunus armeniaca</i>	Khubanai	stem	Gum obtained from stem famed as anticancer	Tree	Cultivated	Common	Arable
Rosaceae	<i>Prunus domestica</i>	Alucha	Fruits	Fruit laxative	Tree	Cultivated	Common	Arable
Rosaceae	<i>Rosa moschata</i>	Gulab	Flowers	Decoction of flowers for curing stomach disorders	Shrub	Indigenous	Scattered	Woodland
Rosaceae	<i>Spiraea spec.</i>	Krachae	Flowers	Tea from its flowers to ease natal pain	Shrub	Indigenous	Common	Woodland
Rutaceae	<i>Skimmia laureola</i>	Nazar pana	Leaves	Burnt incense to expel evils and evil eyes; tea for indigestion, smoke considered as antiseptic	Shrub	Indigenous	Common	Woodland
Rutaceae	<i>Zanthoxylum armatum</i>	Dambara	Fruit	Fruits as antipyretic and for treating stomachache	Shrub	Indigenous	Scattered	Woodland
Saxifragaceae	<i>Bergenia stracheyi</i>	The Spinsar Gat Pana	Rhizome	Powdered rhizome with milk in the mornings as tonic	Perennial	Indigenous	Common	Woodland
Simaroubaceae	<i>Ailanthus altissima</i>	Backyanra	bark	Bark juice mixed with milk to cure dysentery and diarrhea	Tree	Established alien	Common	Arable
Solanaceae	<i>Atropa acuminata</i>	Bargak	leaves	Poultice of leaves against pain and rheumatism	Perennial	Indigenous	Scattered	Woodland
Solanaceae	<i>Capsicum annuum</i>	Marchakay	Fruits	Carminative	Annual	Cultivated	Common	Arable
Solanaceae	<i>Datura stramonium</i>	Batora	Leaves, seeds and flowers	poultice of flowers applied to wounds to reduce pain; seeds narcotic in nature	Annual	Indigenous	Common	Ruderal
Solanaceae	<i>Solanum nigrum</i>	Kachmacho	Leaves and fruit	Leave paste applied to treat skin inflammation, fruits against fever	Annual	Indigenous	Common	Ruderal
Solanaceae	<i>Solanum virginianum</i>	Marraghona y	Fruit	Decoction of fruit diuretic and anthelmintic	Perennial	Indigenous	Scattered	Ruderal

<b>Plant family</b>	<b>Taxon name</b>	<b>Local name</b>	<b>Parts used</b>	<b>Medicinal uses, remedies</b>	<b>Growth form</b>	<b>Plant status</b>	<b>Frequency</b>	<b>Habitat</b>
Solanaceae	<i>Withania somnifera</i>	Kotilal	Whole plant	Aphrodisiac	Shrub	Indigenous	Scattered	Ruderal
Thymelaeaceae	<i>Daphne mucronata</i>	Laighonai	Fruits, leaves	Poultice from fruits and leaves against rheumatism	Shrub	Indigenous	Common	Woodland
Ulmaceae	<i>Celtis australis</i>	Tagha	Fruits, bark	Fruits against colic and amenorrhea; bark decoction as anti-allergic	Tree	Indigenous	Scattered	Woodland
Urticaceae	<i>Debregeasia saeneb</i>	Ajlai	Leaves	Fresh ground leaves in paste form for blistered feet	Shrub	Indigenous	Common	Woodland
Verbinaceae	<i>Verbena officinalis</i>	Shamakai	Whole plant	Decoction is anti-malarial	Perennial	Indigenous	Common	Ruderal

Table 2. List of ethno-medicinal plants applied with different syndromes.

Syndrome category	Plants
<b>Gastrointestinal disorders</b>	<i>Aesculus indica, Ailanthus altissima, Ajuga bracteosa, Allium sativum, Artemisia scoparia, Brassica campestris var. rapa, Bupleurum longicaule, Capsella bursa-pastoris, Caltha alba, Celtis australis, Capsicum annuum, Chenopodium album, Colchicum luteum, Convolvulus arvensis, Coriandrum sativum, Cynoglossum lanceolatum, Dioscorea deltoidea, Diospyros kaki, Diospyros lotus, Euphorbia wallichii, Foeniculum vulgare, Fragaria bucharica, Heracleum candicans, Hypericum perforatum, Indigofera heterantha, Jasminum humile, Melia azedarach, Mentha spicata, Mentha royleana, Nasturtium officinale, Nepeta cataria, Oxalis corniculata, Pimpinella diversifolia, Plantago major, Platanus orientalis, Polygonatum verticillatum, Prunus domestica, Punica granatum, Ricinus communis, Rosa moschata, Sambucus wightiana, Skimmia laureola, Solanum virginianum, Stellaria media, Viburnum grandiflorum, Zanthoxylum armatum</i>
<b>Dermatological and topical diseases</b>	<i>Abelmoschus esculentus, Allium cepa, Allium sativum, Amaranthus viridis, Brassica campestris, Celtis australis, Convolvulus arvensis, Cuscuta reflexa, Cynodon dactylon, Datura stramonium, Debregeasia saeneb, Echinops echinatus, Euphorbia wallichii, Indigofera heterantha, Jasminum officinale, Juglans regia, Melia azedarach, Onosma hispida, Periploca aphylla, Pistacia chinensis, Plantago lanceolata, Plantago major, Salvia lanata, Sambucus wightiana, Silene vulgaris, Skimmia laureola, Solanum nigrum</i>
<b>Respiratory illness</b>	<i>Abelmoschus esculentus, Allium cepa, Allium sativum, Amaranthus viridis, Arisaema jacquemontii, Arenaria griffithii, Artemisia scoparia, Delphinium denundatum, Elaeagnus umbellata, Ficus palmata, Geranium wallichianum, Heracleum candicans, Melia azedarach, Morus alba, Papaver somniferum, Ricinus communis.</i>
<b>Skeleto-muscular problems</b>	<i>Aesculus indica, Aconitum violaceum, Atropa acuminata, Colchicum luteum, Daphne mucronata, Lotus corniculatus, Paeonia emodi, Polygonatum verticillatum, Sambucus wightiana, Sarcococca saligna</i>
<b>Cardio-vascular complaints and circulatory diseases</b>	<i>Ajuga bracteosa, Allium sativum, Colchicum luteum, Cuscuta reflexa, Dioscorea deltoidea, Elaeagnus umbellata, Hedera nepalensis, Otostegia limbata, Pistacia chinensis, Podophyllum hexandrum, Portulaca oleracea, Taraxacum sp.</i>
<b>Fever, headache, analgesic</b>	<i>Cichorium intybus, Delphinium denundatum, Geranium wallichianum, Hypericum perforatum, Jasminum humile, Melia azedarach, Papaver somniferum, Solanum nigrum, Thymus linearis, Verbena officinalis, Xanthium strumarium, Zanthoxylum armatum</i>
<b>Urinary complaints</b>	<i>Abelmoschus esculentus, Allium cepa, Allium sativum, Capsella bursa-pastoris, Chenopodium album, Cuscuta reflexa, Foeniculum vulgare, Fragaria vesca, Hypericum perforatum, Portulaca oleracea, Quercus oblongata, Quercus floribunda, Solanum virginianum, Taraxacum spec.</i>
<b>Dental problems</b>	<i>Isodon rugosus, Juglans regia, Olea europaea, Origanum vulgare, Otostegia limbata, Rumex dentatus</i>

<b>Syndrome category</b>	<b>Plants</b>
<b>ENT complaints</b>	<i>Ajuga bracteosa, Artemisia scoporia, Corydalis stewartii, Origanum vulgare, Primula denticulata</i>
<b>Nerve disorders (anodyne, epilepsy, sedative)</b>	<i>Ajuga bracteosa, Cannabis sativa</i>
<b>Genital and sexual diseases</b>	<i>Allium cepa, Allium sativum, Avena sativa, Celtis australis, Colchicum luteum, Geranium wallichianum, Lotus corniculatus, Polygonatum multiflorum, Polygonatum verticillatum, Quercus dilatata, Withania somnifera</i>
<b>Others (wounds, cuts, narcotic, tonic, tumor, anticancer and stimulant)</b>	<i>Allium cepa, Allium sativum, Avena sativa, Berberis lycium, Bergenia stracheyi, Cannabis sativa, Capsella bursa-pastoris, Coriandrum sativum, Cynodon dactylon, Datura stramonium, Juglans regia, Lathyrus aphaca, Paeonia emodi, Papaver somniferum, Periploca aphylla, Prunus armeniaca, Salvia moorcroftiana, Taraxacum sp.</i>
<b>Delivery</b>	<i>Spiraea sp.</i>

### **Competing interests**

The authors declare that they have no competing interests.

### **Authors' contributions**

NA carried out the field work, analyzed the data and drafted the manuscript. EB revised the whole manuscript and contributed to the editing and interpreting of the data. AR conceptualized and designed the study while WM helped in the initial drafting of the manuscript. All authors read and approved the final manuscript.

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**CHAPTER 3**

**VEGETATION PATTERNS AND HUMAN IMPACT ALONG AN  
ELEVATION GRADIENT IN THE MOUNTAINS OF SWAT, NORTHERN  
PAKISTAN**

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## Abstract

The distribution of the woodland vegetation in the mountains of Miandam, Swat, North Pakistan, has been studied along an elevation gradient between 1600-3400 m. A data set of four hundred relevés was classified using Roleček's modified TWINSpan with Sørensen dissimilarity distance measure. Twelve plant communities corresponding to six elevational zones were established and a georeferenced distribution map is presented. Indicator plant communities related to elevational zones (Alpine, Subalpine, Boreal, Upper Nemoral, Lower Nemoral, Meridional) include: Alpine turf of *Sibbaldia cuneata* with *Juniperus* patches; Subalpine scrub of *Betula utilis*; Subalpine *Betula-Viburnum* treeline scrub; Laurophyllous *Quercus semecarpifolia* forest; Coniferous *Picea smithiana* forest; Woodland of *Abies pindrow* and *Viburnum grandiflorum*; Woodland of *Abies pindrow* and *Indigofera heterantha*; Mixed forest of *Quercus floribunda* and *Pinus wallichiana*; Coniferous forest of *Abies pindrow* and *Geranium wallichianum*; Woodland of *Pinus wallichiana* and *Sorbaria tomentosa* shrubbery; Woodland of *Pinus wallichiana* and *Indigofera heterantha* scrub; Sub-tropical groves of *Ailanthus altissima*. Detrended Correspondence Analysis (DCA) results suggest that elevation is the main explaining factor in the data set. Vascular plant species found comprise 33 trees, 52 shrubs, 11 climbers, and 305 herbaceous plants. A comparison of the vegetation of Miandam with other studies based on dominant forest plants revealed most similarities towards south east, specifically with the vegetation of Ayubia National Park (Abbotabad) and the Bagh district in Kashmir. Our assessment of human impact on the vegetation revealed overgrazing, logging, and locally overcollection of medicinal plants as the most severe threats to woodland ecosystems. We recommend that local and national governments and specifically forest authorities urgently increase their efforts to stop illegal wood cutting and logging.

**Key words:** forest vegetation, georeferencing, vegetation zonation, vegetation classification, woodland

## Introduction

Sitting astride one of the major biogeographical disjunctions of southern Asia, Pakistan's flora and vegetation are highly diverse. Takhtajan *et al.* (1986) delineated five floristic provinces extending into the territory of Pakistan. Two of these, the Southern Iranian Province and the Sindian Province, belong to the paleotropical Sudano-Zambezian Region. The other three floristic provinces belong to the Holarctic Irano-Turanian Region. Of these provinces, Northern Baluchistan and the Western Himalayas form part of the Western Asiatic Subregion, while the Tibetan Province belongs to the Central Asiatic Subregion. The Western Himalayan Province is of particular interest as "the flora of this province occupies a kind of transitional position and is a link between the ancient Mediterranean (Tethyan) and eastern Asiatic floras" (Takhtajan *et al.* 1986). Recent studies on the phytogeography, biodiversity and phytosociology in Pakistan and the Western Himalayan Province have been provided by Ahmed and Mahmood (1998), Chawla *et al.*(2008), Dickoré and Nüsser (2000), Eberhardt *et al.* (2007), Khan (2012), Malik and Hussain (2006), Nüsser and Dickoré (2002), Peer *et al.* (2007), Saima *et al.* (2009) and Shaheen *et al.* (2011).

About 40% of Pakistan's natural forests are located in its northern province of Khyber Pakhtunkhwa, with almost 17% of the total area of this province being wooded (Ahmed and Mahmood, 1998). Most of the natural woodlands in Khyber Pakhtunkhwa are located in the mountainous districts of Chitral, Upper Dir, Lower Dir, Swat, Shangla, Malakand, Buner, Kohistan, Battagram, Mansehra, Abbottabad and Haripur. In the district of Swat and surrounding areas, several studies contributed to the knowledge of woodland types from subtropical levels to the high mountains, e.g. Ahmed *et al.* (2010), Beg and Khan (1984), Hussain *et al.* (1992), Hussain *et al.*(1995), Khan (2012), Rashid *et al.*(2011) and Sher and Al yemeni (2011). Ilyas *et al.* (2012) assessed the vegetation structure and composition in the Qalagai hills, Swat, aiming to pinpoint strategies for the conservation of the threatened forest ecosystems in that area. Recently Khan *et al.* (2013) identified plant communities in the Western Himalayas using multivariate approaches.

In the present study we examined the variation in vascular plant species composition along an elevation gradient in the mountains of Swat, North Pakistan, combining multivariate classification and ordination. Our objectives were (1) to survey and describe woodlands and shrublands in the area of Miandam, (2) to identify the vegetation zones and to reveal similarities with zonal plant communities described from the wider surroundings and (3) to point out human impacts and assess risks for the plant communities.

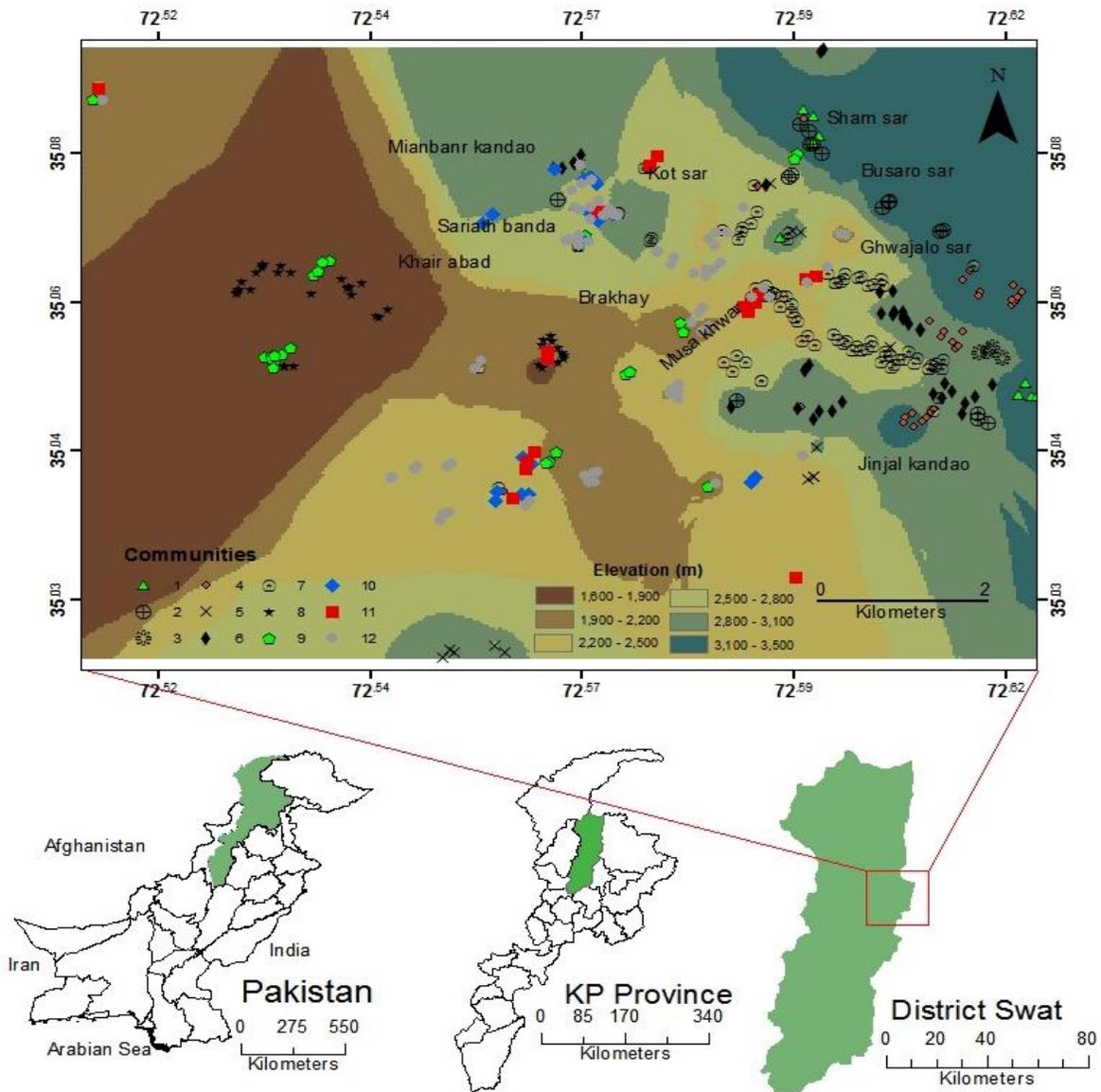


Figure 1. A georeferenced map of the study area of Miandam showing plant communities, localities and elevation zones. Plant community numbers refer to the communities described in the text.

### Study Area

The study area of Miandam (35° 1'- 5' N, 72° 30'-37' E) is located in the District of Swat in the Province of Khyber Pakhtunkhwa (formerly North West Frontier Province). The province is located

on both banks of the river Indus and is bounded by the Himalaya, Karakoram and Hindukush Mountains in the north and Afghanistan in the north-west. The District of Swat is located in the north of Khyber Pakhtunkhwa (Figure 1). Miandam lies about 50 km northeast of Saidu Sharif, district capital of Swat, and 21 km from Khwazakhela, administrative centre of the surrounding villages. Its western boundary is the river Swat. The narrow valley of Miandam is surrounded on the north, east and south by high mountains. It ranges between 1400 to 3400 m.

According to Zahid and Rasul (2011), and based on Thornthwaite's index of thermal efficiency, the research area falls in the "Mild microthermal" zone. The average annual rainfall is 1038 mm (Saeeda, 2005). March, July and August are months with heavy rainfall (New *et al.* 2002). December and January are the coldest months with temperatures down to a mean minimum of  $-10^{\circ}\text{C}$  (Saeeda, 2005).

The Swat valley and adjoining parts of NW Pakistan consist of rock units representing the Kohistan Arc sequence, the Tethys oceanic lithosphere and the Indo-Pakistan plate sequence. The Kohistan Arc sequence consists essentially of late Jurassic-Cretaceous and Tertiary plutonic and metamorphic plutonic, volcanic and sedimentary rocks (Arif *et al.* 2011). The geology of the study area is dominated by a group of plutonic rocks, the Upper Swat Hornblende Group, forming a broad northeast-trending belt which includes granite, granodiorite, syenite, diorite, gabbro, and associated pegmatites (Porter, 1970).

The lower zone of Miandam between 1500–1800 m is covered by terraced crop fields with scattered groups of trees. Maize is the most important cash crop followed by potato and turnip. Wheat is also cultivated in lower areas. Most areas above 1800 m up to 3300 m are wooded. The elevation range in our study was between 1600 m and 3400 m.

## **Materials and methods**

### **Data collection**

Field work was carried out by one of us (NA) in 2010–2012, from May through September. Four hundred vegetation relevés of  $10\text{ m} \times 10\text{ m}$  were preferentially placed in stratified wooded and sparsely wooded areas, yet limited by accessibility. Minimum distance between relevés of the same formation was approximately 50 m. Cover/abundance of vascular plants was estimated using the Braun-Blanquet scale (e.g. Dierschke, 1994). Slope, aspect and other abiotic parameters, further tree, shrub and herb cover, height of the highest and lowest trees and shrubs and tree diameters of old

trees were also assessed. As geological maps were not available we did not identify bedrock types per relevé. Coordinates (WGS 84) and elevation were measured using GPS device. Plant samples were collected of almost all vascular plant species and identified using Ali and Qaisar (2001), Breckle *et al.* (2010) and Urrahman (2012). Herbarium collections of the Botanische Staatssammlung München (M), Germany, were consulted. The assessment of human impact and threat was based on NA's extensive field observations.

#### **Data analysis**

Species, structural and environmental data of all relevés were entered in a Turboveg database (Hennekens and Schaminée, 2001). The relevés were classified using TWINSpan (Roleček *et al.* 2009) under JUICE 7.0 (Tichý, 2002). In the first data set arbitrarily 15 groups were established. Three outlier groups of non-woody vegetation were excluded from further analysis. The remaining 12 groups comprising 387 relevés were found to be interpretable and subjected to further analyses. We used phi coefficient as species fidelity measure. Fisher's exact test was applied and zero fidelity value was given to the species with significance value of  $P > 0.01$ . Diagnostic, constant and dominant species (Chytrý *et al.* 2002) were determined using threshold values of fidelity ( $\Phi$  coefficient) 35 %, frequency 40%, and cover 30 %. Sørensen dissimilarity with Average linkage was used for clustering and Detrended Correspondence Analysis (DCA) (Ter Braak and Šmilauer, 2002) to measure the principal gradient length and to relate species composition to environmental variables.

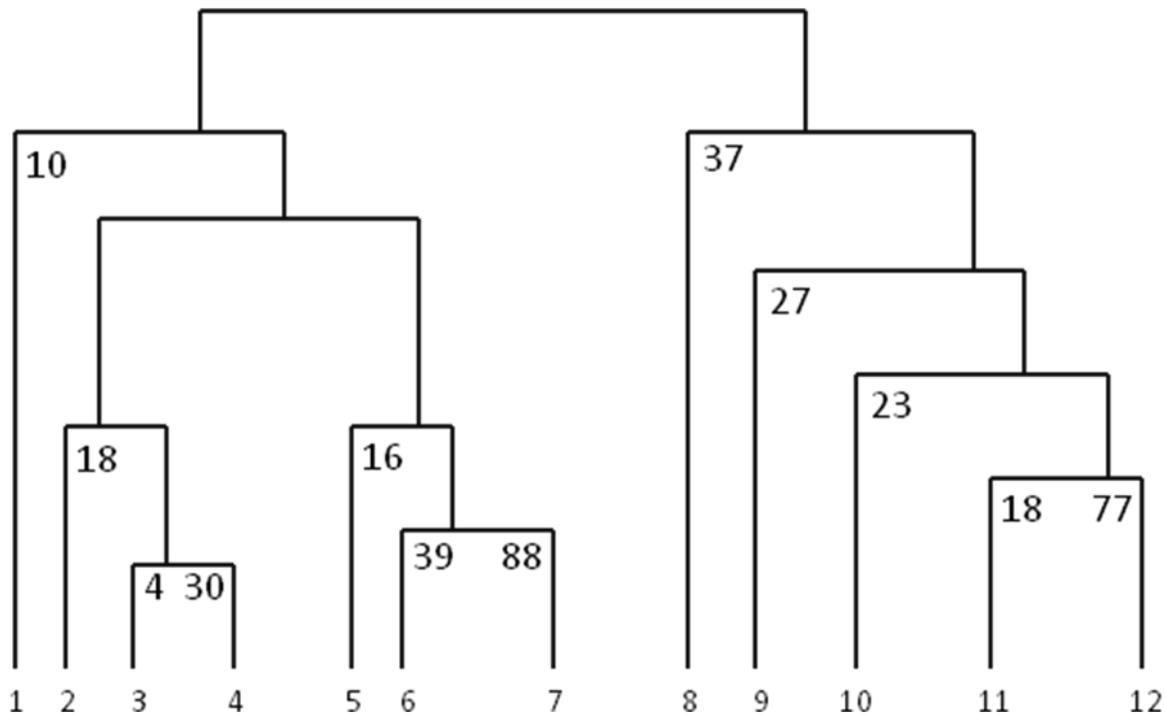


Figure 2. TWINSpan (modified after Roleček *et al.* 2009) classification hierarchy based on 387 relevés collected in Miandam, Swat, North Pakistan. The numbers of the 12 units correspond to the plant communities described in the text. In the corners numbers of relevés in each group are indicated.

A second DCA was performed on a data set restricted to *Abies* and *Picea* woodlands. Elevation (m), aspect, slope (degrees), cover of litter (%) and rocks (%), longitude and latitude were used as environmental variables. Aspect is a circular variable and the values were transformed from degrees to radians then converted to cosine, i.e to a range of  $-1$  to  $+1$ , with aspects close to  $-1$  being southward and those close to  $+1$ , northward. Environmental variables were checked for multicollinearity based on variance inflation factor. Longitude was omitted from analysis as it increased along with increasing elevation. A georeferenced map was prepared using ArcGIS version 10.1 to show the distribution of the plant communities (Figure 1). The allocation of plant communities to vegetation belts corresponds to the terms and zonation outlined by Schroeder (1998). Plant nomenclature follows the Pakistan Plant Database ([www.tropicos.org/Project/Pakistan](http://www.tropicos.org/Project/Pakistan)) except *Quercus oblongata*, *Quercus floribunda*, *Leptopus cordifolius*, *Wulfeniopsis amherstiana*, *Acomastylis elata*, *Isodon rugosus* and *Fragaria bucharica*, for which we preferred The Plant list ([www.theplantlist.org](http://www.theplantlist.org)).

## Results

### Diversity, classification and description of vegetation

The vegetation data set of 387 relevés comprised 401 species, including 33 trees, 52 shrubs, 11 climber and 305 herb species. Modified TWINSpan suggested 12 sufficiently distinct and interpretable vegetation units (Table 1). At the first hierarchy level the data set was separated in two distinct groups based on species composition (Figure 2). The two groups differ also in altitudinal distribution. The units 1-7 are communities of high elevation chiefly beyond 2400 m while the other units 8-12 comprise communities mainly below 2400 m. At the next level unit 1 is separated as humid scrub of *Betula*, unit 2 as forest of *Quercus semecarpifolia*, units 3 and 4 represent subalpine tree line scrub and alpine *Juniperus* patches, respectively. At the other branch of the dendrogram unit 8 is representative of the meridional zone. Units 9-10 represent the lower nemoral and units 11 and 12 the upper nemoral zone.

Together with a brief description of each vegetation unit, we indicated all kinds of local human impact and possibly resulting threats to the ecosystems. Cover values of bedrock, tree and shrub layers, and height of trees and shrubs are given as mean and, in brackets, maximum values.

#### (1) Subalpine scrub of *Betula utilis*

Elevation range: 3100–3200 m, chiefly encountered at Ghwajalo sar (Figure 1)

Bedrock cover: 8(–20) %

Trees: *Betula utilis*, 5.9(–15) m

Shrubs: *Salix* sp. (unident.), 15(–38) %; 0.8(–2.5) m

Diagnostic species: *Arenaria griffithii*, *Pleurospermum candollei*, *Potentilla atosanguinea*, *Ranunculus* (unident.), *Salix* (unident.), *Phacelurus speciosus*, *Poa* sp.

Constant species: *Betula utilis*, *Arenaria griffithii*, *Phacelurus speciosus*, *Pleurospermum candollei*, *Poa* sp., *Potentilla atosanguinea*, *Ranunculus* (unident.), *Salix* (unident.),

Dominant species: *Poa* cf. *pratensis*,

Mean number of species ( $\pm$ SD):  $6.4 \pm 1.7$

Human impact and threat: The local herders take cows, sheep and buffaloes for summer grazing to the alpine pastures of Sham sar, resulting in local overgrazing and trampling close to temporary shelters

Table 1. Synoptic table of 12 vegetation units, classified from 387 relevés, subjected to modified TWINSpan analysis, of Miandam, Swat, Northern Pakistan, with percentage frequencies and fidelities (phi coefficient; italic indices). Frequencies of 50 % or higher are shown as bold figures. Fisher's exact test was applied and zero fidelity value was given to the species with significance value of  $P > 0.01$ . Only species with frequency values of 20 % or more in at least one column are shown. Plant community numbers correspond to numbers of vegetation units in the text. Table sectors for trees, shrubs and herbs, respectively, are separated by simple lines. (1) Subalpine scrub of *Betula utilis*; (2) Laurophyllous *Quercus semecarpifolia* forest; (3) Subalpine *Betula-Viburnum* treeline scrub; (4) Alpine turf of *Sibbaldia cuneata* with *Juniperus* patches; (5) Coniferous forest of *Abies pindrow* and *Geranium wallichianum*; (6) Coniferous *Picea smithiana* forest; (7) Woodland of *Abies pindrow* and *Viburnum grandiflorum*; (8) Sub-tropical groves of *Ailanthus altissima*; (9) Mixed forest of *Quercus floribunda* and *Pinus wallichiana*; (10) Woodland of *Abies pindrow* and *Indigofera heterantha*; (11) Woodland of *Pinus wallichiana* and *Sorbaria tomentosa* shrubbery; (12) Woodland of *Pinus wallichiana* and *Indigofera heterantha* scrub.

Communities	1	2	3	4	5	6	7	8	9	10	11	12
No. of relevés	10	18	4	30	16	39	88	37	27	23	18	77
<i>Betula utilis</i>	40 <sup>31</sup>	.	<b>50</b> <sup>32</sup>	.	.	8	.	.	.	.	.	.
<i>Quercus semecarpifolia</i>	.	<b>67</b> <sup>61</sup>	.	.	12	3	.	.	.	.	.	.
<i>Picea smithiana</i>	.	<b>56</b> <sup>20</sup>	.	13	12	<b>79</b> <sup>50</sup>	22	.	.	4	.	14
<i>Abies pindrow</i>	.	.	.	7	<b>100</b> <sup>27</sup>	<b>59</b> <sup>15</sup>	<b>84</b> <sup>53</sup>	.	.	<b>78</b> <sup>21</sup>	.	17
<i>Taxus wallichiana</i>	.	.	.	10	6	<b>51</b> <sup>57</sup>	2	.	.	.	.	.
<i>Prunus cornuta</i>	.	.	.	.	.	5	16	.	.	38 <sup>28</sup>	11	12
<i>Aesculus indica</i>	.	.	.	.	.	5	27 <sup>26</sup>	.	.	4	.	6
<i>Rhamnus purpurea</i>	.	.	.	.	.	3	21 <sup>23</sup>	.	.	.	.	4
<i>Ailanthus altissima</i>	.	.	.	.	.	.	.	<b>62</b> <sup>71</sup>	.	.	11	.
<i>Olea ferruginea</i>	.	.	.	.	.	.	.	35 <sup>36</sup>	11	.	13	.
<i>Robinia pseudo-acacia</i>	.	.	.	.	.	.	.	27 <sup>37</sup>	.	.	6	.
<i>Ficus palmata</i>	.	.	.	.	.	.	.	27 <sup>30</sup>	9	.	11	3
<i>Celtis caucasica</i>	.	.	.	.	.	.	.	22 <sup>33</sup>	.	4	.	1
<i>Quercus floribunda</i>	.	17	.	.	12	5	2	.	<b>81</b> <sup>66</sup>	.	.	9
<i>Pinus wallichiana</i>	.	.	.	17	.	.	26	8	<b>67</b> <sup>20</sup>	22	28	<b>87</b> <sup>58</sup>
<i>Pyrus pashia</i>	.	.	.	.	.	.	.	8	22 <sup>36</sup>	.	.	.
<i>Ficus species</i>	.	.	.	.	.	.	.	.	21 <sup>30</sup>	.	.	.
<i>Quercus oblongata</i>	.	11	.	.	.	.	.	.	4	.	.	27 <sup>32</sup>
<i>Salix spec.</i>	40 <sup>47</sup>	.	.	.	.	5	.	.	.	.	.	.
<i>Rhododendron hypenanthum</i>	.	21 <sup>33</sup>	.	.	.	.	.	.	.	.	.	.
<i>Viburnum grandiflorum</i>	.	.	<b>50</b> <sup>15</sup>	10	19	<b>56</b> <sup>19</sup>	<b>69</b> <sup>46</sup>	.	22	23	.	14
<i>Juniperus communis</i>	.	.	.	33 <sup>25</sup>	.	.	.	.	.	.	.	.
<i>Berberis calliobotrys</i>	.	.	.	23 <sup>19</sup>	.	5	.	.	.	.	11	5
<i>Juniperus squamata</i>	.	.	.	20 <sup>21</sup>	.	.	.	.	.	.	.	.
<i>Viburnum cotinifolium</i>	.	.	.	10	10	.	11	.	4	43 <sup>28</sup>	.	12
<i>Rubus ulmifolius</i>	.	.	.	.	.	.	.	.	4	4	28 <sup>35</sup>	4
<i>Sorbaria tomentosa</i>	.	.	.	.	.	5	12	8	.	28 <sup>15</sup>	<b>89</b> <sup>40</sup>	29 <sup>13</sup>
<i>Indigofera heterantha</i>	.	.	.	.	21	.	2	12	<b>74</b> <sup>21</sup>	<b>87</b> <sup>26</sup>	<b>78</b> <sup>19</sup>	<b>92</b> <sup>57</sup>
<i>Parrotiopsis jacquemontiana</i>	.	.	.	.	.	10	1	.	14	13	.	43 <sup>47</sup>
<i>Euonymus hamiltonianus</i>	.	.	.	.	.	.	.	.	.	4	21 <sup>26</sup>	.

Communities	1	2	3	4	5	6	7	8	9	10	11	12	
<i>Sarcococca saligna</i>	.	.	.	.	.	.	.	16	<sup>16</sup> 54	<sup>49</sup> 4	.	1	
<i>Isodon rugosus</i>	.	.	.	.	.	.	8	<b>62</b>	<sup>28</sup> 52	<sup>27</sup> 9	33	<sup>12</sup> 48	<sup>27</sup>
<i>Berberis lycium</i>	.	.	.	7	.	5	3	<b>57</b>	<sup>27</sup> 63	<sup>30</sup> 22	17	29	
<i>Rubus fruticosus</i>	.	.	.	.	.	.	.	24	<sup>38</sup>	.	.	.	
<i>Sageretia thea</i>	.	.	.	.	.	.	.	22	<sup>27</sup> 19	<sup>21</sup> 9	.	.	
<i>Cotoneaster microphyllus</i>	.	.	.	.	.	.	.	16	<sup>16</sup> 30	<sup>29</sup> 4	.	5	
<i>Spiraea sp.</i>	.	.	.	.	.	.	5	3	12	9	11	31	<sup>34</sup>
<i>Jasminum humile</i>	.	.	.	.	6	.	.	.	.	11	6	21	<sup>34</sup>
<i>Desmodium elegans</i>	.	.	.	.	.	.	.	11	25	<sup>28</sup>	10	14	<sup>14</sup>
<i>Cestrum nocturnum</i>	.	.	.	.	.	.	.	.	21	<sup>30</sup>	.	.	.
<i>Elaeagnus umbellata</i>	.	.	.	.	.	.	.	.	21	<sup>30</sup>	.	.	.
<i>Arenaria griffithii</i>	<b>60</b>	<sup>77</sup>	.	.	.	.	.	.	.	.	.	.	.
<i>Potentilla atrosanguinea</i>	<b>60</b>	<sup>77</sup>	.	.	.	.	.	.	.	.	.	.	.
<i>Ranunculus spec.</i>	<b>60</b>	<sup>42</sup> 11	.	17	<sup>16</sup>	8	3	.	.	.	.	.	.
<i>Trifolium repens</i>	<b>50</b>	<sup>23</sup>	.	20	.	5	14	11	.	.	28	3	.
<i>Pleurospermum candollei</i>	40	<sup>45</sup>	.	.	.	.	.	.	.	.	.	.	.
<i>Poa cf. pratensis</i>	40	<sup>37</sup> 6	.	17	<sup>24</sup>	.	.	.	.	.	.	.	.
<i>Primula rosea</i>	40	<sup>24</sup>	.	27	<sup>16</sup>	26	<sup>19</sup>	.	.	.	.	.	.
<i>Anemone obtusiloba</i>	35	<sup>27</sup>	.	.	.	.	3	.	.	.	.	.	.
<i>Phacelurus speciosus</i>	35	<sup>36</sup>	.	.	.	.	.	.	.	.	.	.	.
<i>Primula denticulata</i>	.	<b>67</b>	<sup>46</sup>	13	.	36	<sup>33</sup> 3	.	.	.	.	.	.
<i>Impatiens brachycentra</i>	.	33	<sup>46</sup>	.	.	5	1	.	.	.	.	.	.
<i>Arisaema flavum</i>	10	28	<sup>17</sup>	11	12	.	9	.	.	.	.	10	.
<i>Inula grandiflora</i>	.	27	<sup>40</sup>	.	.	.	.	.	.	.	.	.	.
<i>Cypripedium cordigerum</i>	.	27	<sup>40</sup>	.	.	.	.	.	.	.	.	.	.
<i>Potentilla curviseta</i>	.	27	<sup>25</sup>	7	.	.	2	.	.	.	.	.	.
<i>Arum jacquemontii</i>	.	.	<b>100</b>	<sup>100</sup>	.	.	.	.	.	.	.	.	.
<i>Bistorta amplexicaulis</i>	30	<sup>15</sup> 37	<sup>24</sup> <b>100</b>	<sup>50</sup> 20	.	15	7	8	17	4	18	15	.
<i>Aconitum heterophyllum</i>	.	.	<b>100</b>	<sup>81</sup> 7	.	.	.	.	.	.	.	.	.
<i>Swertia petiolata</i>	.	.	<b>100</b>	<sup>81</sup> 7	.	.	.	.	.	.	.	.	.
<i>Arisaema utile</i>	.	.	<b>100</b>	<sup>41</sup> 7	.	3	12	<sup>10</sup>	.	.	.	4	.
<i>Artemisia dubia</i>	.	.	<b>100</b>	<sup>37</sup> 7	.	.	.	3	.	7	6	18	<sup>11</sup>
<i>Salvia lanata</i>	.	.	<b>100</b>	<sup>75</sup>	6	.	1	.	.	.	.	1	.
<i>Origanum vulgare</i>	.	6	<b>100</b>	<sup>28</sup> 33	<sup>20</sup>	12	7	38	<sup>26</sup>	.	6	3	.
<i>Bidens cernua</i>	.	.	<b>75</b>	<sup>50</sup>	.	.	.	.	.	.	.	.	.
<i>Oxyria digyna</i>	.	.	<b>75</b>	<sup>39</sup>	.	5	5	5	.	.	.	4	.
<i>Polygonatum verticillatum</i>	.	.	25	<sup>9</sup>	.	15	7	.	.	.	11	8	.
<i>Sibbaldia cuneata</i>	.	28	25	<b>83</b>	<sup>56</sup> 6	36	<sup>10</sup> 11	.	.	.	.	.	.
<i>Achillea millefolium</i>	.	.	.	<b>50</b>	<sup>56</sup>	5	6	.	.	.	.	.	.
<i>Anaphalis margaritacea</i>	.	.	.	40	<sup>53</sup>	.	.	.	.	.	.	.	.
<i>Taraxacum spec.</i>	.	11	.	40	<sup>38</sup>	10	3	5	.	.	17	1	.
<i>Plantago lanceolata</i>	.	11	.	43	<sup>35</sup>	.	3	24	<sup>18</sup>	.	11	5	.
<i>Phlomis bracteosa</i>	.	.	.	33	<sup>25</sup>	.	.	.	.	.	.	.	.
<i>Poa sterilis</i>	.	.	.	23	<sup>21</sup>	.	1	.	.	.	.	.	.
<i>Gypsophila cerastioides</i>	.	.	.	23	<sup>19</sup>	5	7	.	.	.	.	.	.
<i>Thymus linearis</i>	.	.	.	37	<sup>22</sup>	15	15	<sup>15</sup>	.	.	.	.	.
<i>Geranium wallichianum</i>	.	.	.	10	<b>88</b>	<sup>60</sup> 10	5	.	.	9	6	5	.

Communities	1	2	3	4	5	6	7	8	9	10	11	12
<i>Fragaria bucharica</i>	.	28	.	28	<b>75</b> <sup>14</sup>	46 <sup>10</sup>	49 <sup>10</sup>	5	41 <sup>10</sup>	22	<b>50</b> <sup>10</sup>	<b>58</b> <sup>16</sup>
<i>Mentha royleana</i>	.	.	.	.	<b>50</b> <sup>54</sup>	.	.	5	4	4	.	1
<i>Micromeria biflora</i>	.	.	.	.	44 <sup>47</sup>	.	.	11	.	.	.	3
<i>Epilobium parviflorum</i>	.	.	.	.	39 <sup>43</sup>	.	.	.	.	.	.	.
<i>Carum atosanguineum</i>	.	.	.	.	39 <sup>41</sup>	.	.	.	.	.	.	.
<i>Arisaema jacquemontii</i>	10	.	.	3	39 <sup>32</sup>	13	8	.	19	39 <sup>18</sup>	18	12
<i>Rumex nepalensis</i>	.	18	.	20	39 <sup>29</sup>	16	18	5	4	16	.	10
<i>Viola pilosa</i>	.	.	.	.	38 <sup>23</sup>	3	10	.	7	.	17	6
<i>Rumex acetosa</i>	.	.	.	.	35 <sup>23</sup>	.	17 <sup>15</sup>	.	.	.	.	.
<i>Salvia moorcroftiana</i>	.	.	.	.	25 <sup>44</sup>	.	.	3	.	.	.	.
<i>Microstegium nudum</i>	.	.	.	.	25 <sup>40</sup>	.	.	.	.	9	.	.
<i>Convolvulus arvensis</i>	.	.	.	.	22 <sup>25</sup>	.	.	.	.	.	.	.
<i>Geum urbanum</i>	.	.	35 <sup>19</sup>	3	.	10	41 <sup>37</sup>	.	.	.	17	1
<i>Euphorbia wallichii</i>	.	6	.	30	.	44 <sup>21</sup>	<b>56</b> <sup>50</sup>	.	.	.	.	.
<i>Podophyllum hexandrum</i>	.	.	.	.	.	21	<b>55</b> <sup>51</sup>	.	.	.	11	3
<i>Paeonia emodi</i>	.	.	.	.	.	10	<b>50</b> <sup>53</sup>	.	.	4	11	10
<i>Bergenia ciliata</i>	.	11	.	.	.	31 <sup>31</sup>	5	.	.	17	28 <sup>18</sup>	1
<i>Atropa acuminata</i>	.	.	.	7	.	.	25 <sup>31</sup>	.	.	.	.	.
<i>Aquilegia pubiflora</i>	.	.	.	.	.	15	24 <sup>34</sup>	.	.	.	.	3
<i>Caltha alba</i>	.	.	.	.	.	13	22 <sup>34</sup>	.	4	.	.	.
<i>Valeriana jatamansi</i>	.	.	.	3	.	15	28 <sup>28</sup>	.	15	.	.	14
<i>Rumex dentatus</i>	.	.	.	.	.	.	38 <sup>36</sup>	.	.	.	11	4
<i>Lamium album</i>	.	.	.	.	.	.	25 <sup>35</sup>	14	.	.	.	3
<i>Lycopus europaeus</i>	.	.	.	.	.	3	22 <sup>30</sup>	.	.	.	.	.
<i>Rumex hastatus</i>	10	.	.	.	.	.	2	<b>68</b> <sup>54</sup>	7	43 <sup>24</sup>	.	9
<i>Lepidium pinnatifidum</i>	.	.	.	.	.	.	1	43 <sup>29</sup>	.	.	17	.
<i>Verbascum thapsus</i>	.	.	.	.	.	.	2	43 <sup>50</sup>	.	4	.	4
<i>Tagetes minuta</i>	.	.	.	.	.	.	.	22 <sup>35</sup>	.	.	.	.
<i>Pilea umbrosa</i>	.	.	.	.	.	.	8	22 <sup>20</sup>	.	9	10	6
<i>Bidens tripartita</i>	.	.	.	.	.	.	.	25 <sup>19</sup>	.	.	.	.
<i>Onopordum acanthium</i>	.	.	.	.	.	.	.	24 <sup>24</sup>	33 <sup>30</sup>	9	.	6
<i>Artemisia vulgaris</i>	.	6	.	13	19	3	.	.	.	48 <sup>23</sup>	18	44 <sup>31</sup>
<i>Hedera nepalensis</i>	.	.	.	.	13	.	6	.	11	12	10	22 <sup>20</sup>
<i>Cirsium wallichii</i>	.	.	.	.	6	3	5	8	.	39 <sup>21</sup>	28 <sup>18</sup>	3
<i>Urtica dioica</i>	.	.	.	.	.	8	7	.	.	26 <sup>18</sup>	.	5
<i>Vitis jacquemontii</i>	.	.	.	.	.	.	.	.	.	23 <sup>28</sup>	.	1
<i>Dipsacus inermis</i>	.	.	11	.	.	5	.	.	.	23 <sup>21</sup>	.	1
<i>Eremostachys superba</i>	.	.	.	.	.	.	.	.	.	36 <sup>33</sup>	.	3
<i>Senecio chrysanthemoides</i>	.	6	.	.	6	18	44 <sup>30</sup>	.	.	19	<b>78</b> <sup>30</sup>	12
<i>Clinopodium umbrosum</i>	.	.	.	10	6	.	11	3	.	13	44 <sup>31</sup>	4
<i>Arenaria serpyllifolia</i>	.	.	.	.	.	.	.	.	.	.	37 <sup>40</sup>	.
<i>Chrysopogon gryllus</i>	.	.	.	.	.	.	.	.	7	9	33 <sup>28</sup>	13 <sup>18</sup>
<i>Galium aparine</i>	.	.	.	3	.	.	5	3	11	10	33 <sup>21</sup>	17 <sup>17</sup>
<i>Delphinium denudatum</i>	.	.	.	.	.	.	3	.	.	.	22 <sup>27</sup>	.
<i>Lepidium apetalum</i>	.	.	.	.	.	.	.	.	.	.	22 <sup>46</sup>	.
<i>Eruca sativa</i>	.	.	.	.	.	.	.	.	.	.	21 <sup>33</sup>	.
<i>Salvia nubicola</i>	.	.	.	.	.	.	.	.	.	.	21 <sup>33</sup>	.

(2) Laurophyllous *Quercus semecarpifolia* forest

Elevation range: 2700–3200 m, mainly observed at Sham sar

Bedrock cover: 13(–50) %

Trees: *Picea smithiana*, 26 m, *Quercus semecarpifolia* about 20 m

Shrubs: *Rhododendron hypenanthum*, 0.5 m

Diagnostic species: *Impatiens brachycentra*, *Primula denticulata*, *Quercus semecarpifolia*

Constant species: *Bistorta amplexicaulis*, *Fragaria bucharica*, *Picea smithiana*

Dominant species: *Picea smithiana*, *Quercus semecarpifolia*

Mean number of species ( $\pm$ SD):  $7 \pm 2$

Human impact and threat: *Quercus semecarpifolia* is used for fuel wood by locals; the stem base of *Primula denticulata* (“mamera”), an important medicinal plant, is collected

(3) Subalpine *Betula-Viburnum* treeline scrub

Elevation range: 2900–3300 m, mostly found below Busaro sar

Bedrock cover: not outcropping

Trees: *Betula utilis*, 10 m

Shrubs: *Viburnum grandiflorum*, 32 %; 2.3 m

Diagnostic species: *Aconitum heterophyllum*, *Arisaema utile*, *Artemisia dubia*, *Arum jacquemontii*, *Bidens cernua*, *Oxyria digyna*, *Salvia lanata*, *Swertia petiolata*

Constant species: *Aconitum heterophyllum*, *Arisaema utile*, *Artemisia dubia*, *Arum jacquemontii*, *Betula utilis*, *Bidens cernua*, *Oxyria digyna*, *Salvia lanata*, *Swertia petiolata*, *Viburnum grandiflorum*

Dominant species: *Viburnum grandiflorum*

Mean number of species ( $\pm$ SD):  $13 \pm 0.5$

Human impact and threat: Overcollecting of medicinal plants; *Aconitum heterophyllum* rhizomes are collected to prepare powder used as aphrodisiac and general body tonic.

(4) Alpine turf of *Sibbaldia cuneata* with *Juniperus* patches

Elevation range: (2700), 3300–3400 m, mostly found at Kot sar and Busaro sar

Bedrock cover: 12.5(–50) %

Trees: *Abies pindrow*, *Pinus wallichiana*, 13.6(–40) m

Shrubs: *Viburnum grandiflorum*, *Juniperus communis*, *Juniperus squamata*, 0.6(–1.5 m)

Diagnostic and constant species: *Achillea millefolium*, *Anaphalis margaritacea*, *Plantago lanceolata*, *Sibbaldia cuneata*, *Taraxacum* sp.

Dominant species: *Sibbaldia cuneata*

Mean number of species ( $\pm$ SD):  $11 \pm 3.6$

Human impact and threat: Alpine grasslands are traditionally used in summer for livestock grazing by locals and also by transhumant herders from other areas; local cutting, camp fires and other trekking activities.

(5) Coniferous forest of *Abies pindrow* and *Geranium wallichianum*

Elevation range: 2300–2900 m

Bedrock cover: 2.8(–24 %)

Trees: *Abies pindrow*, *Quercus semecarpifolia*, with *Abies* 37(–68) % and 31(–42) m

Shrubs: *Indigofera heterantha*, *Viburnum grandiflorum*; 1.5(–2.1) m

Diagnostic species: *Carum atosanguineum*, *Epilobium parviflorum*, *Geranium wallichianum*, *Mentha royleana*, *Micromeria biflora*, *Microstegium nudum*, *Salvia moorcroftiana*

Constant species: *Abies pindrow*, *Fragaria bucharica*, *Geranium wallichianum*, *Mentha royleana*, *Micromeria biflora*

Dominant species: *Abies pindrow*

Mean number of species ( $\pm$ SD):  $10 \pm 3.3$

Human impact and threat: Logging of *Abies pindrow*; *Geranium wallichianum* (“Sra Zeela”) is locally over-collected; its roots are dug out for medicinal purposes.

(6) *Picea smithiana* mixed coniferous forest

Elevation range: 2600–2900 m

Bedrock cover: 14.8(–40) %

Trees: *Abies pindrow*, *Taxus wallichiana*, *Picea smithiana*; with *Picea* 26(–68) % and 25(–34) m; *Aesculus indica* occurs scattered but is generally found along streams.

Shrubs: *Parrotiopsis jacquemontiana*, *Viburnum grandiflorum*, 1.1(–2.6) m

Diagnostic species: *Picea smithiana*, *Taxus wallichiana*

Constant species: *Abies pindrow*, *Euphorbia wallichii*, *Fragaria bucharica*, *Picea smithiana*, *Taxus wallichiana*, *Viburnum grandiflorum*

Dominant species: *Picea smithiana*

Mean number of species ( $\pm$ SD):  $11 \pm 4.3$

Human impact and threat: *Picea smithiana* yields valuable timber wood used for house building, furniture, wooden bridges and beams; cones are used as ornamental items. *Taxus wallichiana* wood is used both for fuel and timber. The *Picea* forest area is declining due to over-exploitation; the wood is exported to other parts of the country.

(7) Woodland of *Abies pindrow* and *Viburnum grandiflorum*

Elevation range: 2100–2900 m, prevailing vegetation in the area

Bedrock cover: 11.7(–70) %

Trees: *Abies pindrow*, 30(–70) %; 24(–45) m

Shrubs: *Indigofera heterantha*, *Viburnum grandiflorum*, 1.6 (–3.2) m

Diagnostic species: *Abies pindrow*, *Euphorbia wallichii*, *Geum urbanum*, *Lamium album*, *Paeonia emodi*, *Podophyllum hexandrum*, *Rumex dentatus*, *Viburnum grandiflorum*

Constant species: *Abies pindrow*, *Euphorbia wallichii*, *Fragaria bucharica*, *Geum urbanum*, *Paeonia emodi*, *Podophyllum hexandrum*, *Senecio chrysanthemoides*, *Viburnum grandiflorum*

Dominant species: *Abies pindrow*, *Viburnum grandiflorum*

Mean number of species ( $\pm$ SD):  $13 \pm 2.9$

Human impact and threat: Vulnerable; declining in area as a result of overexploitation by extensive logging for the local and national timber market; trees are also cut to establish terrace cultivation. *Paeonia emodi* and *Valeriana jatamansi* are among the most sought-after medicinal plants and are collected extensively.

(8) Subtropical groves of *Ailanthus altissima*

Elevation range: 1600–2000 m

Bedrock cover: 7.5(–70) %

Trees: *Ailanthus altissima*, *Morus alba*, *Olea ferruginea*, *Pinus roxburghii*, 17.5 % (–44); 7.6 (22) m

Shrubs: *Berberis lycium*, *Desmodium elegans*, *Indigofera heterantha*, *Isodon rugosus*, *Sorbaria tomentosa*, 1.1 (2) m

Diagnostic species: *Ailanthus altissima*, *Olea ferruginea*, *Robinia pseudoacacia*, *Rubus* spec., *Rumex hastatus*, *Tagetes minuta*, *Verbascum thapsus*

Constant species: *Ailanthus altissima*, *Berberis lycium*, *Isodon rugosus*, *Lepidium pinnatifidum*, *Rumex hastatus*, *Verbascum thapsus*

Dominant species: None

Mean number of species ( $\pm$ SD):  $13 \pm 3.3$

Human impact: *Rubus* fruits are collected; leaves of *Robinia* fed to animals, underground rhizome of *Berberis lycium* is harvested to use as blood purifier and against throat infection.

(9) Mixed forest of *Quercus floribunda* and *Pinus wallichiana*

Elevation range: (1700) 2200–2400 (2800) m

Bedrock cover: 4.6(–15) %

Trees: *Olea ferruginea*, *Pinus wallichiana*, *Quercus floribunda*, *Quercus oblongata*, 45(–80) %; 15(–32) m

Shrubs: *Berberis lycium*, *Cotoneaster microphyllus*, *Indigofera heterantha*, *Parrotiopsis jacquemontiana*, *Viburnum grandiflorum*, *Viburnum cotinifolium*, *Sarcococca saligna*, 1.1(–2.1) m

Diagnostic species: *Quercus floribunda*, *Pyrus pashia*, *Sarcococca saligna*

Constant species: *Berberis lycium*, *Fragaria bucharica*, *Indigofera heterantha*, *Isodon rugosus*, *Pinus wallichiana*, *Quercus floribunda*

Dominant species: *Pinus wallichiana*, *Quercus floribunda*, *Sarcococca saligna*

Mean number of species ( $\pm$ SD):  $12 \pm 4.1$

Human impact and threat: *Pinus wallichiana* is over-exploited for timber and fuel, its wood is also used for constructing doors and windows. Acorns of *Quercus floribunda* are collected, roasted and eaten as anti-diuretic. Fruits of *Berberis lycium* are harvested

(10) Woodland of *Abies pindrow* and *Indigofera heterantha*

Elevation range: 2100–2800 m

Bedrock cover: 4.5(–25) %

Trees: *Abies pindrow*, *Aesculus indica*, *Pinus wallichiana*, *Prunus cornuta*, 27(–69)%; 22(–42) m

Shrubs: *Indigofera heterantha*, *Myrtus communis*, *Sageretia thea*, *Sorbaria tomentosa*, *Spiraea* sp., *Viburnum grandiflorum* 1.7(–2.8) m

Diagnostic species: None

Constant species: *Abies pindrow*, *Artemisia vulgaris*, *Indigofera heterantha*, *Rumex hastatus*, *Viburnum cotinifolium*

Dominant species: *Abies pindrow*

Mean number of species ( $\pm$ SD):  $12 \pm 2.8$

Human impact and threat: *Berberis lycium* roots, rhizomes and fruits are collected; potentially vulnerable due to over-collection of *Berberis* and logging of *Abies pindrow*

(11) Woodland of *Pinus wallichiana* with *Sorbaria tomentosa* shrubbery

Elevation range: 1900–2400 m

Bedrock cover: 3.6 (–25) %

Trees: *Pinus wallichiana*, *Platanus orientalis*, *Robinia pseudoacacia*; 8.1(–43) %; 6.2(–28) m

Shrubs: *Berberis lycium*, *Indigofera heterantha*, *Sorbaria tomentosa*, 1.9(–3.1) m

Diagnostic species: *Arenaria serpyllifolia*, *Lepidium apetalum*, *Rubus ulmifolius*, *Sorbaria tomentosa*

Constant species: *Clinopodium umbrosum*, *Fragaria bucharica*, *Indigofera heterantha*, *Senecio chrysanthemoides*, *Sorbaria tomentosa*

Dominant species: *Indigofera heterantha*, *Origanum vulgare*

Mean number of species ( $\pm$ SD):  $14 \pm 3.7$

Human impact and threat: Being easily accessible and close to settlements, this plant community is highly degraded and partly substituted by terraced croplands of maize, potato, turnip, pea and others, and fruit trees such as apple, walnut, persimmon and peach. *Pinus wallichiana* woodland is threatened by land use and over-exploitation as the trees are cut both for fuel and timber wood. *Origanum vulgare* is collected as medicinal plant.

(12) Woodland of *Pinus wallichiana* with *Indigofera heterantha* scrub

Elevation range: (1900) 2100–2400 (2900) m

Bedrock cover: 10.5(–65) %

Trees: *Pinus wallichiana*, *Prunus cornuta*, *Rhamnus purpurea*, 38(–80) %; 21.5(–40) m

Shrubs: *Spiraea* (unident.), *Viburnum cotinifolium*, *Zanthoxylum armatum*; 1.6(–2.7) m

Dominant and diagnostic species: *Pinus wallichiana*, *Indigofera heterantha*

Constant species: *Artemisia vulgaris*, *Fragaria bucharica*, *Indigofera heterantha*, *Isodon rugosus*, *Parrotiopsis jacquemontiana*, *Pinus wallichiana*

Mean number of species ( $\pm$ SD):  $14 \pm 3.8$

Human impact and threat: The wood of *Pinus wallichiana*, being durable and moderately hard, is used for construction works. Locals consider it good firewood in spite of its pungent resinous smoke.

The *Pinus* woodland is thus moderately susceptible to logging. Fruits of *Zanthoxylum armatum* are collected and used as condiment.

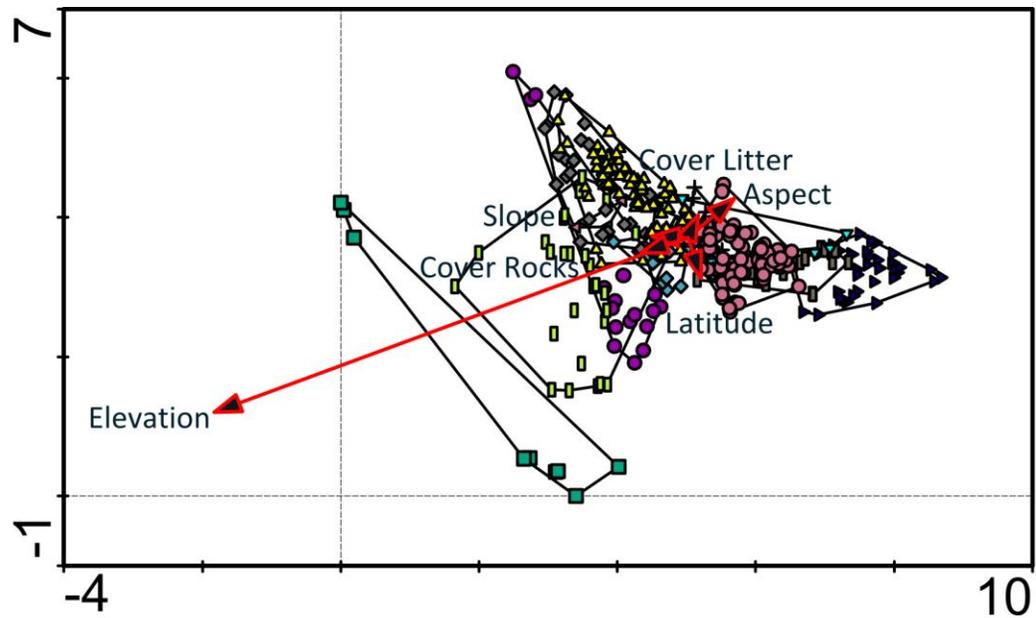
### Gradient analysis and altitudinal zonation

The first two DCA axes accounted for 34% of cumulative percentage variance of species-environment relation (Table 2). Elevation was by far the most important variable explaining the distribution of species in the ordination space (Table 3). Based on Pearson's correlation coefficient relevé scores on axis 1 were negatively correlated to elevation (interset correlation value  $-0.799$ ). From left to right, along the first axis, plant communities are represented from high to low elevation (Figure 3). Also slope (correlation value  $-0.039$ ) decreases along axis 1. Communities such as *Betula utilis* scrub, *Quercus semecarpifolia* and *Picea smithiana* forests tend to occur at steeper slopes. Latitude is positively correlated with axis 2 (correlation value  $0.139$ ) (Table 3).

As revealed by the first ordination axis, aspect plays an important role in woodland communities of *Abies pindrow* and *Pinus wallichiana*.

Table 2. Summary of eigenvalues, gradient length, sum of all unconstrained eigenvalues (total inertia) and cumulative percentage variance explained by the first two DCA axes spanning the ordination space of (A) 12 plant communities and (B) four coniferous (*Picea*, *Abies*) communities

Summary	A	B
Eigenvalue axis 1	0.679	0.571
Eigenvalue axis 2	0.537	0.472
Gradient length axis 1	8.675	5.088
Gradient length axis 2	6.094	5.065
Total inertia	29.744	18.673
Percentage variance explained	34.2	8.9



- |   |  |
|---|--|
| ■ 1. Subalpine humid scrub of <i>Betula utilis</i>                                  | ● 2. Humid laurophyllous forest of <i>Quercus semecarpifolia</i>                   |
| ◄ 3. Subalpine <i>Betula-Viburnum</i> treeline scrub                                | ▤ 4. Alpine turf of <i>Sibbaldia cuneata</i> with <i>Juniperus</i> patches         |
| ◆ 5. Coniferous forest of <i>Abies pindrow</i> and <i>Geranium wallichianum</i>     | ◆ 6. Coniferous forest of <i>Picea smithiana</i>                                   |
| ▲ 7. Woodland of <i>Abies pindrow</i> and <i>Viburnum grandiflorum</i>              | ▶ 8. Subtropical semiarid groves of <i>Ailanthus altissima</i>                     |
| ▤ 9. Mixed forest of <i>Quercus floribunda</i> and <i>Pinus wallichiana</i>         | + 10. Woodland of <i>Abies pindrow</i> and <i>Indigofera heterantha</i>            |
| ▼ 11. Woodland of <i>Pinus wallichiana</i> with <i>Sorbaria tomentosa</i> shrubbery | ● 12. Woodland of <i>Pinus wallichiana</i> with <i>Indigofera heterantha</i> scrub |

Figure 3. Indirect ordination plot (DCA) of 12 plant communities with environmental variables plotted a posteriori. For eigenvalues and gradient length along the first two axes refer to Table 2.

Table 3. Correlations between DCA relevé scores and explanatory variables along the first two ordination axes. Values of Pearson's correlation coefficient (r) and significance probabilities (P) are shown.

Explanatory variables	Axis 1		Axis 2	
	r	P	r	P
Elevation	<b>-0.799</b>	<0.001	-0.022	—
Slope	-0.039	—	0.037	—
Aspect	<b>0.110</b>	0.029	-0.046	—
Litter cover	-0.009	—	0.070	—
Rock cover	-0.068	—	-0.009	—
Latitude	0.040	—	<b>0.139</b>	0.005

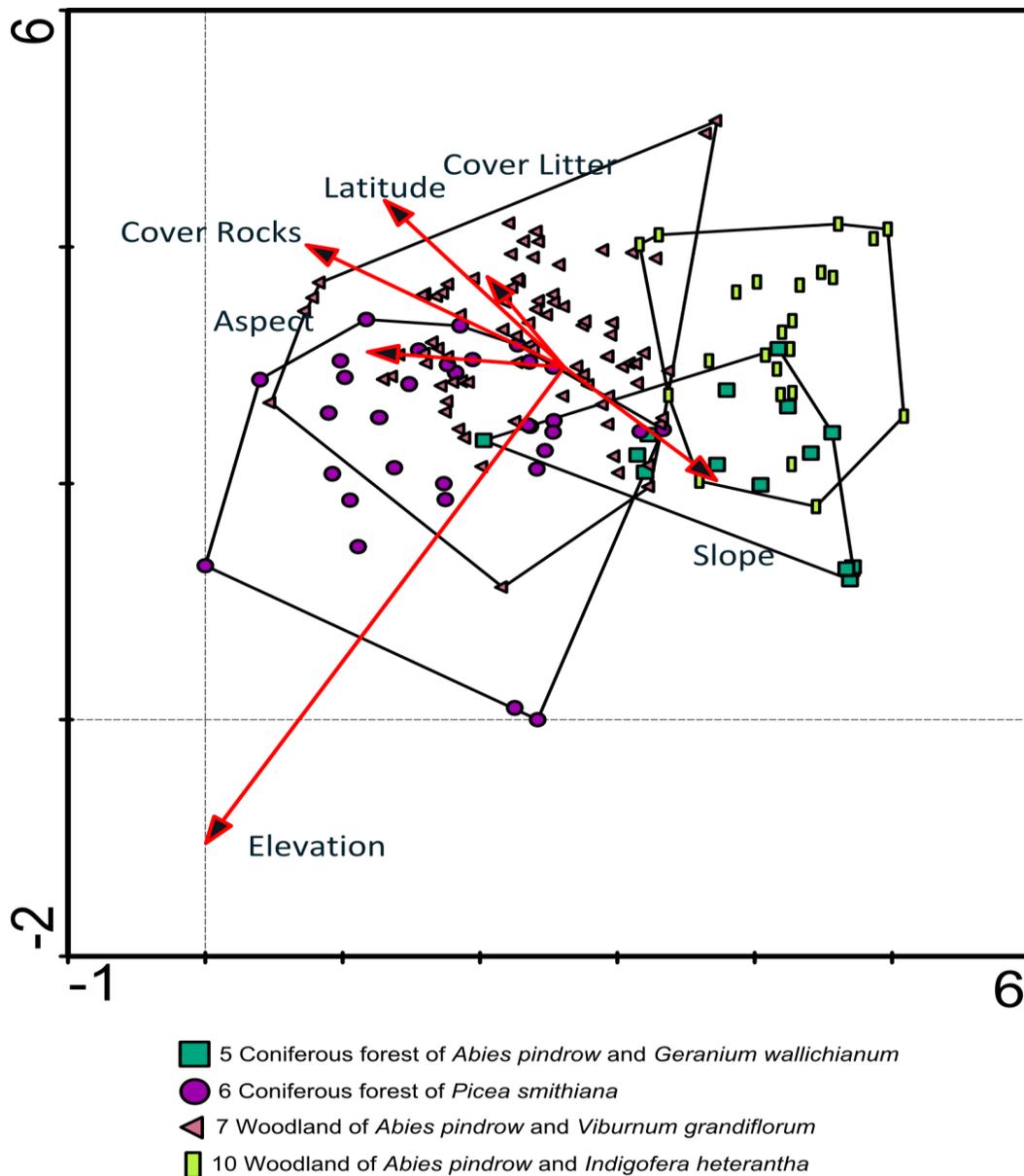


Figure 4. Indirect ordination plot (DCA) of 4 coniferous (*Abies* and *Picea*) plant communities with environmental variables plotted a posteriori. For eigenvalues and gradient length along the first two axes refer to Table 2.

The closed canopy supports forest plants such as *Podophyllum hexandrum*, *Paeonia emodi* and *Euphorbia wallichii* in the understory. Compared to other *Abies* communities the *Abies pindrow*-*Geranium wallichianum* forest occurs as open vegetation on steep slopes (Figure 4). Litter and rock contributed to explain the ecological conditions of *Abies pindrow* and *Viburnum grandiflorum* woodland (Figure 4). *Picea smithiana* forest occurs at high elevation about 2700 m. There were pure

stands of *Picea smithiana* and others mixed with *Abies pindrow*. Woodland of *Abies pindrow* and *Indigofera heterantha* was found at lower elevation.

Correlation analysis of the predictors (elevation, aspect, slope, cover litter, cover rocks and latitude) revealed that elevation is the main determinant of the floristic composition and zonation in the mountains of Miandam (Table 3). Elevation is a proxy of both macro- and meso-climatic differentiation.

Table 4. Elevation belts (named after Schroeder, 1998) in the area of Miandam, North Pakistan, with corresponding vegetation units, their relative cover in the total area and human impact on the vegetation. Vegetation units are numbered as in the text. Overlap in elevation range owing to different aspects.

Vegetation belts with elevation range (m )	Vegetation units	Approximate proportion of the plant community in the study area (%)	Human impact assessment					
			Wood pasture	Mountain pasture	Grass cutting	Medicinal plants collection	Domestic wood exploitation	Commercial wood exploitation
Alpine 3300–3400	4. Alpine turf of <i>Sibbaldia cuneata</i> with <i>Juniperus</i> patches	2-5	-	+++	+	++	-	-
Subalpine 2900–3300	1. Subalpine scrubof <i>Betula utilis</i>	1-2	++	++	-	++	-	+
	3. Subalpine <i>Betula-Viburnum</i> treeline scrub	2-5	+	++	+	+++	-	-
Boreal 2600–3200	2. Laurophyllous <i>Quercus semecarpifolia</i> forest	2-5	++	-	+	+	++	++
	6. Coniferous <i>Picea smithiana</i> forest	5-10	++	-	+	++	++	+++
Upper Nemoral 2100– 2900	7. Woodland of <i>Abies pindrow</i> and <i>Viburnum grandiflorum</i>	30-35	+++	-	+	+++	+++	+++
	10. Woodland of <i>Abies pindrow</i> and <i>Indigofera heterantha</i>	10-15	+	-	+	+++	++	+++
	9. Mixed forest of <i>Quercus floribunda</i> and <i>Pinus wallichiana</i>	5-10	+	-	+	++	++	++
Lower Nemoral 1900–2400	5. Coniferous forest of <i>Abies pindrow</i> and <i>Geranium wallichianum</i>	2-5	++	-	+	++	++	+++
	11. Woodlandof <i>Pinus wallichiana</i> and <i>Sorbaria tomentosa</i> shrubbery	2-5	+	-	+	++	+++	+
	12. Woodlandof <i>Pinus wallichiana</i> and <i>Indigofera heterantha</i> scrub	15-20	++	-	+	++	+++	++
Meridional 1600–1800	8. Sub-tropical grovesof <i>Ailanthus altissima</i>	1-2	+++	-	++	++	++	+

+++Severe, ++Moderate, +Low, -no impact

The observed plant communities formed six major vegetation belts (Table 4), viz. Meridional (community 8), Lower Nemoral (11, 12), Upper Nemoral (5, 7, 9, 10), Boreal (2, 6), Subalpine (1, 3) and Alpine (4). The timberline at about 3300-3400 m separates alpine pastures largely covered with *Sibbaldia cuneata* and grasses (*Poa* spp.) from subalpine krummholz with *Betula utilis*. In the boreal zone forests of *Quercus semecarpifolia* with *Picea smithiana* or *Abies pindrow* with *Picea smithiana* occur. *Quercus floribunda* and *Pinus wallichiana* were representatives of mixed forest in the upper nemoral zone. In the lower nemoral zone *Prunus cornuta*, *Rhamnus purpurea*, *Pinus wallichiana* and *Robinia pseudoacacia* were distinct trees. At lower elevations, 1600–1800 m, *Ailanthus altissima*, *Ficus palmata*, *Morus alba*, *Melia azedarach*, *Olea ferruginea* and *Robinia pseudoacacia* were prominent trees of the meridional zone. Non-native trees such as *Robinia pseudoacacia* and *Ailanthus altissima* are restricted to the lower zones where human influence is more profound. In a similar elevational sequence, shrub layers may be used to identify the subalpine belt (*Salix* spec.), and the boreal (*Viburnum grandiflorum*, *Lonicera griffithii*, *Parrotiopsis jacquemontiana*), upper nemoral (*Indigofera heterantha*, *Berberis lycium*, *Cotoneaster microphyllus*, *Sarcococca saligna*), lower nemoral (*Sageretia thea*, *Indigofera heterantha*, *Vitex negundo*, *Sorbaria tomentosa*, *Rubus ellipticus*), and meridional belts (*Isodon rugosus*).

## Discussion

### Comparison with other studies in wider surroundings

In comparison with other studies in the wider surroundings of Hindukush-Himalaya we found that there are similarities and differences regarding the zonation. In the alpine belt species of mesic grasslands (*Sibbaldia cuneata*, *Danthonia cachemyriana*, *Phleum alpinum*, *Agrostis pilosula*) (Rana *et al.* 2011), trampled places (*Cenchrus setigerus*, *Poa annua*, *Eragrostis poaeoides*) (Kala and Mathur, 2002; Sher *et al.* 2013) and moist sites (*Rheum australe*, *Iris hookeriana*, *Carex nivalis*, *Carex nubigena*, *Carex setigera* and *Bistorta affinis*) (Khan *et al.* 2011; Rana *et al.* 2011) have been recorded. Of these, only *Sibbaldia cuneata* and *Poa* spec. were common in the alpine vegetation of Miandam. *Betula utilis* krummholz seems to be rather unique in our study area as there is no report by other authors except Khan *et al.* (2011). Species of *Rhododendron* (*anthopogon*, *campanulatum*, *lepidotum*), *Carex* (*setigera*, *nivalis*), *Agrostis pilosula*, *Salix* (*lindleyana*, *denticulata*), *Persicaria*

*polystachya*, *Lonicera obovata*, *Berberis (jaeskeana, callibotrys)* reported by Rana *et al.* (2011) have not been recorded from the subalpine belt in the Miandam area.

Table 5. Comparison of the vegetation units described in the present article with those described in other studies of the Hindukush-Himalaya region in the wider surroundings of our study area.

	<b>Present study</b>	<b>Bokhari et al. 2013</b>	<b>Amjad et al. 2013</b>	<b>Sher et al. 2013</b>	<b>Ilyas et al. 2012</b>	<b>Shaheen et al. 2012</b>	<b>Khan et al. 2011</b>	<b>Rana et al. 2011</b>	<b>Ahmed et al. 2010</b>	<b>Saima et al. 2009</b>	<b>Kala and Mathur, 2002</b>
<b>Localities</b>	Miandam, Swat	Azad Kashmir	Nikyayal, Kotli	Sudan galli, Bagh	Qalagai, Swat	Bagh, Azad Kashmir	Naran, Mansehra	Manali, Kullu, India	Swat, Dir, Chitral	Ayubia, Abbotabad	Ladakh, India
<b>Elevation range (m a.s.l.)</b>	1600–3400	799–2900	1535–1860	2200–2500	1450–2892	1400–2800	2450–4100	3540–4485	1600–2927	Above 2244	3000–5500
<b>Alpine</b>	4			13			4,5	5-8			2
<b>Subalpine</b>	1,3						3	1-4			6
<b>Boreal</b>	2,6	4,5,6		11	6-8	1,3-8,10	2		3-6	1,4	5
<b>Upper Nemoral</b>	7,10, 9,5	2,3,7,8	12,13	5,7-10,12	5	2,9,11,12	1		1,2,7,8	3	1,3,4
<b>Lower Nemoral</b>	11,12	1	5-11	1-4,6	3,4					5,2	
<b>Meridional</b>	8	9	1-4	1,2							

**Present study:** 1. Sub alpine scrub of *Betula utilis*; 2. Laurophyllous forest of *Quercus semecarpifolia*; 3. Subalpine *Betula-Viburnum* treeline scrub; 4. Alpine turf of *Sibbaldia cuneata* with *Juniperus* patches; 5. Coniferous forest of *Abies pindrow* and *Geranium wallichianum*; 6. Coniferous *Picea smithiana* forest; 7. Woodland of *Abies pindrow* and *Viburnum grandiflorum*; 8. Sub-tropical groves of *Ailanthus altissima*; 9. Mixed forest of *Quercus floribunda* and *Pinus wallichiana*; 10. Woodland of *Abies pindrow* and *Indigofera heterantha*; 11. Woodland of *Pinus wallichiana* and *Sorbaria tomentosa* shrubbery; 12. Woodland of *Pinus wallichiana* with *Indigofera heterantha* scrub.

**Bokhari et al. 2013:** 1. *Pinus roxburghii*–*Pinus wallichiana*; 2. *Cedrus deodara*–*Pinus wallichiana*; 3. *Abies pindrow*–*Aesculus indica*; 4. *Picea smithiana*–*Abies pindrow*; 5. *Picea smithiana*–*Taxus fuana*; 6. *Pinus wallichiana*–*Picea smithiana*; 7. *Abies pindrow*–*Pinus wallichiana*; 8. *Pinus wallichiana* monospecific stand; 9. *Pinus roxburghii* monospecific stand

**Amjad et al. 2013:**1. *Myrsine–Pinus–Rhus*; 2. *Olea–Punica–Berberis*; 3. *Olea–Themeda–Pinus*; 4. *Myrsine–Rhus–Pinus*; 5. *Quercus*; 6. *Rubus–Quercus–Oxalis*; 7. *Olea–Themeda–Pinus*; 8. *Myrsine*; 9. *Quercus–Oxalis–Justicia*; 10. *Quercus–Myrsine–Berberis*; 11. *Quercus–Rabdosia–Themeda*; 12. *Pinus–Quercus–Indigofera*; 13. *Pinus–Quercus–Oxalis*

**Sher et al. 2013:**1. *Pinus–Berberis–Carex*; 2. *Pinus–Sarcococca–Hedera*; 3. *Pinus–Sarcococca–Carex*; 4. *Pinus–Viburnum–Poa*; 5. *Pinus–Sarcococca–Carex*; 6. *Abies–Sarcococca–Fragaria*; 7. *Abies–Sarcococca–Anogromma*; 8. *Abies–Sarcococca–Urochloa*; 9. *Abies–Viburnum–Fragaria*; 10. *Abies–Viburnum–Galium*; 11. *Abies–Viburnum–Viola*; 12. *Abies–Pinus–Carex*; 13. *Cenchrus–Poa–Eragrostis*

**Ilyas et al. 2012:**1. *Populus–Debregeasia–Nasturtium*; 2. *Olea–Plectranthus–Micromeria*; 3. *Pinus roxburghii–Plectranthus–Rumex*; 4. *Quercus–Indigofera–Amaranthus*; 5. *Pinus wallichiana–Indigofera–Galium*; 6. *Cedrus–Indigofera–Thymus*; 7. *Cedrus–Viburnum–Pteridium*; 8. *Pinus wallichiana–Viburnum–Leucas*

**Shaheen et al. 2012:**1. *Abies pindrow–Poa alpine*; 2. *A. pindrow–Viburnum grandiflorum*; 3. *Pinus wallichiana–Poa pratensis*; 4. *Pinus wallichiana–Poa alpine*; 5. *P. wallichiana–Poa pratensis*; 6. *P. wallichiana–Poa pratensis*; 7. *A. pindrow–P. wallichiana*; 8. *A. pindrow–Poa alpina*; 9. *A. pindrow–V. grandiflorum*; 10. *A. pindrow–Poa alpina*; 11. *A. pindrow–V. grandiflorum*; 12. *A. pindrow–V. grandiflorum*

**Khan et al. 2011:** 1. *Pinus wallichiana–Sambucus weightiana*; 2. *Abies pindrow–Betula utilis*; 3. *Juniperus excelsa–Artemisia brevifolia*; 4. *Rheum australe–Sibbaldia cuneata*; 5. *Aster falconeri–Iris hookeriana*

**Rana et al. 2011:**1. *Rhododendron anthopogon, R. campanulatum, Carex setigera, Agrostis pilosula*; 2. *Salix lindleyana, Carex nivalis, C. setigera, Sibbaldia cuneata*; 3. *Rhododendron campanulatum, R. anthopogon, Persicaria polystachya*; 4. *Lonicera obovata, Berberis jaeschkeana, Rhododendron lepidotum, Salix denticulata, Carex nivalis*; 5. *Carex nivalis, Agrostis munroana, Danthonia cachemyriana, Phleum alpinum*; 6. *Carex nubigena, Agrostis pilosula, Carex setigera, C. nivalis, Bistorta affinis*; 7. *Poa alpina, Carex setigera, C. nubigena, Trachydium roylei*; 8. *C. nubigena, Phleum alpinum, Iris hookeriana, Sibbaldia cuneata*

**Ahmed et al. 2010:**1. *Deodar–Juglans*; 2. *Deodar–Quercus*; 3. *Deodar–Taxus*; 4. *Deodar–Picea*; 5. *Deodar–Abies*; 6. *Deodar–Pinus gerardiana*; 7. *Deodar–Pinus wallichiana*; 8. monospecific *Deodar* forests

**Saima et al. 2009:**1. *Pinus wallichiana–Fragaria indica*; 2. *Fragaria indica–Galium aparine*; 3. *Adiantum venustum–Asplenium trichomanes*; 4. *Pinus wallichiana* association; 5. *Plectranthus rugosus–Indigofera gerardiana*

**Kala & Mathur, 2002:** 1. *Ephedra–Artemisia*; 2. *Poa annua–Ranunculus hirtellus–Pedicularis oederi*; 3. *Caragana brevifolia–Cotoneaster*; 4. *Hippophae rhamnoides–Myricaria germanica*; 5. *Artemisia–Salsola collina–Krascheninnikovia ceratoides*; 6. *Agropyron–Trisetum–Oryzopsis–Carex*

In the boreal zone we found *Picea smithiana* mixed forest, similar only to Bokhari *et al.* (2013) and Ahmed *et al.* (2010) but in these studies co-occurring with *Cedrus* (Table 5). Ilyas *et al.* (2012) reported two communities dominated by *Cedrus deodara* from the Qalagai area of Swat. *Cedrus deodara* is absent as a native tree in our study area while Bokhari *et al.* (2013) reported a *Cedrus deodara–Pinus wallichiana* community distributed between 1852 and 2134 m at Sharda and Keran, Azad Kashmir. Ahmed *et al.* (2010) reported that Deodar cedars grow in moist to dry temperate mountain woodlands in northern Pakistan from 1650 m (Kaghan) to 2900 m (Chitral). Similar to our findings, Shaheen *et al.* (2012) reported that in Kashmir *Abies pindrow* and *Pinus wallichiana* dominate moist temperate forests showing exclusive dominance. In the upper nemoral zone *Pinus wallichiana* is a common forest species reported in almost all studies. Khan *et al.* (2011) found *Pinus wallichiana*, *Aesculus indica*, *Prunus cerasoides*, *Indigofera heterantha*, *Viburnum grandiflorum*, *Viburnum cotinifolium*, *Paeonia emodi*, *Bistorta amplexicaulis* and *Trifolium repens* in woodlands of the Naran Valley, Mansehra. Along an 18 km transect in the Ayubia National Park, district of Abbottabad, Saima *et al.* (2009) described five plant associations of which the *Pinus wallichiana* association with *Abies pindrow* and *Taxus wallichiana* corresponds to our *Pinus–Abies* woodlands. In the lower nemoral zone *Quercus oblongata* has been reported by Ilyas *et al.* (2012) and Sher *et al.* (2013) at the same elevation as in our study area. The meridional zone in our study area and that of Amjad *et al.* (2013) are similar in the common occurrence and dominance of species such as *Pinus roxburghii*, *Olea ferruginea*, *Indigofera heterantha*, *Quercus floribunda*, *Berberis lycium* and *Themeda anathera*. Other prominent species of the meridional zone of Miandam, *Ailanthus altissima* and *Isodon rugosus*, are not mentioned by Amjad *et al.* (2013). In the upper nemoral zone we found a floristic similarity of 23 % of 109 species recorded in our study (with frequency 20 % and more in our case) with the study of Amjad *et al.* (2013).

#### **Human impact**

Although we did not gather plotwise data on this, we observed extensive clear-cutting of trees and reduced naturalness of the forests. More specifically, we inferred decreasing total area of the

following communities: Coniferous forest of *Abies pindrow* and *Geranium wallichianum*, woodland of *Abies pindrow* and *Viburnum grandiflorum*, subtropical groves of *Ailanthus altissima* and woodland of *Pinus wallichiana* with *Sorbaria tomentosa* shrubbery. Interestingly, privately owned



Figure 5. (a) Scants transportation (b) dumped for supply to local market (c) or left in the gorges (d) or later used as fuel wood when spoiled. Also a herder can be seen with goats and sheep (e) Fuel wood collection by children (f) Cattle and goat grazing and browsing.

forests seem to be better protected and more intact than forests under national protection. Exceptional firs (*Abies pindrow*) on private land such as at Shahidano sar were found to measure more than 10 m stem circumference.

Natural succession is commonly inhibited as juvenile trees and saplings are cut, with the intention of enhancing grass growth for cattle. At lower levels, terrace cultivation is increasing. Locals being inquired regarding their preferences about reforestation or agriculture, by majority preferred cultivating various economic crops to sustain family incomes. *Ailanthus altissima* groves are under the pressure of expanding settlements. The climatically favoured Miandam area attracts people from outside as summer resort, to acquire land and build houses. Illegal clear-cutting, often at night, is chiefly accountable to local businessmen employing laborers. The timber is harvested by local made axe and sometimes diesel chain saws, the logs cut up by two persons with peg-toothed saw, and later transported to the local market (Figure 5). Forest abuse concerns chiefly *Abies pindrow* and *Pinus wallichiana* woodlands and specifically the ecosystems of *Pinus wallichiana* with *Indigofera heterantha*, *Abies pindrow* and *Indigofera heterantha*, and *Abies pindrow* and *Viburnum grandiflorum*. Apart from visual evidence, overexploitation of timber was confirmed by celebrities and local informants. In the upper nemoral zone the *Abies pindrow*-*Viburnum grandiflorum* woodland ecosystems are further threatened by overcollection of the medicinal plants *Paeonia emodi* and *Podophyllum hexandrum*. Medicinal plant trade is in very few hands with access to local and national markets. Forest communities near to settlements are endangered due to logging. Trees are completely girdled to dry and then used as fuel wood and for other domestic purposes. Alpine grasslands in the study area are locally degraded due to overgrazing by livestock of both nomadic and sedentary herding.

*Aconitum heterophyllum*, *Origanum vulgare* and *Oxyria digyna* are important medicinal plants of the subalpine *Betula*-*Viburnum* scrub. *Primula denticulata* is one of the sought after medicinal species in the boreal zone (Akhtar *et al.* 2013; Singh *et al.* 2014). Fuel wood harvesting further aggravates the problem of environmental degradation because of selective wood harvesting and also harvesting for sale. Local communities and forest departments, but also every single person is challenged in a participatory manner to work for the protection of the natural environment. Timber mafia should be discouraged and illegal logging cartels must be identified and punished as per forest laws. In spite of possible legislative deficiencies implementation of existing laws will serve to protect the forest from further deterioration.

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## **Conflict of interest**

The authors do not have any conflict of interest with people or any organization.

## **Authors agreement**

The authors have read the article and agree with the contents of the article

## **References**

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## CHAPTER 4

# SPECIES RICHNESS, ALPHA AND BETA DIVERSITY OF TREES, SHRUBS AND HERBACEOUS PLANTS IN THE WOODLANDS OF SWAT, PAKISTAN

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## **Abstract**

We explored the variation in species richness and diversity of trees, shrubs and herbs in the mountains of Miandam, Swat, North Pakistan, along an elevation gradient between 1600 m and 3400 m. Field data were collected in 18 altitudinal intervals of 100 m each. Polynomial regression was used to find relations of the different growth forms with elevation. The Shannon index was used for calculating  $\alpha$ -diversity and the Simpson index for  $\beta$ -diversity. Species richness and  $\alpha$ -diversity of herbs were unrelated to elevation. Herbaceous species turnover was high, ranging between 0.46 and 0.89, with its maximum between 2700 and 3000 m. Hump-shaped relationship was observed for shrubs with maximum richness between 2000 and 2200 m; and  $\alpha$ -diversity decreased monotonically. Turnover of shrub species was highest between 2000 and 2500 m. Tree species richness was highest at low elevations, and  $\alpha$ -diversity was relatively low along the entire gradient. Tree species turnover was also high in the lower zone and again at 2600-2800 m. Species richness of all vascular plants was highest at 2200-2500 m, and  $\alpha$ -diversity was highest in the lower part of the gradient. Beta diversity of all growth forms was quite high ranging between 0.53 and 0.87 along the entire gradient reflecting high species and structural turnover.

**Key words:** elevation gradient, Himalayas, mountain woodlands, plant diversity, Shannon index, Simpson beta diversity, vegetation zonation

## Introduction

Variation in species richness along elevation has been observed for over a century (Wallace, 1878; Pianka, 1966; Lomolino, 2001; Sanders and Rahbek, 2012). Rahbek (1995; 2005), in his reviews of scale and species richness, found that most studies showed mid-elevation peaks along elevation gradients. He identified three main patterns of richness: (1) monotonic decrease with increasing altitude, (2) a plateau at low altitudes and (3) hump-shaped distribution with high richness at intermediate altitudes. Similarly, according to (McCain, 2009) elevational patterns in species richness fall into four common patterns (1) decreasing, (2) low plateau, (3) low plateau with mid-elevational peak and (4) mid-elevation peak. Evidently, the pattern of species richness along elevation differs in different regions, with monotonic decrease (Austrheim, 2002; Ohlemüller and Wilson, 2000; Panayiotis *et al.*, 2013), hump-shaped relationship (Lomolino, 2001; Acharya *et al.*, 2011; Bhattarai and Vetaas, 2006), or both patterns in the same region (Grytnes, 2003). In some studies even bimodality has been reported (Xu *et al.*, 2011). Wang *et al.* (2007) found that richness and density (richness/log-transformed area) of seed plants at species, genus, and family levels all showed hump-shaped patterns along the altitudinal gradient. Bhattarai and Vetaas (2003) found that shrubs, trees and total species (sum of all life forms) showed unimodal responses, ferns decreased monotonically and woody climbers increased monotonically. Richness of all woody groups increased monotonically with increasing mean annual rainfall and humidity. Some researchers, like Grytnes and Beaman (2006) and Kessler (2000), established that elevational patterns in species richness depend on the group studied and on the region, e.g. ferns in Mexico (Tyron, 1989), Bolivia (Kessler, 2000) and Malaysia (Parris *et al.*, 1992). Ren *et al.* (2006) found that total vascular plant species richness did not exhibit a linear altitudinal pattern, albeit species groups with different ecological features showed strong elevational patterns. Individual growth forms vary in response to elevation, e.g. herbs in New Zealand (Ohlemüller and Wilson, 2000), trees and shrubs in South Africa (O' Brien, 1993) and climbers in Mexico (Vazquez and Givnish, 1998).

The South Asian mountain ranges (Himalayas, Hindukush, Karakorum), with the highest peaks in the world, comprise a very wide range of ecoclimate zones (Dobremez and Jest, 1976). These mountains are therefore an excellent system for evaluating ecological and biogeographical patterns and theories of species richness (Körner, 2000). Some authors (Khan *et al.*, 2010; Khan *et al.*, 2011; Saqib *et al.*,

2011; Shaheen and Shinwari, 2012) provided studies related to species diversity, community structure and distribution patterns of plant species in the Hindukush-Himalaya region in Northern Pakistan. Our study is the first for any area in northern Pakistan with statistical determination of species richness and diversity of different growth forms along elevation. We focused on two questions: (I) Do species richness and diversity vary along elevation and among different growth forms? (II) Is variation along the elevational gradient monotonic, unimodal or otherwise?

## **Materials and Methods**

### **Study area**

The study was carried out in the area of Miandam, district of Swat, North Pakistan (35°1-5' N, 72°30-37' E; Figure 1). The mountainous area, about 50 km NNE of the district capital, Saidu Sharif, is part of an offshoot of the Himalaya range ascending to 3500 m. According to Zahid and Rasul (2011) and based on Thornthwaite's index of thermal efficiency (ratio of temperature to evapotranspiration), the research area falls in the "mild microthermal" zone. March, July and August are months with heavy rainfall (New *et al.*, 2002). December and January are the coldest months with temperatures down to a mean minimum of -10°C in the higher reaches of the nemoral forest areas (Saeeda, 2005). On the valley sides at 1600-1800 m the area is dominated by sparse shrubby vegetation of *Berberis lycium*, *Isodon rugosus* and *Sorbaria tomentosa*. In the boreal belt as defined by Schroeder (1998) *Picea smithiana* is the dominant tree and *Taxus wallichiana* associated. The upper and lower nemoral belts are characterized by *Abies pindrow* and *Pinus wallichiana* forests, respectively. *Indigofera heterantha* and *Viburnum grandiflorum* are common understory shrubs of *Pinus* and *Abies* woodlands. In the subalpine belt *Betula utilis* and *Salix* spp. dominate; in the alpine zone *Sibbaldia cuneata* is common.

### **Field sampling**

Field work was carried out in the summer months of 2010 through 2012. The elevation gradient between 1600 and 3400 m was divided into 100 m intervals. Four hundred vegetation quadrats of 10 × 10 m were placed along the gradient in stratified wooded and sparsely wooded areas covering all intervals and the entire vegetation zonation. Elevation was measured using GPS device. Plant samples were collected of almost all vascular plant species and identified using (Ali and Qaisar, 2001; Breckle *et al.*, 2010; Urrahman, 2012). Herbarium collections of the Botanische Staatssammlung (M), München, Germany, were compared for confirmation.

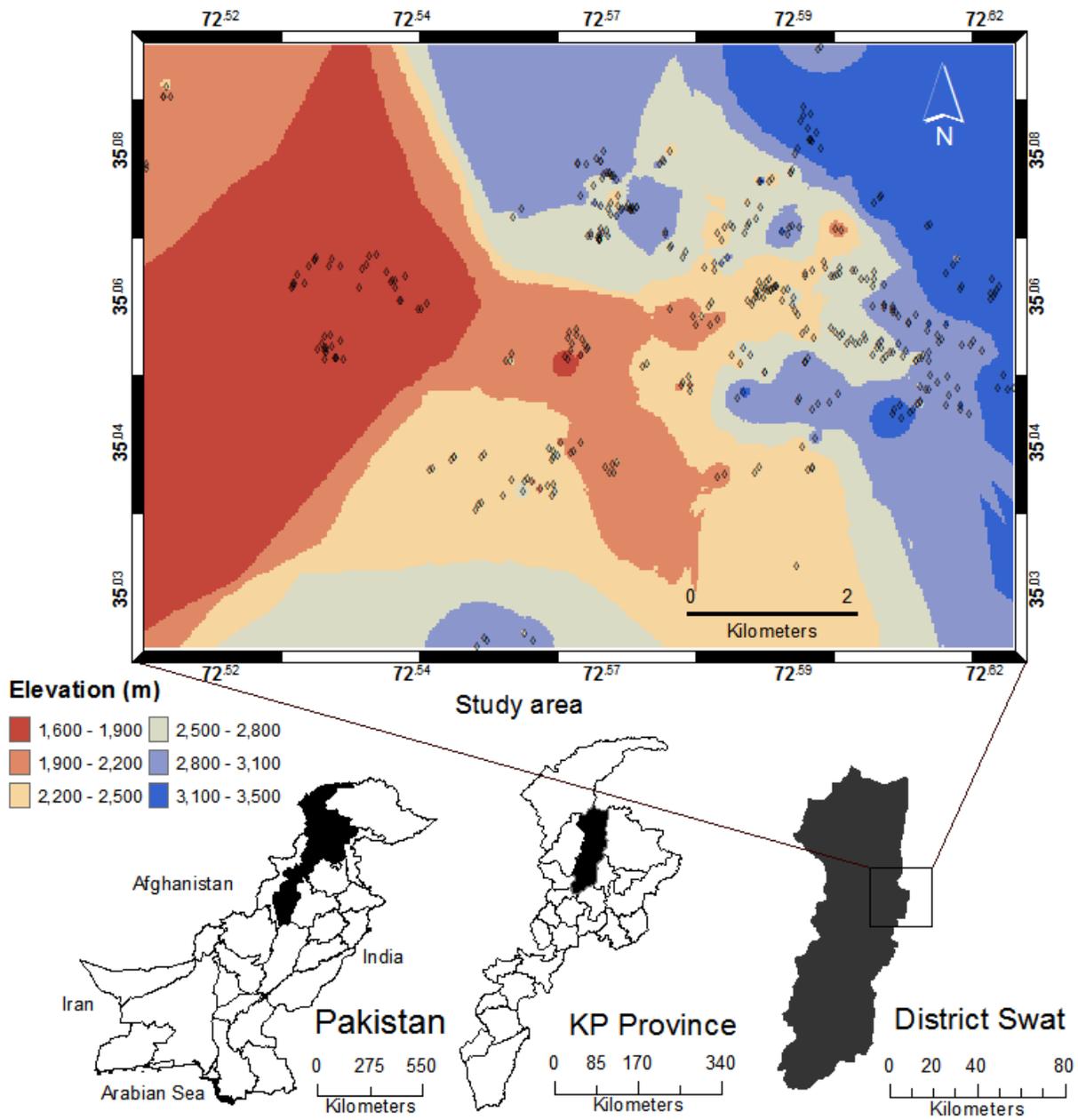


Figure 1. Georeferenced map showing the sampling sites (rhombi) and topography of the study area in the district of Swat, Khyber Pakhtunkhwa (KP) Province, Northern Pakistan.

## Data analysis

In our analyses, we distinguished the growth forms herb, shrub and tree. Three indices were chosen to estimate richness and diversity: (1) species richness, i.e., the total number of plant species recorded in each 100 m elevation interval (Bhattarai *et al.*, 2004; Grau *et al.*, 2007; Vetaas and Grytnes, 2002). (2) Shannon (“Shannon-Wiener”) index of diversity ( $H' = -\sum_{i=1}^S p_i \ln p_i$ ) where  $S$  is the total number of species at the elevation and  $p_i$  is the proportion of all the individuals in the quadrat. Instead of counting the individual plants species, cover relative to the total cover was calculated (Fosaa, 2004). Values of Shannon index were exponentiated as suggested by (Jost, 2006). (3) Simpson beta diversity index ( $\beta_{\text{simp}} = 1 - \frac{\alpha}{\min(b,c)+\alpha}$ ) (Koleff *et al.*, 2003), where  $\alpha$  is the number of shared species between two quadrats while  $b$  and  $c$  are numbers of species unique to either quadrat. In our case  $\beta_{\text{simp}}$  is pairwise comparison among quadrats based on presence and absence of species. Here  $\min(b, c)$  is the minimum number of unique species of either  $b$  or  $c$ . As the sample plots were unequally distributed in the study area we calculated the three indices based on seven quadrats per 100 m interval (seven quadrats being the minimum number sampled in any interval). We randomized our samples five times in each elevation interval where more than seven quadrats were sampled. After randomization mean values were taken for further analyses. To find patterns of diversity, species richness, Shannon and Simpson beta diversity indices were regressed against elevation. Diversity indices were computed in JUICE 7.0 (Tichý, 2002) and polynomial regression in R 2.15.3 (R Core Team, 2014). Akaike’s information criterion (AIC) was used for model selection, with the minimum AIC as the best-fit estimator.

## Results

### Species richness in relation to elevation

We recorded a total of 411 species in the samples. Most of the species were herbaceous (77 %), trees account for 8 %, shrubs constitute 12 %, and woody climbers 3 % of the total number of species.

The variation in species richness of the three growth forms and total species richness is shown in Figure 2. The polynomial regression models did not predict a significant relationship between herb richness and elevation. A hump-shaped relationship was found between shrub richness and elevation with maximum richness between 2000 and 2200 m. Minimum shrub richness was observed between 3000 and 3200 m. Tree species richness initially decreased until 2200 m, then increased and from

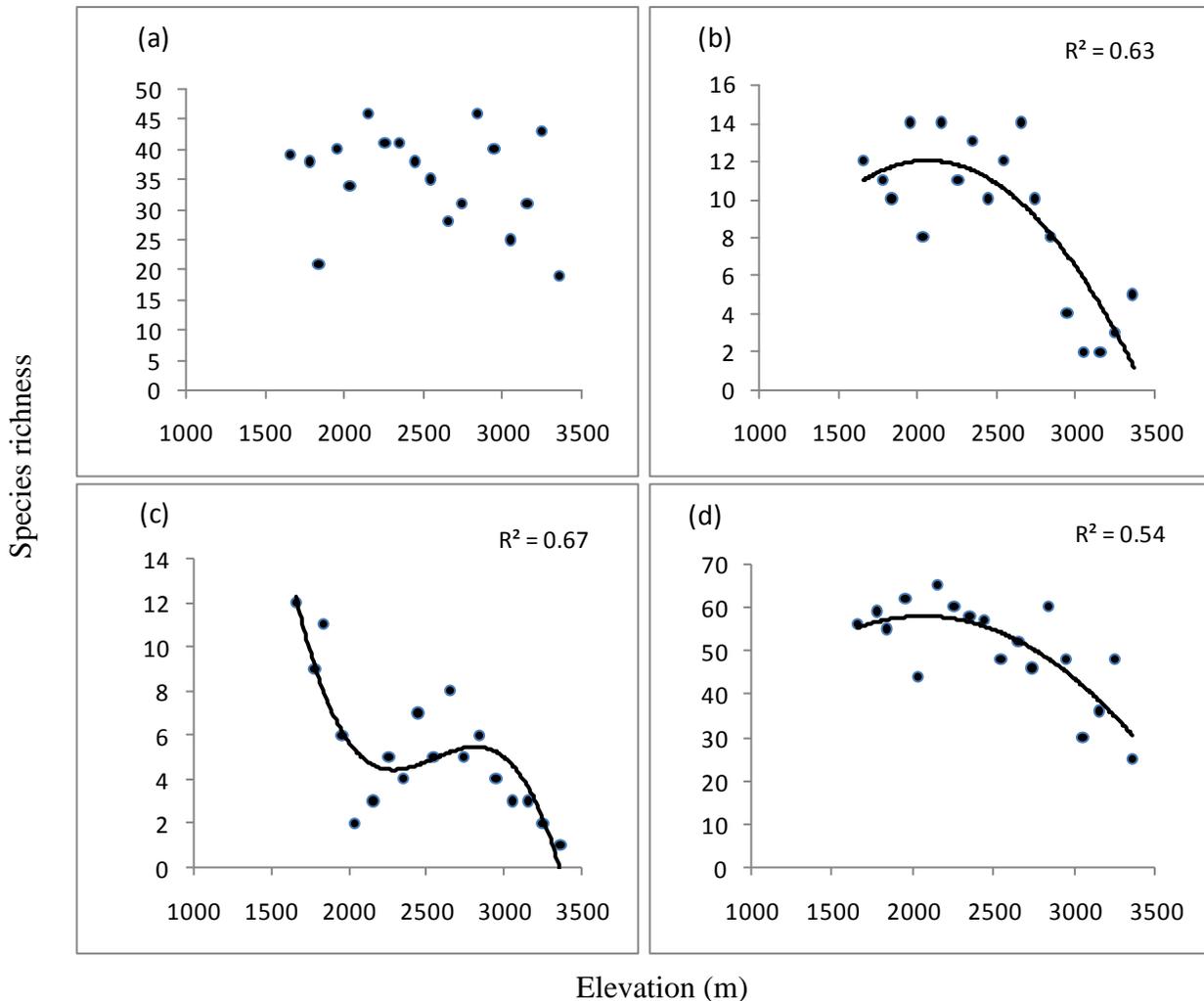


Figure 2. Relationship between species richness and elevation for (a) herbs, (b) shrubs, (c) trees, and (d) total vascular plants.  $R^2$  value is adjusted. While herb richness along elevation was statistically insignificant, quadratic, cubic and quadratic regressions based on significant F and AIC values were significant for richness of shrubs, trees and total vascular plants, respectively.

2800 m onward decreased again. Total species richness followed a unimodal pattern along the elevation gradient; quadratic regression showed a significant fit to the trend of variation.

$$\exp\left(H' = -\sum_{i=1}^s p_i \ln p_i\right)$$

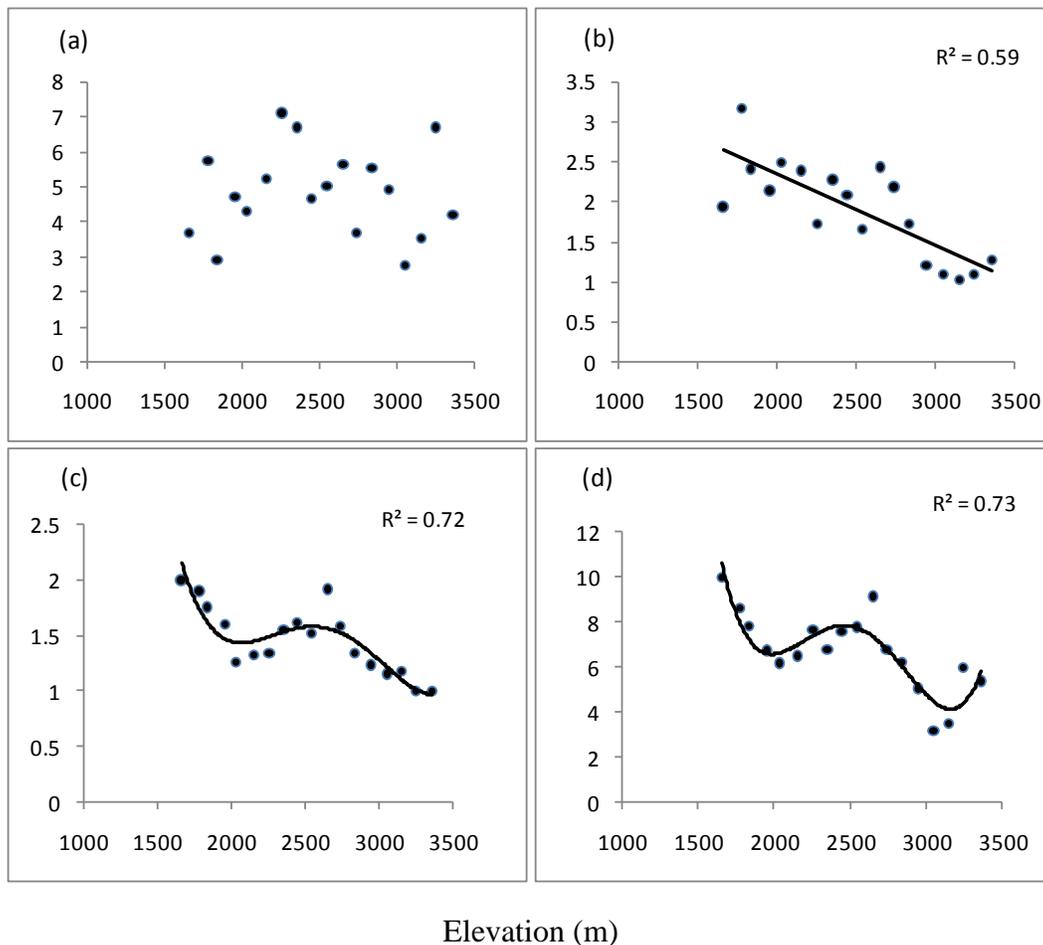


Figure 3. Relationship between exponentiated Shannon diversity with elevation for (a) herbs, (b) shrubs, (c) trees, and (d) total vascular plants.  $R^2$  value is adjusted. Based on significant F and AIC values linear, cubic and quartic regressions were significant for alpha diversity of shrubs, trees and all vascular plants, respectively. For herbs Shannon diversity was insignificant.

#### Alpha diversity in relation to elevation

Shannon diversity for herbs was insignificant to elevation. All polynomial models up to 4th order failed to predict any significant relationship of herb diversity with elevation (Figure 3). For shrubs the Shannon diversity decreased monotonically. The lowest Shannon diversity of 1.02 for shrubs was observed at about 3150 m and the highest Shannon diversity of 3.15 was observed at low elevations of about 1800 m. Shannon diversity for trees was also low along the gradient studied. Alpha diversity for vascular plants as a whole was highest at low (1600 m) and medium (2700 m) altitudes and lowest in the uppermost forest zone (3100 m).

**Beta diversity in relation to elevation**

Between 1600 and 2000 m there was gradual decrease in  $\beta$ -diversity of herbs. Then a sudden decrease beyond 2900 m was observed (Figure 4). Shrubby species turnover fluctuated along the gradient. First it decreased between 1600 and 2000 m, then increased up to 2500 m, then gradually decreased up to 3100 m, and in the subalpine zone once again increased. Tree species turnover was

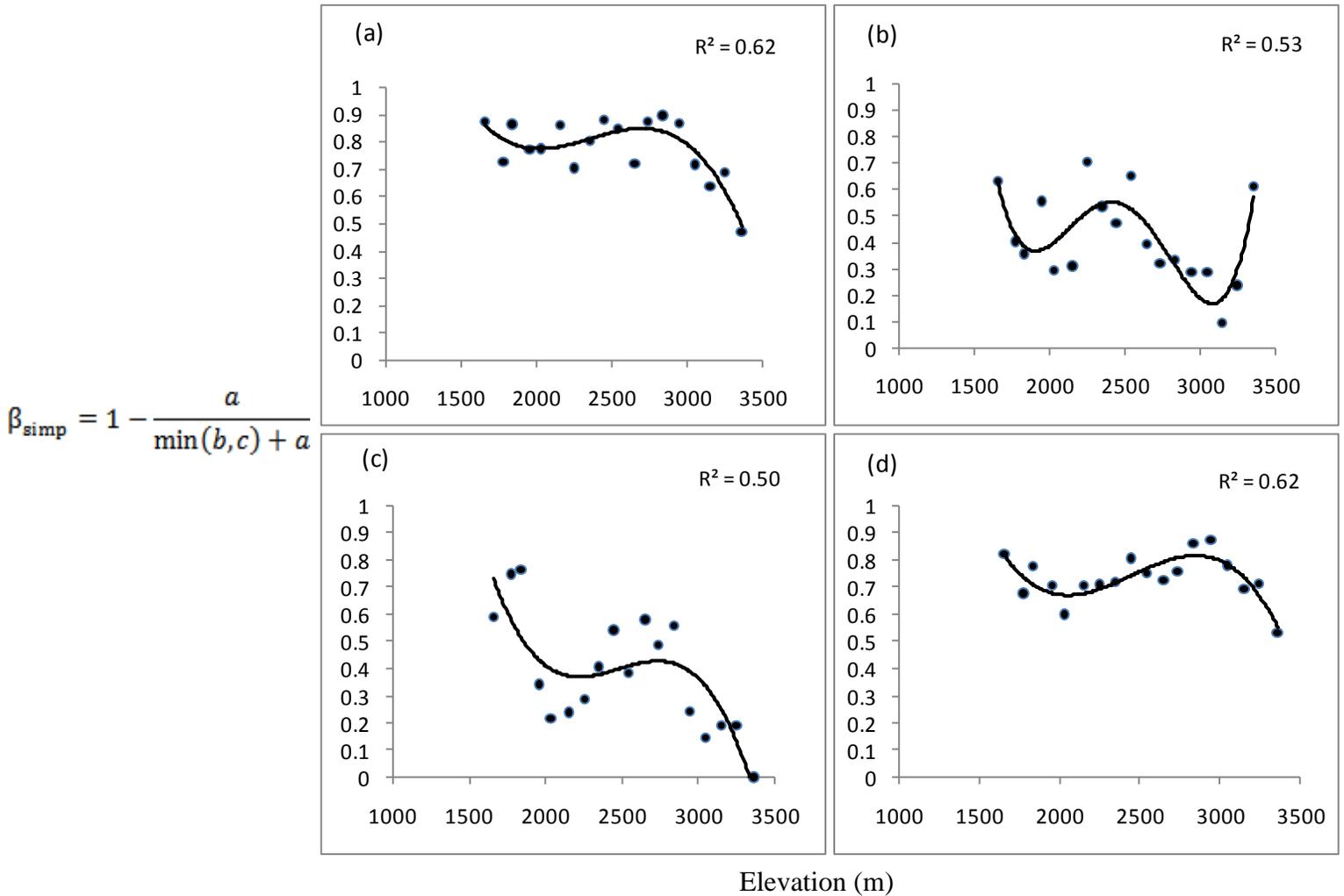


Figure 4. Relationship between  $\beta$ -diversity with elevation for (a) herbs, (b) shrubs, (c) trees, and (d) total vascular plants.  $R^2$  value is adjusted. Based on significant F and AIC values cubic, quartic, cubic and cubic regressions were significant for beta diversity of herbs, shrubs, trees and all vascular plants, respectively.

high at low elevations, then decreased as the elevation increased, remaining fairly constant along the forest zones until a further decrease at and above 3000 m. Species turnover for vascular plants *in toto* ranged between 0.53 and 0.87 showing overall high  $\beta$ -diversity.

## **Discussion**

### **Variation in species richness**

Similar to (Bhattarai and Vetaas, 2003) the relationship between herb richness and elevation was statistically insignificant but for shrubs, trees, and vascular plants as a whole richness was significant. In a study from New Zealand, Ohlemüller and Wilson (2000) found no relationship between herbaceous species richness (groundflora) and elevation. In terms of species richness herb diversity is high if compared to the findings of (Khan *et al.*, 2011). In lower areas, annual disturbance indicators such as *Dicliptera bupleuroides*, *Sonchus spp.*, *Cannabis sativa*, *Lepidium pinnatifidum*, *Chenopodium album*, *Solanum pseudocapsicum* and many others are common and outnumber genuine woodland plants. At subalpine reaches light-demanding perennial species such as *Potentilla atrosanguinea*, *Pedicularis pyramidata*, *Sibbaldia cuneata*, *Impatiens thomsonii*, *Pleurospermum stellatum* and *Clinopodium umbrosum* are common. Effects of different life forms may blur a possible richness response of woodland herbs among which hemicryptophytes and geophytes are prevailing. Mahdavi *et al.* (2013) found that annuals decreased, and hemicryptophytes increased along a 3000 m altitudinal gradient in Iran.

Shrubs showed a unimodal pattern in the studied area with maximum richness in the middle of the elevation gradient. Transhumance affecting shrub growths in woodlands particularly at lower and at subalpine levels close to the winter and summer pastures, respectively, may explain such a pattern. High tree species richness in the lower zone is probably due to anthropogenic habitat disturbance and deforestation supporting alien tree species such as *Ailanthus altissima* and *Robinia pseudoacacia*, but also opportunistic native trees such as *Ficus palmata*. Infrequent deciduous tree species like *Rhamnus purpurea* and *Prunus cornuta* which are largely confined to the nemoral zone add to the relatively high mid-elevation tree species richness.

Decreasing total species richness above about 2700 m may be due to increasingly harsh natural conditions in the upper boreal and subalpine belts (Colwell and Lees, 2000; Grytnes and Vetaas, 2002). A mid-elevation peak of species richness as observed in Swat is a common pattern on many mountains (Grytnes, 2003).

### **Variation in $\alpha$ -diversity**

In our index for  $\alpha$ -diversity we used relative species cover. As with richness, and probably for the same reasons (see above) we could not identify a relationship between herb diversity and elevation. Alpha diversity of shrubs, being low throughout, decreased along the gradient. Some shrub species, e.g. *Isodon rugosus*, *Desmodium elegans*, *Sorbaria tomentosa*, are more or less equally distributed but decrease at upper levels. Patterns of tree species richness and  $\alpha$ -diversity are quite similar and indicate that abundance of different tree species seems to affect  $\alpha$ -diversity in much of the elevation gradient. Quartic regression model shows a significant trend of variation of  $\alpha$ -diversity of the vascular plants against elevation. The pattern is similar to  $\alpha$ -diversity of trees and, interestingly, in consonance with a 1300 m elevation gradient in the Sierra Nevada, Mexico (Sánchez-González and López-Mata, 2005).

### **Variation in $\beta$ -diversity**

Beta diversity is a key concept for understanding ecosystem patterns, for biodiversity conservation and ecosystem management (Legendre *et al.*, 2005). In the study area, species turnover of herbs varied along the gradient between 0.46 and 0.89. Beta diversity of the herbs and of the vascular plants as a whole were similar. Low-elevation woodland disturbance indicators including neophytes such as *Cannabis sativa*, *Datura innoxia* and *Galinsoga parviflora* add to the high level of beta diversity at lower altitudes. From 2900 m onward, there is low turnover of herbs, probably due to the increasingly controlling effect of climate over other environmental factors. Increase in beta diversity of shrubs at 1800-2400 m and 3100-3350 m reflects the effect of certain range-restricted native species. Between 1800 and 2400 m *Indigofera heterantha*, *Viburnum grandiflorum* and *Sarcococca saligna* appear. The first two are among the most widely distributed shrub species of the area. At and beyond the subalpine belt characteristic species such as *Salix* spp. and *Cassiope fastigiata* cause high beta diversity at the high end of the gradient. Species turnover of trees is high only on the valley sides and rather low at higher reaches. This is due to the dominance at nemoral through boreal levels of the competitive forest trees *Pinus wallichiana*, *Abies pindrow* and *Picea smithiana*.

### **Conclusion**

We confirmed our initial research questions. Shrubs, trees and non-woody plants varied in richness and diversity along the investigated elevation gradient of 1800 m from the valley bottom to the summits. Much of the richness and diversity variation along elevation of shrubs and trees could be explained by different response models including monotonic, hump-shaped, and more complicated

relationships. The growth form category 'herb' seems to be too unspecific to reveal a significant elevational pattern. Life form categories responding to the climatic change along the altitudinal gradient may be expected to perform better. There is considerable redundancy in our study in what is revealed by the concepts of species richness and  $\alpha$ -diversity, while  $\beta$ -diversity provided additional clues for interpretation. The detailed interpretation of the findings proves difficult and is likely to be multi-faceted. Apart from the obvious, increasing precipitation and decreasing temperature with increasing altitude, disturbance effects in the woodlands of Swat seem to be accountable for some of the altitudinal diversity and richness phenomena. The effect of ruderal annuals and arboreal and herbaceous neophytes, for instance, is most pronounced on the low valley sides close to settlements. In the higher reaches, especially towards the subalpine belt, decreasing richness and  $\alpha$ -diversity as well as high turnover may reflect natural and human-made opening of woodland. Not all findings may be explained satisfactorily, though, and a much larger number and denser network of thorough descriptive case studies than available at present is urgently needed as reference data for the interpretation of spatial patterns and future change in plant and vegetation diversity of northern Pakistan.

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## CHAPTER 5

### SYNTHESIS

The results of the present investigation provide important insight into the vegetation pattern and local plants usage in the area of Miandam, Swat, North Pakistan. The aim was to identify species composition, vegetation zonation and plant species diversity along elevation. Ethnobotanical use of plants has also been described. This quantitative study based on multivariate analysis is the first such study for this area in the province of Khyber Pakhtunkhwa. The botanically as well as ecologically largely unexplored Miandam area was selected to add to the ongoing botanical and ecological exploration of Pakistan. Below the three major aspects of the research project are described in terms of objectives, approach, outcome, and what is deduced from the results. The summary of the three chapters is given in the context of ethnobotanical findings, phytosociological and phytogeographical aspect and measurement of species diversity.

#### **Ethnobotanical findings**

In many parts of Pakistan although use of allopathic drugs has increased multifold, plants are still used for minor ailments and in some cases even for serious diseases. In a local medicinal plants business system known as “pansara” medicinal plants are prescribed and sold by Hakeems (local traditional doctors). In the research area study was carried out to document which medicinal plant species are used by locals, which plant parts are used and what kind of habitat is largely accessed for collecting medicinal plants. Along with other areas of the Khyber Pakhtunkhwa province, Miandam harbors rich medicinal plant diversity. For the first time in any region of Pakistan, the medicinal plants of the study area are classified according to biological and distributional properties as well as ecological preference. It is essential to know where and in which habitats ethno-medicinal plants occur; as such knowledge is a prerequisite to identify vulnerable plant species susceptible to overcollecting or habitat change. In the research area medicinal plants are collected from the wild but cultivated medicinal plants are also used. Based on assessment and questioning local elders and traditional healers 106 plants were identified that are used by locals for different purposes. Out of these, 99 plant species are used for human health problems, three for livestock and four for both livestock and humans. The number of plants used for livestock in the region is probably higher but based on the information from elderly people only some of them could be ascertained in the present study. Eighty out of 106 medicinal plants are indigenous to the area while the others are cultivated

(20) or established alien plants (6). Also among the indigenous medicinal plants the majority of species is common (61%) or scattered (33%) in the area, thus neither of immediate conservation concern. Only five medicinal plant species (6%) are rare in the study area: *Aconitum violaceum*, *Colchicum luteum*, *Elaeagnus umbellata*, *Jasminum humile* and *Sambucus wightiana*. *Sambucus* and *Elaeagnus* are woodland shrubs of which leaves and fruits or leaves and flowers, respectively, are collected for medicinal purposes. Slightly more than 50% (55) of the ethno-medicinal plant species encountered in the study area occur in man-influenced habitat and almost 50% (51) in semi-natural habitats. Most species occurred in different kinds of woodland, while only few occur in wetlands (4) and mountain grasslands (4). Mountain grassland medicinal plants known in the Miandam valley comprise *Colchicum luteum*, *Corydalis stewartii*, *Nepeta cataria* and *Thymus linearis*. *Podophyllum hexandrum* and *Paeonia emodi* are the two excessively harvested important medicinal plants. Medicinal plants from wild are an important source of income for local communities but, if not properly managed, overcollection may lead to the destruction of habitat and in return extinction of species. Therefore, there is a need to find ways to harvest medicinal plants sustainably from the wild and to train local collectors (Shinwari, 2010). For plant conservation and to increase the locals' income it is suggested that vulnerable woodland medicinal plants of commercial value should be cultivated in newly designed and locally administered self-government agroforestry systems. One of the concerns of the locals is availability of land for medicinal plant cultivation. In a mountainous area with less available land for cultivation the locals prefer to cultivate cash crops like wheat, maize and potato for the sustenance of their families. It is recommended to use available land partly for medicinal plants and partly for other cash crops. Thus pressure on the wild medicinal plants can be reduced. Due to the specific habitat demands of many woodland plant species better results may be obtained through well managed agroforestry systems than in ex-situ sites.

### **Phytosociological and phytogeographical aspect**

To cover the phytosociological and phytogeographical aspect of the present project the vegetation of Miandam was thoroughly investigated with particular focus on woodlands and shrublands. The study area was previously unexplored except partial studies on forest conservation by some authors (Adnan *et al.* 2006; Sher and Hussain, 2007; Latif *et al.* 2006) and partly by WWF (World Wide Fund) Pakistan. The aim was to report plants of the research area and quantify their abundance. The findings of the vegetation study were compared with other studies in the wider surroundings of Hindukush-Himalaya. It was also assessed that how the forest ecosystem is threatened by different

anthropogenic activities in the research area. The vascular plant species found comprise 33 trees, 52 shrubs, 305 herbs and 11 climbers. Based on multivariate analysis twelve plant communities were established including subtropical semiarid groves of *Ailanthus altissima* to alpine turf of *Sibbaldia cuneata* with *Juniperus* patches. Woodland of *Abies pindrow* and *Viburnum grandiflorum* is the dominant vegetation in the area. In comparison to other studies that contributed to the knowledge of woodland types from subtropical levels to the high mountains in the Hindukush-Himalaya region, e.g. Ahmed *et al.* (2010), Beg and Khan (1984), Hussain *et al.* (1992), Hussain *et al.* (1995), Khan (2012), Rashid *et al.* (2011) and Sher and Al yemeni (2011), it is evident that the present study encompasses some aspects that are not covered by other researchers. To my knowledge for the first time information about vegetation has been georeferenced. It will help to re-visit plots and locate biodiversity hot spots. Based on extensive field observations and discussions with local dignitaries the current forest situation has been described and human impact has been appraised. Ilyas *et al.* (2012) assessed the vegetation structure and composition in the Qalagai hills, Swat, to pinpoint strategies for the conservation of the threatened forest ecosystems in that area. Khan *et al.* (2013) identified plant communities in the Western Himalayas using multivariate approaches. More such studies and phytogeographical assessment is needed to get a clear picture of the forest habitats and vegetation distribution.

### **Measurements of species diversity**

Three different indices were used for measuring diversity among three different growth forms i.e. trees, shrubs and herbs along an elevation gradient in the mountains of Miandam. Some of the patterns of species richness found in the Miandam Mountains, e.g. total species richness of flowering plants, are similar to other studies in the Himalayas (Bhattarai and Vetaas, 2003; Vetaas and Grytnes, 2002). Some patterns of diversity like beta diversity of shrubs were unique to the area. Contrary to our findings Tang *et al.* (2012) found that along altitudinal gradient,  $\beta$ -diversity of both trees and shrubs showed non-significant trends in most mountains. Species richness of all the vascular plants was highest between 2200-2500 m. A hump-shaped relationship was found between shrub richness and elevation with maximum species richness of shrubs between 2000 and 2200 m. For all the vascular plants alpha diversity was high in the lower zone of the elevation gradient. Beta diversity of all the growth forms was quite high along the entire gradient reflecting high species turnover. Documenting and understanding patterns in beta diversity and species turnover at different spatial scales, in different areas and for different target organisms is in many ways a challenge (Tuomisto,

2010). Anderson *et al.* (2011) suggested that plurality in the concept of beta diversity (use of different indices of beta diversity) can yield important ecological insights when navigated well. By knowing the properties of the measures being used and applying more than one, the underlying ecological structures in the data generating patterns in beta diversity can be revealed. Therefore it is suggested if other indices of beta diversity are used then ecologically useful findings can be obtained for diverse forest ecosystem of Miandam.

### **Major contributions of the present project**

- ❖ Preparation of floral list of more than 5000 plants for Pakistan by collecting data from different sources. Researchers, botanists, vegetation analysts, palynologists, ecologists and students will benefit and are benefitting to further their botanical and ecological knowledge.
- ❖ A georeferenced map was developed for different plant communities of the area. For modeling the distribution of species and analyzing the correlation of species with environment georeferencing is important. It will help in tracking plant species of interest and prioritizing conservation.
- ❖ The research area was thoroughly explored to make a botanical inventory of plants of the area.
- ❖ Different elevation belts of vegetation were defined and human impact was assessed.
- ❖ Variation in richness and diversity of herbs, shrubs and trees was statistically evaluated to see patterns of species turnover at different elevation.
- ❖ Medicinal plants usage by locals was documented with ecological and chorological characteristics of plants.

Though this project has contributed and results have been summarized above but there is always room for improvement. Therefore following recommendations are made to further the understanding of mountainous as well as forest ecosystem and their services.

### **Recommendations**

- ❖ So far plant exploration is concerned, there are many critical areas and particularly mountain valleys require extensive and continuous efforts for plant exploration. New taxa may be discovered.
- ❖ There is a need to develop liaison between universities and industries for sharing information regarding biodiversity and its conservation. Universities and industries either have minimum or negligible coordination. Different stakeholders like universities, industries and research organization if brought together can unanimously reach some conclusion regarding BAP (Biodiversity action plan) based on which future policies can be formulated.

- ❖ As herbal medicines are used in the region, therefore it is important to test efficacy and safety of the medicine. It is fine to document the existing medicinal plants knowledge but it should be furthered in terms of phytochemical screening and pharmacological testing.
- ❖ Indigenous knowledge should be confirmed on scientific footings.
- ❖ There should be sustainable use of medicinal plants. It was observed during field research that those who are involved in the medicinal plants collection are totally indifferent about loss of medicinal plants in the area because of their vested interest.
- ❖ Post-harvest losses of medicinal plants should be minimized.
- ❖ For the economic benefit of local population the people should be trained about value addition to raw material.
- ❖ For promoting medicinal plant cultivation and for biodiversity conservation government should give some incentives on a small scale to attract people towards medicinal plants cultivation which will help in minimizing pressure on natural forest ecosystem.
- ❖ Modern computer tools should be used for quantitative vegetation analyses
- ❖ One important aspect of the present quantitative analysis could be soil analysis that can help understanding the diversity and composition of plant species in different habitats.
- ❖ Red List Categories of plants of Pakistan as per recommendation of IUCN do not exist. This matter should also be given priority.
- ❖ As vegetation types of many parts of Pakistan are far from being fully explored it is essential to investigate all different types of vegetation and their climatic and topographic features. Such phytosociological studies are essential for protecting the natural plant communities and biodiversity as well as understanding the changes experienced in the past and continuing on into the future. Vegetation studies performed so far are not sufficient for constructing a vegetation map of Pakistan.

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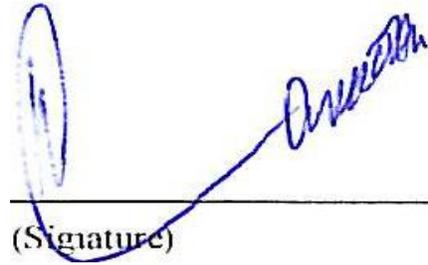
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**Declaration of originality and certificate of ownership**

I, Naveed akhtar, hereby declare that this dissertation entitled “Exploring Patterns of Phytodiversity, Ethnobotany, Plant Geography and Vegetation in the Mountains of Miandam, Swat, Northern Pakistan” is my own work and to the best of my knowledge I have documented all sources used.



(Signature)

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4. Workshop on Training of Trainers in Conservation Strategies for Plant Biodiversity of Pakistan at University of Peshawar, August 20-21, 2007

5. Training Course on Utilization of DNA Technology in Plant Improvement at University Of Hazara, May 22-26, 2007
6. HEC Workshop on Identification of Flowering Plants and Herbarium Techniques at University Of Sindh Jamshoro, March 24<sup>th</sup>-25<sup>th</sup>, 2008
7. 35<sup>th</sup> All Pakistan Science Conference at ICCBS/LEJ University of Karachi, Karachi, Dec. 20-23, 2008
8. Workshop on Effective Professional Communication at Staff Training Institute, University of Peshawar, January 18-22, 2010
9. International Seminar on Natural Disaster and Sustainable Development in Göttingen, Germany, 17<sup>th</sup> -18<sup>th</sup> April, 2013.