PLANT COMMUNITIES AND VEGETATION ECOSYSTEM SERVICES IN THE NARAN VALLEY, WESTERN HIMALAYA

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by

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Declaration

I hereby declare that no part of this thesis has been previously submitted to this or any other university as part of the requirements for a higher degree. The content of this thesis is the result of my own work unless otherwise acknowledged in the text or by reference. The work was conducted in the field at the Naran Valley Himalayas and Department of Biology University of Leicester during the period September 2008 to May 2012.

Shujaul Mulk Khan

Dedicated to my

Loving Parents,

Affectionate Teachers,

Serene Wife,

Divine Daughters,

Sincere Sisters,

Respectful Brothers

&

Amazing Friends

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Abstract

Plant communities and vegetation ecosystem services in the Naran Valley, Western Himalaya

By

Shujaul Mulk Khan

The Naran Valley, western Himalayas, is of high floristic interest owing to its geographic location and altitudinal range. It represents other remote Himalayan valleys where rugged terrain and geopolitics restrict plant biodiversity and conservation assessment, but has experienced no previous quantitative ecological or ethnobotanical research. This study had three objectives: (i) assess species distributions and plant communities using phytosociological techniques; (ii) identify environmental gradients responsible for vegetation variation; (iii) quantify vegetation ecosystem services for indigenous people.

Species attributes were measured along altitudinal gradients using transect and quadrat methods on slopes with different aspects (elevation range 2400-4100 m). One hundred and ninety-eight plant species from 68 families were quantified along 24 transects. Classification and ordination techniques (PCORD & CANOCO) identified 5 major plant communities. Indicator Species Analysis (ISA) and assortment of fidelity classes identified indicator/characteristic species. Detrended Correspondence Analysis (DCA) and Canonical Correspondence Analysis (CCA) showed altitude and aspect to be the strongest drivers of community classification. The vegetation changed from a moist-cool temperate community characterised by woody species, to dry-cold subalpine and alpine herbaceous communities both along valley sides and at higher elevations. Plant species diversity reached an optimum at mid-altitude (2800-3400 m) as compared to lower (2400-2800 m) and higher elevations (3400-4100 m). Questionnaire methods were used to record and quantify plant uses and indigenous ethnobotanical knowledge. Plant Use Values (UV) were calculated using quantitative ethnobotanical techniques while the phytosociological data yielded Importance Values (IV). UV and IV data were combined to illustrate anthropogenic influences, with a focus on rare, endangered and endemic species.

This study contributes to an enhanced understanding of (i) plant diversity in the Western Himalayas; (ii) ethnobotanical and ecosystem service values of mountain vegetation within the context of anthropogenic impacts; (iii) local and regional plant conservation strategies and priorities.

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Shujaul Mulk Khan

Publications arising to date from this thesis

The following papers have been published based on some results presented in Chapters 4, 5 & 6;

i. **Khan, S. M.**, S. Page and H. Ahmad, D. M. Harper, 2012. Phyto-climatic gradient of vegetation and habitat specificity in the high elevation Western Himalayas. *Pakistan Journal of Botany,* (Special Issue for ICB conference in September 2012, ***under review***).

ii. **Khan, S. M.**, S. Page and H. Ahmad, D. M. Harper, 2012. Linking plants abundance with human uses to assess anthropogenic pressures on vegetation of the western Himalayas. *Journal of Environmental Management,* (submitted; manuscript number- ENM-12-0159, ***under review***).

iii. **Khan, S. M.**, S. Page and H. Ahmad, D. M. Harper, 2012. Ethno-ecological importance of plant biodiversity in mountain ecosystems with special emphasis on indicator species; a case study of the Naran Valley in the Western Himalayas. *Journal of Ecological Indicators* (submitted; manuscript number- Ms. Ref. No.: ECOLIND-2235, ***under review***).

iv. **Khan, S. M.**, S. Page and H. Ahmad, D. M. Harper, 2012. Plant species and communities indicate environmental gradients in the Western Himalayas. *Journal of Ecological Informatics* (submitted; manuscript number- Ms. Ref. No.: ECOINF-D-12-00004, ***under review***).

v. **Khan, S. M.**, S. Page and H. Ahmad, D. M. Harper, 2012. Anthropogenic influences on the natural ecosystem of the Naran valley in the Western Himalayas. *Pakistan Journal of Botany,* (manuscript number- Ms. PJB (SCEE)-05, ***accepted***).

vi. **Khan, S. M.**, D. M. Harper, S. Page and H. Ahmad, 2011. Residual Value Analyses of the medicinal flora of the western Himalaya; The Naran Valley Pakistan. *Pakistan journal of Botany,* 43 (SI): 97-104.

vii. **Khan, S. M.**, D. M. Harper, S. Page and H. Ahmad, 2011. Species and Community Diversity of Vascular Flora along Environmental Gradient in the Naran Valley: A Multivariate approach through Indicator Species Analysis. *Pakistan Journal of Botany,* 43 (5): 2337-2346.

The following abstracts have been published based on conference talks or posters;

i. Delivered a talk entitled *"Vegetation Dynamics in the Western Himalayas, Diversity Indices and Climate Change"* in the international conference on "***Climate Change: Opportunities and Challenges***" at National University of Sciences & Technology (NUST) Islamabad, Pakistan. May 9-11, 2012.

ii. Delivered a talk entitled *"Anthropogenic influences on the natural ecosystem of the Naran valley in the Western Himalayas"* in the international symposium on "***Strategies for Conservation of Endangered Ecosystems***" at Department of Botany, University of Agriculture Faisalabad, Pakistan. April 16-18, 2012.

iii. Delivered a talk entitled *"Residual Value Analyses of the medicinal flora of the western Himalaya; the Naran Valley Pakistan"* in international workshop "***Medicinal Plants: Conservation & Sustainable Use***" at Quaid-i-Azam University Islamabad, Pakistan. December 8-10, 2011.

iv. Delivered a talk and presented a poster entitled *"The Ethnobotanic importance of mountain ecosystems: a case study of Naran Valley in the Western Himalayas"* in 4th ESP international conference "***Ecosystem Services: integrating Science and Practice***" at University of Wageningen, the Netherlands. October 04-07, 2011.

v. Delivered a talk entitled *"Vegetation abundance and anthropogenic pressure on it, in a remote western Himalayas, the Naran Pakistan"* in international conference "***People and Nature in***

Mountains: Changing Land Use and Landscape Dynamics" at Museum of Natural history, Trondheim, Norway. September 21-23, 2011.

vi. Presented poster entitled *"Plant species and communities indicate environmental gradients in the Western Himalayas"* in international conference "***Spatial Ecology & Conservation***" at University of Birmingham, United Kingdom. September 05-07, 2011.

vii. Presented poster entitled *"Life on the Edge: balancing the needs of nature and people in the remote western Himalayas"* in ***"7th Festival of Postgraduate Research"*** at University of Leicester, United Kingdom. June 16th 2011.

viii. Delivered a talk entitled *"Ecosystem services and analytical Tool for their quantification"* in three days International Capacity Building Symposium on "***Basic Techniques in Research, Dissertation & Paper Writing in Life Sciences",*** Department of Zoology, Hazara University Mansehra, Pakistan. July 27-29, 2010.

The following abstracts have been accepted for oral talks or posters in international conference;

i. Abstract entitled *"Evaluation of plants environment relationship and recognition of indicator species using multivariate statistics"* - Submission Number: **0022** has been accepted for poster presentation in the "***International Statistical Ecology Conference 2012***" at Oslo, Norway. July 3 - 6, 2012.

ii. Abstract entitled *"Plant Biodiversity in the western Himalayas under the scenario of climatic change"* has been accepted for oral presentation in the 5th International Conference of ESES "***Climate Change and Water Resources***" at Ismailia, Egypt. July 10 - 11, 2012.

iii. Abstract entitled *"Assessments of ecosystem services and rarity of the endemic flora in the western Himalayas"* has been accepted for poster presentation in the 6th Annual International ESP Conference on "***Ecosystem Services: Come of Age: Linking Science, Policy and Participation for sustainable Human Well-Being***" at Portland, Oregon, United States. July 31 - August 4, 2012.

iv. Abstract entitled *"Assessment of conservation status of vascular flora by linking its abundance and uses in the western Himalayas"* has been accepted for poster presentation in the "***3rd European Congress of Conservation Biology***" at Glasgow, United Kingdom. August 28 - September 1, 2012.

v. Abstract entitled *"Phyto-climatic gradient of vegetation and habitat specificity in the high elevation Western Himalayas"* has been accepted for oral presentation in the "***12th National and 3rd International Conference of Botany (ICB-2012)***" organized by Pakistan Botanical Society at Quaid-i-Azam University, Islamabad Pakistan. September 1 - 3, 2012.

vi. Abstract entitled *"Health-giving Flora and Ethnoecological Knowledge in the Western Himalayas, the Naran Valley Pakistan"* has been accepted for poster presentation in the "***12th National and 3rd International Conference of Botany (ICB-2012)***" organized by Pakistan Botanical Society at Quaid-i-Azam University, Islamabad Pakistan. September 1 - 3, 2012.

vii. Abstract entitled *"Social perception about the natural vegetation in the Western Himalayas a step towards conservation and ecological restoration"* has been accepted for oral presentation in the "***8th European Conference on Ecological Restoration***" at Ceske Budejovice, Czech Republic. September 9 - 14, 2012.

viii. Abstract entitled *"Assigning IUCN red list criteria to the Western Himalayan vegetation at regional level"* has been accepted for oral presentation in the 4th International Ecosummit "***Ecological Sustainibility; Restoring the Planet's Ecosystem Services***" at Columbus, Ohio, United States. September 30 - October 5, 2012.

We hope, at least two more journal papers will be published from this thesis.

Glossary of abbreviations

Ae	Aesthetic
CA	Cluster Analysis
CANOCO	Canonical Community Ordination
CBD	Convention on Biodiversity
CCA	Canonical Correspondence Analysis
CITES	Convention on International Trade of Endangered Species
Com.	Community
Cons.	Constancy
CR	Critically Endangered
DCA	Detrended Correspondence Analysis
EN	Endangered
ES	Ecosystem Service
F	Food
Fd	Fodder
GIS	Geographic Information System
GPS	Global Positioning System
Gr	Grazing
ISA	Indicator Species Analysis
IUCN	International Union for Conservation
IV	Importance Value
IVI	Important Value Index
Md	Medicinal
MS	Microsoft
NT	Nearly Threatened
NTFPs	Non Timber Forest Products
Ot	Others
PCA	Principal Component Analysis
SAC	Species Area Curve
Spp	Species
SPSS	Statistical Package for the Social Sciences
NT	Nearly Threatened
TWCA	Two Way Cluster Analysis
UV	Use Value
VU	Vulnerable

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Chapter 1 INTRODUCTION

1.1 Natural vegetation and Ecosystem Services

Biological resources are imperative for the survival and socio economic activities of mankind. Ecosystems, particularly terrestrial ones, support particular combinations of plant species and plant communities under certain ecological circumstances (Jackson, 2006, Chawla *et al.*, 2008). Mountain ecosystems harbor high levels of plant and animal biodiversity which provides direct services for sustainable human life. The influence of mountain ecosystems is much broader, however, than their physical limits as the lowlands also depend on them for services. In the case of Pakistan for example beside the direct services of plant biodiversity to local people, the mountains are crucial for the resilience of agriculture even in the Indus plain which depends on montane catchments for its water supply (Manandhar & Rasul, 2009, Xu *et al.*, 2009, Rasul 2010,). Plant species are the building blocks for ecosystem formation and also the primary source of services to human kind either directly or indirectly. Deane defines Ecosystem Services (ES) as “conditions and processes through which ecosystems and species in them sustain and fulfil human life” (Deane, 1999). Economists define ecosystem services as components of nature used for human wellbeing (Boyd & Banzhaf, 2006). In remote mountainous areas of the developing world there is limited scientific knowledge of the plant wealth. Yet despite this lack of knowledge, human actions are drastically affecting natural ecosystems, especially in mountainous areas where vegetation regeneration becomes extremely difficult due to climatic and physiographic constraints. Besides regulating services, plants provide direct provisioning services to humans in terms of food, fodder, medicines, timber, fuel-wood, grazing, and a number of other multipurpose utilities. Unwise use of these resources results not only in soil erosion, floods and landslides but also is a threat to the biodiversity and the proper functioning of mountain ecosystems (Sharma *et al.*, 2010, Tarrasón *et al.*, 2010).

In mountain ecosystems, ecologists attempt to understand the variation in species diversity along environmental gradients, e.g., altitudinal or edaphic gradients to plan better appropriate conservation strategies (Daubenmire, 1968, Thompson & Brown, 1992, Vetaas & Grytnes, 2002). Internationally, political awareness and interest has been increasing for the last decade to formulate regulations for the protection and conservation of biodiversity (Barbault, 2011, Herkenrath & Harrison, 2011, Normander *et al.*, 2012). An enormous depletion of plant biodiversity has been linked to an increase in ecological hazards e.g., desertification, erosion and floods. Conserving plant biodiversity is therefore imperative and needs consistent and robust botanical data (Clubbe *et al.*, 2010). Furthermore all stakeholders should be taken into consideration when formulating long term conservation strategies (Langpap, 2006, Levrel *et al.*, 2010,). Understanding plant species individually, in aggregation, in relation to environment and in relation to humans is important for management, socioeconomic and academic purposes. The Himalayas are the world's youngest and highest mountains, possessing diverse vegetation and are important locations for research on ecology and biodiversity conservation, in common with other large mountain systems in the world.

1.2 Scientific approach to ecosystem evaluation

Mountain ecosystems all over the world have diverse biological communities due to their rapidly changing landscape, climate and history and hence are often given high conservation priority (Brown *et al.*, 1993a, Myers *et al.*, 2000, Olson *et al.*, 2001, Olson *et al.*, 2002, Herben *et al.*, 2003, Fosaa, 2004). They also provide a range of valuable ecosystem services, many of which are derived from the vegetation. Ecosystems are large and complex systems and therefore often difficult to subject to routine scientific experimentation. Nevertheless certain techniques can be applied to the biotic and abiotic components of ecosystems to measure their overall performance. In each and every ecosystem, plants are the most important among the biotic components as, primarily, the whole food web is based on them. To understand the plant ecology of an ecosystem it is necessary to know about the distribution of individuals and populations of each species in the community. It is also imperative to know the structure of the whole community in floristic and physiognomic terms (Billings, 1972, Daubenmire, 1974). Evaluation of vegetation diversity is popular not only for its fundamental importance but also because vegetation is the modifier of environment and energy, mineral and oxygen cycles for the upper trophic levels of an ecosystem. Change in plant diversity causes changes in the variety of all other organisms in an ecosystem (Billings, 1972, Pimm, 1984).

Due to the complexity of ecosystems in the mountainous regions and the cost and time factor various techniques can be used to evaluate their overall representation, ecosystem services, conservation and future survival. Tools and techniques related to the sciences of Phytosociology (Quantitative Ecology) and Ethnobotany can be used to evaluate Ecosystem

Services and conservation status of the natural vegetation. Data obtained through these techniques may also be essential for conservation managers and biodiversity planners to evaluate the services provided by mountain ecosystems and to formulate sustainable management options.

1.3 The phytosociological approach; species, community and environment

Understanding plant communities is a critical prerequisite in ecosystem ecology, natural resource management and conservation. This knowledge is particularly important when studying rare or infrequent species and for developing management strategies for protecting them, and/or reducing fragmentation of their habitats (Ewald, 2003). The description of vegetation has been providing firm foundations for the development of the ecological sciences for many decades. Plant species at an individual level or community level and in relation to environment can be studied using phytosociology (quantitative ecology). Through both quantitative and qualitative approaches from species to community levels, phytosociology can also be used as a tool for investigating vegetation ecosystem services since it provides knowledge of species abundances and importance values (Whittaker *et al.*, 2001, Greig-Smith, 2010, Tüxen & Whittaker, 2010). Distribution of individuals of the same and different plant species in a community is the function of micro environmental variations, time and biotic relationships. Plant species assemble in a community in a definite fashion and hence this knowledge can be helpful during quantification and evaluation of ecosystem services (Daubenmire, 1968, Billings, 1972, Mueller-Dombois & Ellenberg, 1974, Rieley & Page, 1990, Greig-Smith, 2010). The analysis of biodiversity is also a key concern to conservationists since it provides the basis for international conservation policy (CBD, 1992, Pahwa *et al.*, 2006). Phytosociological field techniques allow ecologists to calculate diversity, richness and abundance of plant species in an ecosystem which not only help them to understand about their conservation but also their role as indicators of particular habitat types. Moreover, importance value indices (IVI) can be calculated from such data which not only give insight into heterogeneity of vegetation phenomena but can also be used in combined analyses with use value indices (UVI) to provide evidence of plant species conservation priorities (Phillips *et al.*, 1994, Mucina, 1997, Da Cunha & De Albuquerque, 2006). In addition, frequency, constancy and fidelity analyses help to identify the most threatened species and those habitats needing protection (Baillie, 2004, Zou *et al.*, 2007, Hester & Brooker, 2007).

1.4 Ethnobotany; plant human relationships & integrating ecological data with information on traditional knowledge

Ethnobotany explains the relationships that exist between people and plants (Harshberger, 1895). Ethnobotanists aim to reliably document, describe and clarify complex relationships between cultures and plants (Acharyya *et al.*, 2009). Quantitative ethnobotany is a new emerging field was introduced by Phillips and her colleagues (1994) by quantifying the importance of forest products to people and comparing their subsistence and commercial values. Ethnobotanical studies investigate the structural relationships between society and environment, using socio-anthropological methods, and hence can be used as a useful tool to quantify ecosystem services (Ford, 1994).

In the Himalayas, natural resources are very diverse and vegetation types are highly varied (Shrestha & Joshi, 1996). The Himalayas not only support a large number of plants due to their diverse nature but the people of the Himalayas comprise also a mixture of several tribes. They utilize available resources using their indigenous knowledge e.g. ethnomedicinal knowledge. Medicinal plants are primarily used by Tibbee dawakhanas (herbal medical centres) of indigenous doctors (Tabeebs) known as hakims in this part of the world (Aumeeruddy, 2003, Mahmood *et al.*, 2003, Bantawa & Rai, 2009). This system was originated with ancient Greek philosophers and was brought to the Indo-Pakistan subcontinent by Arab scholars and practiced there for centuries. It also mixed with and has benefited from the Ayurvedic system of medicines, a pre-existing system of this sub continent (Ahmad *et al.*, 2003, Sridharan *et al.*, 2011). To date most ethnobotanical studies have focused on qualitative botanical data. Himalayan people depend for their livelihood mainly on the surrounding natural ecosystem; this includes use of plants for medicinal purposes. However, an imbalance is taking place between use and demand of natural resources due to the enormous increase in the human population and a decrease in natural resources, especially plant diversity. The western Himalayan mountains have great conservation value for global biodiversity but are under great pressure from local people in terms of expansion of agricultural land, cutting of woody vegetation for timber and fuel, multipurpose plant collection, over grazing, lack of awareness and absence of practical conservation strategies (Hamayun *et al.*, 2006, Sharma *et al.*, 2010). Over the past few decades conservationists have been comprehensively working to scrutinize global, regional, national, and local endangered and vulnerable species. Long-term conservation plans need to seek harmony among society, scientists and politicians (Miller *et al.*, 2007, Hanson *et al.*, 2009). This requires an insight into the present abundance of species and an assessment of the anthropogenic pressures that they face. The mountainous valleys of the Himalayas also host cultural and traditional diversity and a huge asset of traditional knowledge, which also needs to be documented and preserved (Anthwal *et al.*, 2010, Negi, 2010, Singh *et al.*, 2011). Evaluation of plant biodiversity in the light of both ecological and ethnobotanical indices is increasingly used to provide an indicator of sustainable environmental continuity (Normander *et al.*, 2012, David, 2012, Vačkář *et al.*, 2012). In this thesis, phytosociological indices are compared with ethnobotanical indices to assess anthropogenic pressures and determine the conservation status of species at a regional level.

1.5 Study area

The Naran Valley lies in North West Pakistan, 270 km north from the capital, Islamabad (34° 54.26´N to 35° 08.76´ N latitude and 73°.38.90´ E to 74° 01.30´ E longitude; elevation range 2450 to 4100 m above mean sea level). It occupies an important location on the extreme western boundary of the Himalayan range, after which the Hindu Kush mountains start, running west of the River Indus. The distinctive physiographic, climatic and geological history has contributed to make this area distinctive in floristic terms, but the tense geo-political situation in adjacent border areas has limited intensive vegetation exploration (Takhtadzhian & Cronquist, 1986). The present project was launched in 2008 with the objective of bringing modern tools for vegetation classification and ecosystem studies into the remote western Himalayas in general and the Pakistani part in particular.

1.6 Research aim and objectives

The aim of this PhD study is the classification of the vegetation of the Naran Valley with special emphasis on integration of phytosociological data with ethnobotanical data in order to quantify the ecosystem services provided by the natural vegetation and to assess the anthropogenic pressures on that vegetation. The present project was launched and sequentially completed in three phases. In the first phase, the quantification of available plant species was carried out using phytosociological techniques. In the second phase indigenous knowledge of plant species amongst the local people was recorded using questionnaires and interviews throughout the valley. In the last phase, the results of both studies were analysed both independently and jointly to classify the vegetation and quantify the vegetation ecosystem services and also the anthropogenic pressures in order to provide a conservation assessment.

1.6.1 Objectives

In order to meet the aim, three objectives were sequentially met. In Year 1, the objectives were to quantify the vegetation using phytosociological techniques, collecting quadrats (relevés) in replicate at specific elevation intervals along altitudinal transects on different aspects to explain vegetation composition, pattern and environmental gradients. In year 2, the ethnobotanical uses and use values of the plant species in the valley were quantified through structured interviews with the rural population. In year 3, these two data sets were integrated in their analyses to understand the value of different ecosystem services and also the pressure on vegetation at species and community levels. The objectives were addressed by testing the following hypotheses:-

1.6.1.1 Objective of the phytosociological study

Hypothesis 1: Variation in aspect (north- and south-facing) and altitude would have an impact on the composition, abundance and importance value (IV) of individual plant species and also on plant community.

1.6.1.2 Objective of the ethnobotanical study

Hypothesis 2: The native plant communities provide measurable ecosystem services particularly with reference to human health.

1.6.1.3 Objective of the ecosystem services and conservation study

Hypothesis 3: Local communities utilize the plant species of the valley according to their importance based on community indigenous knowledge irrespective of their abundance and importance value (IV) and this use can exert enormous pressure on the maintenance of plant biodiversity.

1.7 Summary of the field activities

Data were collected using phytosociological techniques in summer 2009. These data were analyzed during winter 2009-10. The second field campaign was in summer 2010 when ethnobotanical data were collected using questionnaires and interviews in combination with data from the first field work period. Subsequently, these data were analyzed separately and jointly in 2011.

1.8 Structure of this thesis

Keeping the thesis goal and objectives in mind, this thesis comprises of seven chapters. Brief particulars of each chapter are as follows. Chapter 1 is an introduction that gives a overview of vegetation ecosystem services, the science of phytosociology, ethnobotany, project aims and objectives, a summary of the fieldwork campaigns, importance of the location of the study area and structure of thesis. Chapter 2 contains a literature review covering relevant literature including a review of the techniques and applications used in this thesis. Chapter 3 describes the study area. The results chapters (Chapter 4-6) have been written in the format of journal articles, each possessing an introduction, methodology, data analysis, results and discussion. The first results chapter (Chapter 4) is about classification and ordination of vegetation along environmental gradients. Evaluation of provisioning ecosystem services provided by natural vegetation is discussed in chapter 5, whilst chapter 6 links abundance of plant species with human use to assess the anthropogenic pressures. The final chapter (Chapter 7) discusses and synthesises the findings, with particular reference to their relevance for a region of the Himalayas that is relatively unexplored botanically and provides suggestions for a botanical conservation strategy that prioritizes plant species and habitats.

Chapter 2 REVIEW OF LITERATURE

2.1 Vegetation classification

Phytosociology (also known as plant sociology or quantitative plant ecology) is the science of vegetation classification based on species co-occurrence and its relation to the surrounding environment. This science has provided valuable methods for vegetation assessment that can be applied in vegetation mapping, ecosystem services quantification and biodiversity conservation (Rieley & Page, 1990, Ewald, 2003, Biondi, 2011). Phytosociology takes different approaches from species to community and habitat levels and is used as a tool for investigating vegetation and habitats types. Mountains have high conservation importance as they possess diverse vegetation and habitat types and hence provide a number of services to mankind (Herben *et al.*, 2003, Huai & Pei, 2004). The health of ecosystems, especially in mountainous regions, is closely allied to its plant biodiversity (Ruiz *et al.*, 2008, Schäfer, 2011) and vegetation classification and mapping is therefore the first step towards ecosystem conservation.

2.1.1 History and scientific back ground of vegetation classification

Phytosociology started with the Swiss ecologist Josias Braun Blanquet (1884-1980) in Europe. A number of schools in plant sociology developed in the beginning of the 20th century, two of which gained much popularity, i.e., the Zurich-Montpellier and the Uppsala school of thought. In 1915, following the first school, Braun Blanquet defined the plant community as a plant group having characteristic (indicator) species and more or less stability with the surrounding environment (Podani, 2006). The plant community of a region is a function of not only time but also of other factors, including altitude, slope, latitude, aspect, rainfall and humidity, all of which play a role in its formation and composition (Kharkwal *et al.*, 2005a). The ecological diversity of vegetation communities is considered to be a measure of the strength of the whole ecosystem (McGrady-Steed & Morin, 2000). Over 230,000 species of higher plants have been recorded in the world (Thorne, 1992) and there has been much research attempting to describe and explain this vast diversity, and to discover the mechanisms which maintain it (Pitman *et al.*, 1999). For this reason vegetation needs to be studied in relation to both climatic and physiographic features and variation in species diversity along environmental gradients (of climate, productivity and so on) has been a major topic of ecological study in recent years (Vázquez G & Givnish, 1998, Willig *et al.*, 2003, Currie & Francis, 2004).

On the Asian sub-continent, early extensive botanical work was carried out by Bentham & Hooker (1862-1880) who documented the flora of this region in their books the *‘Genera Plantarum’* and ‘*Flora of British India’.* All subsequent botanical studies on the sub-continent, including ecological studies, have depended upon this early work (Bharucha, 1975). In the early 20th century, S. P. Agharkar, who can be considered the region’s first resident pioneer ecological researcher, published his work on *'The means of dispersal and the present day distribution of the xerophytes and the sub-xerophytes of north-west India'* in 1920. By the time of the division of British India in 1947, however, there was no comprehensive document about the vegetation of the Pakistani part of the country, other than the early works of Bentham and Hooker, even though by these books were 70 years old and also did not include the entire area of the new country of Pakistan. Other early interest in the botany of the sub-continent was driven by the collection of botanical specimens. R. R. Stewart (1890-1993), for example, made extensive plant collections from all over Pakistan, published as *“An Annotated Catalogue of the Vascular Plants of Pakistan and Kashmir”* (Stewart, 1972) which is now considered to provide the backbone for the ‘*Flora of Pakistan’*. After the division of British India, botanical studies in India and Pakistan took place in isolation due to geopolitical conflicts. Writing of the Flora of Pakistan was initiated in 1966 and to date descriptions of 215 families have been published including 1389 genera and 4758 species. Five families, comprising about 760 species, are yet to be published (Ali, 2008). Apart from work on floristic, there have also been studies of plant communities. Champion *et al*. (1965) and Beg (1975) identified various types of forests in Pakistan (Champion & Harry, 1965, Beg, 1975). Rafi (1965) presented similar studies from Balochistan Province, while Hussain & Illahi (1991) presented their work on the Lesser Himalaya of Pakistan. There are, however, still some places in this country which have not received extensive floristic and phytosociological exploration (Hussain, 1991).

In the mountainous regions altitude has greater effect on temperature than latitude and the rate of decrease is much more rapid in summer than in winter that ultimately cause the altitudinal zonation of vegetation (Heaney, 1989, Tanner *et al.*, 1998, Givnish, 1999). Precipitations and redistribution of water that decrease with the increase in altitude associated with low temperature, are the main factors that control vegetation succession and existence in those mountains (Peer *et al.*, 2007) and there are still large knowledge gaps in the fields of taxonomy, phytosociology and vegetation mapping, particularly in the dynamic mountainous regions of the country.

2.1.2 Scientific methods for studying phytosociological characteristics of vegetation

The choice of sampling method depends on the types of data desired, the objective of the study, morphology of the vegetation, geomorphology of the region and available time and resources (Biondi, 2011, Moore & Chapman, 1986). A number of samples can be taken from a study area with the assumption that these samples will provide a good representation of the plant communities of that area. The most common quantitative sampling methods are the quadrat and lines transect methods. The quadrat method originated with Frederick Edward Clements (1874-1945) (Weaver & Clements, 1966-938). In its simplest form the quadrat is used to count the individuals and estimate cover of each species to determine their abundance. It is also used to determine differences in the composition and structure of vegetation. The quadrat method allows the user to define a fixed area, called a plot or releve, within which plant characteristics are measured. This method may be adapted in a variety of ways for analyzing almost any type of vegetation. The line transect method in which a baseline is drawn, along which sampling is conducted, is typically used when there are apparent vegetation differences from one point of interest to another within a sampling site. Sometimes the two methods are used together especially when both quantification of vegetation and assessment of ecological gradients are desirable. Everson and Clarke (1987) compared and analysed six sampling methods and pointed out that the quadrat and point techniques were the most reliable for detailed ecological studies (Everson & Clarke, 1987a). Species composition, plant species density, cover and abundance are usually considered the most important characteristics for sampling with quadrats (Cox, 1996). Several scales for ranking vegetation cover have been suggested of which two of the most commonly used are the Braun Blanquet (1884-1980) and Daubenmire (1968) cover class scales (Daubenmire, 1968, Braun-Blanquet *et al.*, 1932). Diameter of tree species at breast height (DBH) is measured for cover values, while for herbaceous and shrubby vegetation this is done by assigning cover class estimates (Goldsmith *et al.*, 1986).

2.1.3 Data analyses, phytosociology and vegetation classification

Phytosociology is concerned with the phenomena of vegetation, and needs to be examined in a statistical framework from the very beginning. Statistical techniques in vegetation ecology e.g., multivariate statistical analyses, have emerged in the last few decades. In community ecology, multivariate analysis helps ecologists to discover structure in the data set and helps them to analyze the effects of environmental factors on whole groups of species (Clymo, 1980, Bergmeier, 2002, Anderson *et al.*, 2006).

The introduction of computer technology has revolutionized the field of ecology, with a range of statistical programs available to help ecologists to understand and interpret ecological data in a more precise way. Software packages such as TWINSPAN, DECORANA (Hill, 1979, Hill & Gauch Jr., 1980), CANOCO (ter Braak, 1989, ter Braak & Smilauer, 2002) and PC-ORD (McCune, 1986, McCune & Mefford, 1999., Grandin, 2006), for vegetation classification are examples of recent advancements in the field of quantitative ecology (Gilliam & Elizabeth, 2003). These packages are used for vegetation classification and ordination. Classification and ordination summarize community data by constructing a low dimensional space in which similar samples and species are placed close together and dissimilar ones far apart from each other. They serve to overcome human limitations in data assessment by producing effective low dimensional summaries from field data by convenient and objective means (Gauch, 2010). Agglomerative Cluster Analysis (ACA), Indicator Species Analysis (ISA), Detrended Correspondence Analysis (DCA), Principal Components Analysis (PCA) and Canonical Correspondence Analysis (CCA) are the most widely used classification and ordination techniques to determine plant communities, their ecological gradients, indicator species and the significance of the relationships between floristic and environmental data (Hill & Gauch Jr., 1980, Dufrêne & Legendre, 1997, Ter Braak, 1987).

2.2 Ecosystem services and ethnobotany

Broadly, ecology can be bifurcated into two major fields namely population ecology and ecosystem ecology (Barbault, 1997). Ecosystem is a relatively recent term used by Sir Arthur Tansley in 1935 for a unit of a whole community of organisms and its environment (Chapman & Reiss, 1998). Ecosystem ecology gained importance when natural ecosystems gradually came under modification due to anthropogenic activities. In pre-history, modification of natural ecosystems dates back to the beginning of the use of fire and later on to the introduction of agriculture. More recently agricultural expansion linked with increases in population and industrialization coupled with climatic changes, have been recognised as the main causal factors of the degradation of natural ecosystems, especially terrestrial ecosystems (Billings, 1972, Odum, 1972). In each and every ecosystem, plants are the most important among the biotic components as, primarily, the whole food web is based on them. Furthermore, they are important ecologically in the regulation and maintenance of the abiotic environment. In the scenario of scientific advancement combined with anthropogenic disturbance and an increasing desire for sustainable management it is necessary to know about the distribution both of individual species as well as groups of plants (communities) and their surrounding abiotic factors (Jules *et al.*, 2008).

Ecosystem services are categorized into biotic resources (products from plants and animals) and abiotic resources (environment linked). Natural and semi-natural ecosystems provide resources e.g., oxygen, water, food, medicine, clothing, building, energy, and genetic resources. Some other common ecosystem services associated particularly with forests are hydrologic regulation, climatic control, soil formation, carbon capture and recreation. Ecosystem services result from interactions between biotic and abiotic components of ecosystems (Singh, 2002). Two of the main reasons for species and habitat losses are human disturbances and unsustainable utilization of various services (Giam *et al.*, 2010). In mountain ecosystems, inhabitants exploit the vegetation through a number of activities such as farming, herding, fuel and timber collection and trade in plants, e.g. for medicinal and timber purposes.

Table 2.1 Classification of Ecosystem Services in the region with slight modifications to broader categories specified by the Millennium Ecosystem Assessment (MEA) (Wallace, 2007, Kremen, 2005, MA, 2003)

S. No.	Ecosystem Service (ES) Category	Sub Categories	Ecosystem service providers/ tropic level in case of biotic components	Inclusion in this study
1	**Provisioning Services**	i. Food ii. Fodder and grazing land iii. Medicine iv. Timber v. Fuel vi. Ornamental resources	i. All biodiversity ii. Vegetation iii. All biodiversity iv. Tree species v. Trees, shrubs, rarely herbs vi. All biodiversity and landscape	Quantification of abundance and uses of vascular plant species
2	**Regulating Services**	i. Climate regulation ii. Air quality iii. Water regulation iv. Water quality v. Flood and erosion control vi. Biodiversity vii. Pollination viii. Pest regulation	i. Vegetation ii. Vegetation and microorganisms iii. Vegetation and natural habitats iv. Vegetation, soil & aquatic micro-organisms v. Vegetation vi. Diverse species vii. Insects, birds and mammals viii. Invertebrate and vertebrate predators	
3	**Supporting Services**	i. Soil formation ii. Nutrient cycling iii. Water cycling iv. Primary production	i, ii & iii. Leaf litter and soil invertebrates; micro-organisms; nitrogen-fixing organisms; Weathering agencies iv. Plant and animal	
4	**Cultural Services**	i. Cultural diversity ii. Knowledge systems iii. Recreation & ecotourism iv. Aesthetics	i. All biodiversity ii. Traditional knowledge about the natural resources iii. Sceneries like lakes, peaks & meadows give the opportunities for swimming, boating, hiking, skiing etc.	Documentation of traditional knowledge about the uses of plant biodiversity especially ethnomedicines

2.2.1 *Mountain vegetation, indigenous people and provisioning services*

Natural vegetation provides basic needs for indigenous human communities and is often their prime source of livelihood, especially in the developing world. Plant-human relationships are as old as human history itself. Plants provide wood, fuel, food, medicines and tools, and fodder and grazing for livestock. In AD 77, the Greek surgeon Dioscorides published "De Materia Medica", a catalogue of about 600 plants in the Mediterranean. It also included information on how the Greeks used the plants, especially for medicinal purposes. The records from early historical cultures of Africa, China, the Nile and Indus valleys have also revealed the uses of herbal medicines by the inhabitants of those regions over several millennia (Baqar, 2001). The American botanist John William Harshberger used the term ethnobotany for the first time in 1895 in a lecture in Philadelphia. Ethnobotany (from "ethnology" - study of culture and "botany" - study of plants) is the scientific study of the relationships that exist between people and plants (Harshberger 1895). It involves botany, anthropology, ecology, economics and linguistics. Ethnobotany can inform us about the present day use of plant species, their conservation status and their uses, including the development of new products such as drugs from plants. Traditional botanical knowledge can be used in the assessment of economic benefits derived from plants, both at basic and commercial levels. Such knowledge can also be used as an analytical tool for the quantification of Provisioning services provided by vegetation and can also maximise the value of traditional ecological knowledge. Ethnoecological knowledge can be applied in long term management and conservation strategies (Pieroni & Giusti, 2009, Anthwal *et al.*, 2010, Tang & Gavin, 2010). Additionally, plant materials have provided the models for 50% of the present day allopathic (Western) drugs (Robbers *et al.*, 1996) and the World Health Organization (WHO) has recognized the role that plants play in traditional healing systems and thereby their contribution to the provision of health services, particularly in the developing world. Due to their immense value, however, some of the plants utilized for ethno medicines are under high anthropogenic pressure as a result of non-sustainable exploitation.

Ethnobotanical studies investigate the structural relationships between human society and the environment using socio-anthropological methods and hence they can be used as a useful tool to quantify ecosystem services (Ford, 1994, Phillips *et al.*, 1994). These relationships can be social, economic, symbolic, religious, commercial and/or artistic

(Aumeeruddy, 2003). Recently in the fast developing parts of the world, the trend is shifting from merely the production of inventories of plant species towards more practical quantitative approaches which place an emphasis on conservation and sustainable use of plant resources (Rossato *et al.*, 1999, Da Cunha & De Albuquerque, 2006, Uniyal *et al.*, 2006, De Albuquerque, 2009, Teklehaymanot & Giday, 2010).

2.2.1.1 The status of ethnobotany in Pakistan

In Pakistan, ethnobotany has been introduced quite recently to the curricula of a few of the universities. Pakistan is rich both in medicinal flora and indigenous ecological knowledge (Shinwari, 1996, Athar & Bokhari, 2006). Medicinal plants are primarily used in Tibbia Dawakhana (herbal medical centres) by indigenous physicians known as hakims (Mahmood *et al.*, 2003, Hamayun *et al.*, 2006, Qureshi *et al.*, 2009). This system was founded by ancient Greek philosophers and was used and brought to the Indo-Pakistan subcontinent by Muslim scholars during the period of Islamic civilization and practiced there for centuries. It also benefited from the Ayurvedic system of medicines already practiced on the sub-continent (Ahmad *et al.*, 2003, Ahmad *et al.*, 2009). Many of the mountain systems and valleys in the Himalayas have long been neglected by botanists and vegetation ecologists because of their inaccessibility, severe climate and prevailing poverty. The northern areas of Pakistan have great conservation value for global biodiversity but these mountains are also under great pressure from local people because of illegal cutting of plants for timber and fuel wood, expansion of agricultural land, poor collection and storage methods of plants collected for medicinal or other purposes, over grazing, low literacy rates and poor laws enforcement (Hamayun *et al.*, 2003a, Hussain *et al.*, 2007, Ibrar *et al.*, 2007, Fazlur-Rahman, 2009).

2.2.1.2 Ethnobotanical data collection and analyses

Information on how indigenous people interact with the natural environment can be collected and analysed in a number of ways depending on the study objectives and research questions. Such analyses may range from laboratory analyses, to market surveys and assessment of priorities for conservation management. Whatever the analyses may be used for, one common requirement is that the information is obtained in a systematic manner (Martin, 2004, Thomas *et al.*, 2007). Interaction with indigenous communities requires the researcher to have additional skills i.e., calmness, patience, courtesy, empathy, keeping secrets etc (Ragupathy *et al.*, 2008, Miehe *et al.*, 2009). There are a number of ways to analyse ethnobotanical data which depend again mainly on the research question and hypothesis. Ethnobotanical data can be analysed qualitatively to record plant uses and the plant parts that are collected etc. Recently, quantitative ethnobotany has led to hypothesis-based analyses of data sets (Phillips *et al.*, 1994, Rossato *et al.*, 1999, Da Cunha & De Albuquerque, 2006, De Albuquerque, 2009). Ethnobotanical data sets based on indigenous traditional knowledge can be tallied and analysed together with vegetation surveys to provide a better understanding and management of ecosystems (Moerman, 1991, Negi, 2010).

2.3 Floristic importance of mountain ecosystems with reference to Pakistan

The Irano-Turanian region of the Tethyan subkingdom has a rich and significant floristic diversity due to the presence of various mountain systems. As a country, Pakistan supports some of the world's most diverse vegetation, owing to varying geo-climatic zones and the presence of five significant mountain systems. North-Western Pakistan is situated in this region where the Kirthar, Suleiman, Hindu Kush, Karakorum and the Himalayas (western part) congregate together and contribute to a high plant biodiversity. The Kirthar range starts from the Arabian Sea and extends about 300 km northwards to the Mula River in east-central Balochistan. Due to low rainfall, poor soil conditions, deforestation and grazing pressures these mountains are less rich in floristic diversity and are predominantly occupied by xerophytic plant species such as *Ziziphus nummularia, Salvadora oleoides*, *Dodonea viscose*, *Grewia tenax* and *Capparis deciduas* (Enright *et al.*, 2005, Perveen & Hussain, 2007). The Sulaiman Mountains are a major geological feature of the northern Balochistan province of Pakistan that extend westward to the Zabul province in Afghanistan and northward to the Hindu Kush. The vegetation is sparse and scattered in the form of tufts of grasses and thorny plants; *Pinus gerardiana* (Chilghoza) forests are exceptional to this range. Being situated at lower latitudes and with infrequent summer precipitation, the Kirthar and the Suleiman ranges support subtropical thorny vegetation (Champion & Harry, 1965, Dasti *et al.*, 2010).

The Hindu Kush mountain range stretches 800 km between the Suleiman range (from the south west) the Himalayas (from the east) and the Karakuram (from the north east) forming the geopolitical boundary of Pakistan and Afghanistan. The forest areas of the Hindu Kush are represented by *Cedrus deodara*, *Picea smithiana*, *Pinus wallichiana*, *Pinus roxburgii* and *Abies pindrow* especially in wetter areas that come under the influence of the monsoon. The altitudinal ranges of these native species are; *Cedrus* (2400 to 2900 m), *Picea*

(2800 to 3500 m), *Pinus* (2500 to 3400 m), and *Abies* (2500 to 3500 m). Other important woody plant species of the Hindu Kush range are *Taxus baccata, Quercus ilex, Quercus incana, Olea ferruginea, Juniperus macropoda, Ephedra gerardiana* and *Ephedra intermedia* (Chaudhri, 1963). The eastern part of the Hind Kush becomes more similar to the Himalayas in terms of climate and flora thus most bio-geographers term it the Hindu Kush-Himalaya (HKH) (Miehe *et al.*, 2009, Dong *et al.*, 2010).

The Karakorum Mountain range, which is about 500 km long, connects the plateaux of Tibet and the Pamir and forms a part of the political border between Pakistan, India and China (Xiang *et al.*, 2002, Phartiyal *et al.*, 2005 Eberhardt *et al.*, 2007, Marston, 2008, Khan *et al.*, 2009). The vegetation composition is mainly xeric in nature due to the cold climate. Vegetation zones can be categorized on the basis of humidity and elevation gradient from semi-desert, through montane shrub to alpine meadows. A few studies indicate the shrubby nature of the vegetation at lower altitudes (around 2700 m), with alpine pastures at higher altitudes (above 3500 m). Characteristic plant species of the Karakorum range are *Salix karelinii, Juniperus semiglobosa, Capparis spinosa, Artemisia scoparia, Artemisia brevifolia, Ephedra intermedia, Thymus linearis, Oxytropis humifusa, Carex plectobasis, Minuartia kashmirica Polygonum cognatum, Androsace baltistanica, Gentiana tianschanica, Poa sterilis, Geranium himalayense, Rhodiola pamiroalaica, Poa alpina, Sibbaldia cuneata,* and *Rheum spiciforme* (Miehe *et al.*, 1996, Eberhardt *et al.*, 2007).

The Himalayan range of mountains is about 2500 km long and 400 km wide and has a comparatively small part in Pakistani territory due to political boundaries. Plant diversity decreases with a decrease in the monsoon effect as one moves from south east to north west in the Himalayas. Other factors responsible for this decline are the increase in altitudinal and latitudinal gradients. Important indicator species of the Himalayan range are *Pinus wallichiana, Abies pindrow, Rhododendron* species, *Fragaria nubicola, Viola* species, and *Clematis* species. Floristically, the vegetation of the western and northern Himalayas becomes similar to respectively the Hindu Kush and the monsoon belt of the Karakorum in terms of species composition and richness, perhaps owing to geologic, physiographic and climatic correspondence. Characteristic species of this transitional belt of the western Himalaya, the southern Karakorum and the eastern Hindu Kush are *Cedrus deodara, Picea smithiana, Ephedra gerardiana, Thymus linearis* and *Cotoneaster microphyllus* (Zobel & Singh, 1997, Sheikh *et al.*, 2002, Kharkwal *et al.*, 2005b, Oommen & Shanker, 2005, Chawla *et al.*, 2008, Christensen & Heilmann-Clausen, 2009). Alpine and sub alpine habitats, where altitude becomes the most powerful limiting factor, further strengthen the floristic affinities with higher elevation vegetation of the Hinsu Kush and the Western Himalaya; characteristic species are of the *Juniperus, Poa, Sibbaldia, Geranium, Rhodiola, Rheum, Androsace, Iris, Primula, Potentilla* and *Polygonum genera* in these adjoining parts of these three mountain ranges (Miehe *et al.*, 1996, Pei, 1998, Hamayun *et al.*, 2006, Eberhardt *et al.*, 2007, Qureshi *et al.*, 2007, Wazir *et al.*, 2008, Ahmad *et al.*, 2009, Ali & Qaiser, 2009a). According to a review by Dhar (2002), the dominance of an endemic flora in the western Himalaya, especially at high elevations, indicates the high conservation importance of these ecosystems. This author further advocates that the timberline zones should be protected as priority regions (Dhar, 2002). In the Himalayas these conservation values are threatened due to human exploitation through a number of activities such as farming, herding, fuel, timber, and medicinal plant collection etc. Accordingly, mountain vegetation has become a significant focus in recent ecological, conservation and ethnobotanical studies (Hamayun *et al.*, 2003b, Parolly, 2004, Lovett *et al.*, 2006).

2.4 Botanical conservation

Natural plant biodiversity is the source of food, timber, shelter substance, fuel, ethno-medicines and number of other utilizations for millions of people. Vegetation not only provides services necessary for human survival but also supports the non-plant biodiversity (Giam *et al.*, 2010). Furthermore, continuity of agricultural crops depends upon the natural and wild flora of mountain regions which are responsible for the overall function and regulation of lowland ecosystems and also provide a potential source of genetic resources for crop improvement. Plant biodiversity is also vital for lessening the impacts of climate change and global warming (Feehan *et al.*, 2009). In mountain ecosystems a number of endangered plant species are on the verge of disappearance from their native habitats, especially because of their narrow ecological amplitudes. Special topography such as slope, aspect, and altitude provide characteristic spatial patterns for mountain ecosystem and processes (Radcliffe, 1982). The loss of diversity is often attributed to anthropogenic activities such as deforestation and introduction of invasive species for various purposes (Hobbs & Huenneke, 1992). Although some species are resilient to environmental modification and have a long history of cultural interaction, others are more fragile and cannot be recovered if once destroyed. Proper documentation and IUCN criteria can be assigned to plant species in mountain ecosystems. This provide an information about the existing threats to plant biodiversity, as well as the longer term trend and future risk of extinction (IUCN, 2003, van Vuuren *et al.,* 2006, Hayward, 2011). Additional measures like the one in which the Royal Botanic Gardens, Kew is developing the Millennium Seed Bank Project for wild species in a spirit aligned with the recommendation of CBD can also being undertaken in other parts of the world (Van Slageren, 2003).

Bringing sustainability into the use and management of non-timber forest products (NTFPs), and especially medicinal plant (MPs) collection in the Himalayas and other adjacent mountains, is a challenging task. In the Himalayan region there is a long established practice of curing diseases with ethno-medicines. Haphazard and uncontrolled collection of these plants has, however, caused increasing rarity of some of these species, many of which are now critically endangered and threatened. The marketing of these species, rather than just direct use, further worsens their conservation status (Rai *et al.*, 2000, Ghimire *et al.*, 2005).

In the Himalayas and in the majority of cases, policy makers and politicians have ignored the scientific evidence on plant biodiversity and threats to its survival when making decisions and taking decisions related to natural resource management. Effective management and conservation plans should be based on methodological approaches (Pullin *et al.*, 2004) but there have also been insufficient records of inventory based botanical studies in recent years. A similar situation applies also to the urgent need for qualitative assessment and conservation strategies for biodiversity in the near future (Ahrends *et al.*, 2011). In the scenario of possible future continuation of anthropogenic and climate driven alterations to ecosystems, proper assessment of plant biodiversity and of conservation priorities need to be ensured.

2.4.1 Mountains vegetation; a wider picture

Plants and plant communities survive at the edge of life in high mountains all over the world; these are also ecosystems where climatic change is more visible and where species extinction is very rapid (Kullman, 2010). Mountains are the most remarkable land forms on the earth’s surface with prominent vegetation zones based mainly on altitudinal and climatic variations. Aspect variation also enhances habitat heterogeneity and brings micro environmental variation in to the vegetation pattern (Clapham, 1973). High mountains all over the globe are important hot spots for endemic floras (Dirnböck *et al.*, 2001, Vetaas & Grytnes, 2002, Casazza *et al.*, 2005, Fu *et al.*, 2006, Casazza *et al.*, 2008, Nowak *et al.*, 2011) and (Halloy & Mark, 2003, Kazakis *et al.*, 2007,).

Mountain vegetation has manifold functions not only within the mountain system itself but also regionally in the adjacent lowland ecosystems by regulating floods and flows in streams. The Himalayas are the birth place of ten of the largest rivers in Asia and a large and important carbon sink. Economy of south Asian countries is mainly based on the flow of these rivers from the Himalayas. These rivers ensure food security by providing irrigation water for rice and wheat crops which are the major staple food (Archer & Fowler, 2004, Rasul, 2010,). Regionally, shrubby vegetation of high altitudes also regulates avalanche movements and protects soil (Hester & Brooker, 2007). Ecological changes in the Himalayas affect the global climate by bringing about changes in temperature and precipitation patterns of the world. Globally, these mountains also play important role in combating the climate change and greenhouse effects. The diverse Himalayan vegetation ranges from tropical evergreen species in the south east to thorn steppe and alpine species in the north western parts (Behera & Kushwaha, 2007). At high altitude, the extent of vegetation cover is related to the melting of snow. Irregular loss of its ice might have dangerous rise in world sea-levels (Xu *et al.*, 2009). These mountains are extremely sensitive to global climatic change (Thompson & Brown, 1992). Such hazardous glimpses have already been observed in the form of flood in Pakistan, India, china and Thailand in the last three years. They are also important places for investigating global warming and climate change.

2.4.2 Conservation efforts; a regional picture

The Himalayas, although possessing diverse vegetation, have not been examined thoroughly due to a number of climatic, socioeconomic and geopolitical constraints. Generally, natural resources are very diverse and vegetation types are highly varied in the Himalayas (Shrestha & Joshi, 1996). These mountains support approximately 18,500 plant species of which approximately 7,500 are medicinal species (Pei, 1998). Published literature on the Himalayas and adjoining mountain ranges within the national boundaries of Pakistan show that plant scientists have prepared inventories based on qualitative data either for ethnobotanical purposes or for flora writing (e.g., Shinwari & Gilani, 2003, Hussain *et al.*, 2007, Khan *et al.*, 2007a, Khan & Khatoon, 2007, Qureshi *et al.*, 2009, Ahmad *et al.*, 2009, Ali & Qaiser, 2009a). Although these types of botanical studies have a fundamental importance, the effective planning of conservation strategies requires broader quantitative data sets. In the case of phytosociological studies, most researchers have studied either qualitative characteristics of the vegetation or have recorded species importance value indices. A very limited number of studies have used modern numerical/statistical techniques to quantify and model plant species, communities and environmental as well as cultural drivers of vegetation variation, particularly in the distant and least accessible parts of these mountains. In addition, research on plant community identification and classification (using modern techniques) has so far been restricted to the plains and low altitude areas (Qureshi *et al.*, 2006, Malik & Husain, 2006, Dasti *et al.*, 2007, Malik & Husain, 2007, Perveen & Hussain, 2007, Saima *et al.*, 2009, Siddiqui *et al.*, 2009). Most of the remote mountainous areas should, however, be hotspots for vegetation studies due to their important phytogeographical location. One such area is the Naran Valley which occupies a transitional position between the Hindu Kush, Himalaya and Karakorum ranges. Apart from the scientific exploration of biotic and abiotic components of mountain ecosystems, there is an immediate need of facilitation, social mobilization and education for the people of these remote regions. Education and awareness about climate change, habitat destruction, decreasing biodiversity and increasing population are top priorities (Díaz *et al.*, 2006, Ma *et al.*, 2007, Hermy *et al.*, 2008, Giam *et al.*, 2010). The present project was initiated to furnish an account of the vegetation diversity both at species and assemblage levels in one remote mountain valley, with the crucial targets of understanding the environmental gradients responsible for the distribution of species and communities and the cultural gradients of vegetation utilization, and undertaking an assessment of anthropogenic pressures on plant species. In this study, a quantitative ethnobotanical approach (applied for the first time in this region) linked abundance and Importance Values (IV) of the plant species to the Use Values (UV) of the same species for better assessment of their conservation status.

Chapter 3 STUDY AREA – THE NARAN VALLEY, WESTERN HIMALAYAS

3.1 Introduction

This chapter provides an introduction to the study area and its main physiographic and floristic features with reference to present vegetation study and sampling locations. The various mountain ranges that are collectively known as the Himalayas stretch for some 2500 km across five central Asian countries and comprise one of the Earth's most complex, diverse and remarkable biomes, characterized by a comparatively harsh climate, a strong degree of resource seasonality and diversity of both plant species and communities (Kala & Mathur, 2002, Oommen & Shanker, 2005). Existing in the range of world's largest mountain ranges north-western Pakistan, is one of the place having high phytogeographic and floristic importance. Due to their location, rugged landscapes and critical geopolitical situation, however, many of the more remote mountainous valleys in this region have not yet undergone detailed vegetation studies. Furthermore, most of the botanical accounts that have been published comprise qualitative data without proper quantification (Dickoré & Nüsser, 2000, Ahmad *et al.*, 2009, Signorini *et al.*, 2009). Far less effort has been made to provide quantitative descriptions of the plant communities along geo-climatic, environmental gradients in order to elucidate the main determinants of local or regional vegetation patterns (Dasti *et al.*, 2007, Malik & Husain, 2008, Wazir *et al.*, 2008, Saima *et al.*, 2009).

The Naran is a mountainous valley in the western Himalayas situated in Pakistan, some 270 km from the capital, Islamabad (34° 54.26´N to 35° 08.76´ N latitude and 73°.38.90´ E to 74° 01.30´ E longitude; elevation range 2450 to 5000 m above mean sea level). The entire area is formed by crosswise ridges of mountains on either side of the River Kunhar which flows in a northeast to southwest direction down the valley to the town of Naran. The River Kunhar has its source at Lake Lulusar near the Babusar pass at an elevation of 3455 m. It is bounded on the south east side by Azad Kashmir, on the north by Chilas and Gilgit agencies and on the west by Kohistan and Batgram districts and Mansehra tehsil. It forms the most northern part of British India and is now a part of the District Mansehra, Khyber Pakhtunkhwa, Pakistan (Fig. 3.1 & 3.2). Geographically, the Naran Valley is located on the extreme western boundary of the Himalayan range, from where after the Hindu Kush range of mountains start to the west of the River Indus. Floristically, the valley has been recognised as an important part of the western Himalayan province with some vegetation features that are Sino-Japanese in nature due to the influence of the rain-bearing monsoon winds (Ali & Qaiser, 1986, Takhtadzhian & Cronquist, 1986).

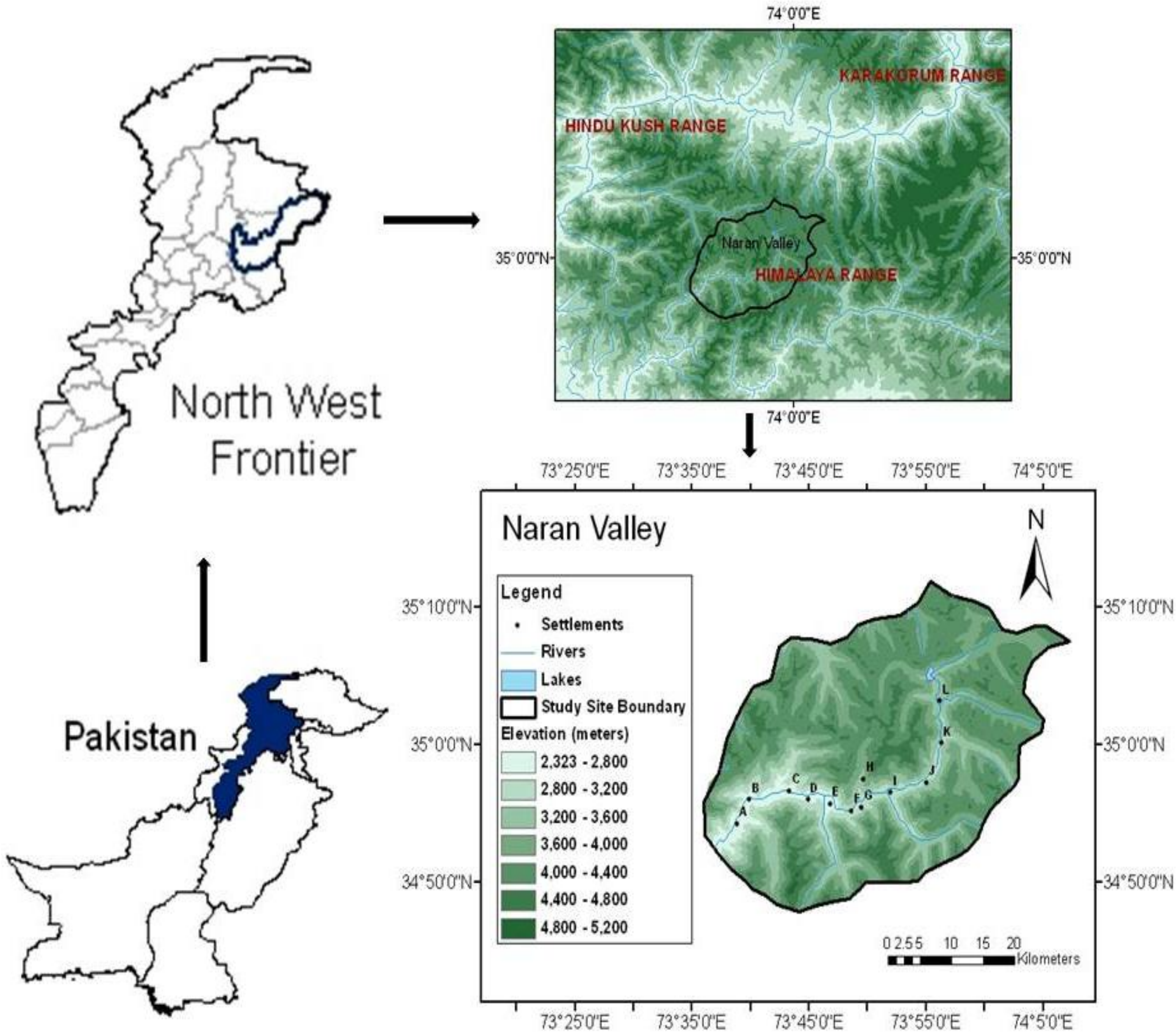


Fig. 3.1 Maps showing the location of the project area, the Naran Valley, with respect to Pakistan and the three largest mountain systems (the Himalayas, Hindu Kush and Karakorum), and the altitudinal range and position of the 12 sampling localities (A-L) in the valley (see Chapter 4 and 5 for more detail).

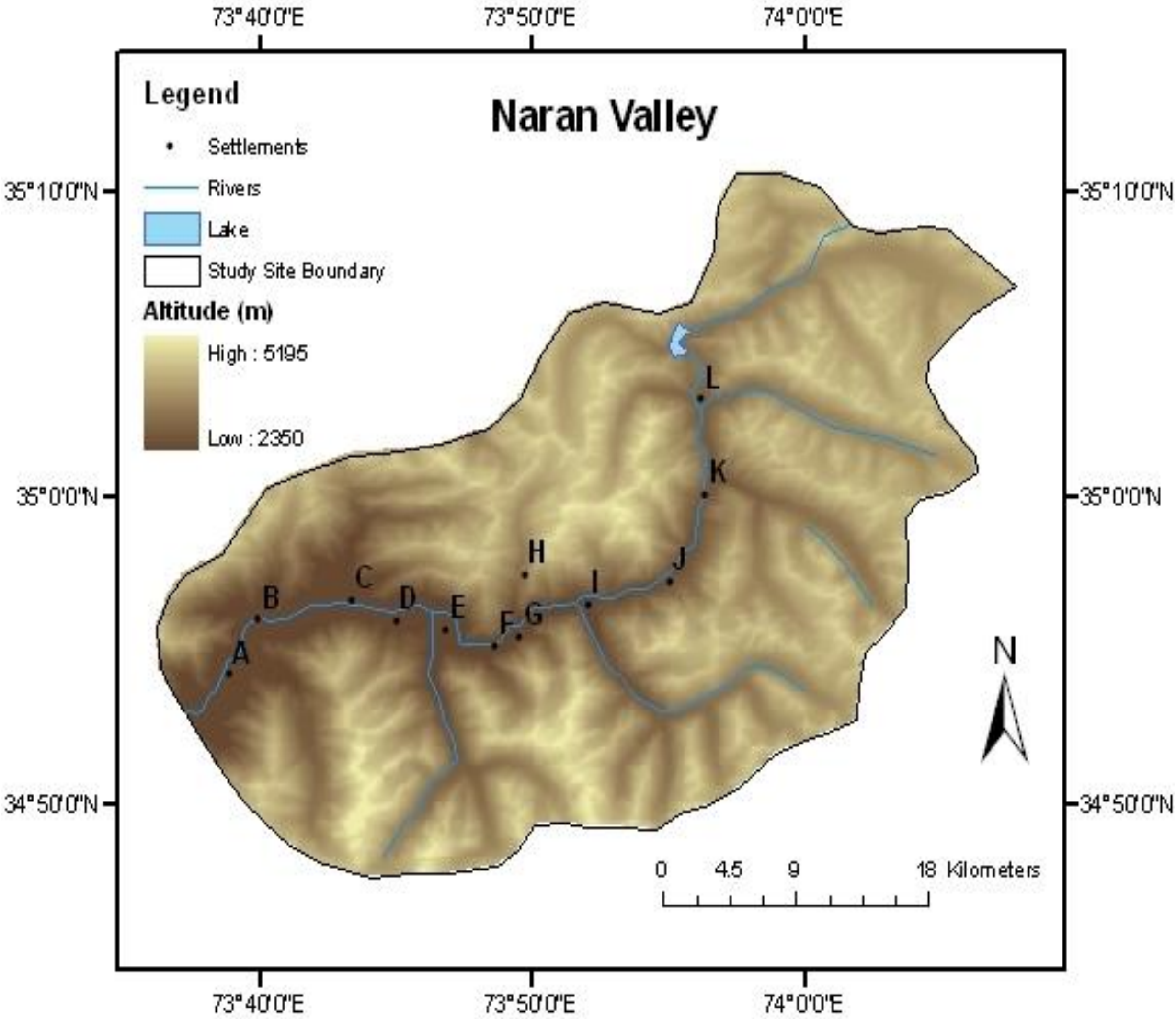


Fig. 3.2 Map of the Naran Valley (project area) showing elevation range and location of its settlements (A-L) nearby which phytosociological and ethnobotanical surveys were carried out.
(Elevation data were obtained from the ASTER GDEM, a product of METI and NASA)

3.2 Geology

The 2500 km long Himalayan range resulted from a continental collision between the Indian and Eurasian plates about 60 million years ago, causing an uplift process which is continuing even today. The Naran Valley is situated on the extreme north western margin of the Indian Plate (Fig. 3.3). The rocks of the valley can be subdivided into basement rocks of amphibolites, marble, dolomite, quartzite and deformed granite (O'Brien *et al.*, 2001, Foster *et al.*, 2002, Wilke *et al.*, 2010). Geologically the area is very important as the Kaghan/Naran ultrahigh-pressure (UHP) assemblage is at the exposed leading edge of the Indian plate continental crust, where it is still colliding against the Kohistan arc of the Eurasian plate (Clift *et al.*, 2008, Parrish *et al.*, 2006).

Fig. 3.3 Map showing the location of the project area with respect to its regional geological setting; the Naran Valley is located at the junction of the Indian and Eurasian plates (http://eol.jsc.nasa.gov/handbooks/arabianpages/platesmap.jpg)

3.3 Climate

Monsoon winds are the main source of precipitation and also a primary force controlling erosion and climatology and hence topography and vegetation in the Himalayas. In the western Himalayas and especially in the Naran Valley, high mountains situated at the opening of the valley act as a barrier to the incoming summer monsoon from the south and limit its penetration into the upper northern parts of the valley (Clift *et al.*, 2008, Syed *et al.*, 2010). Thus summers remain cool and relatively dry and most of the valley has a dry temperate climate with clear seasonal variations. Total average annual precipitation is low at only 900-1000 mm but there is heavy snowfall in winter which may occur at any time from November to April (average annual snowfall 3 m). The range reflects a sharp increase in depth of snow with increasing altitude. There is a distinct wet season in January – April, while the driest months of the year are June - November (Fig. 3.4).

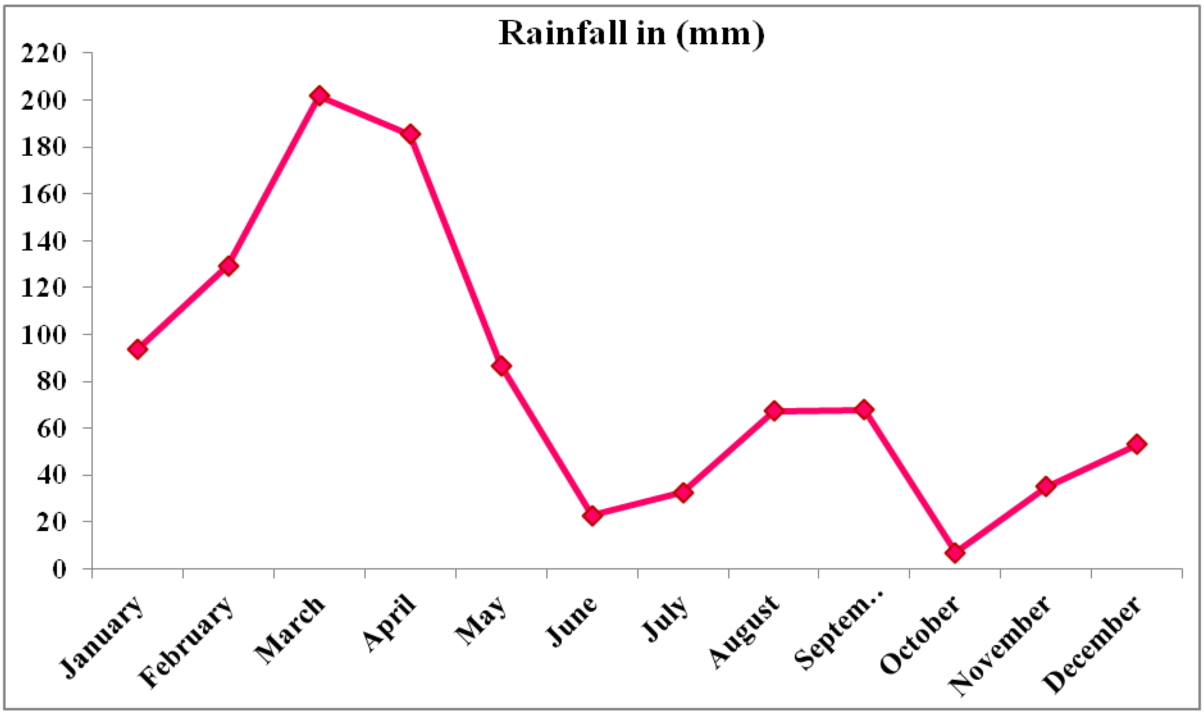


Fig. 3.4 Average monthly rainfall recorded in the Naran Valley over the period of 10 years 1998-2008 (Source; Department of Metrology Islamabad, Pakistan)

Most of the year the monthly average temperature remains below 10 °C. December to March, are the coldest months during which temperatures remain below freezing. June to August is the main growing season, with average daytime temperatures in the range of 15-20 °C (Fig. 3.5). Melting snow (May to September) is the main source of water for both plant growth and flow the River Kunhar and also gives rise to avalanches at the onset of summer which not only disrupt travel in the valley but also cause enormous erosion to habitats and damage to the vegetation (De Scally & Gardner, 1994) (Fig. 3.6).

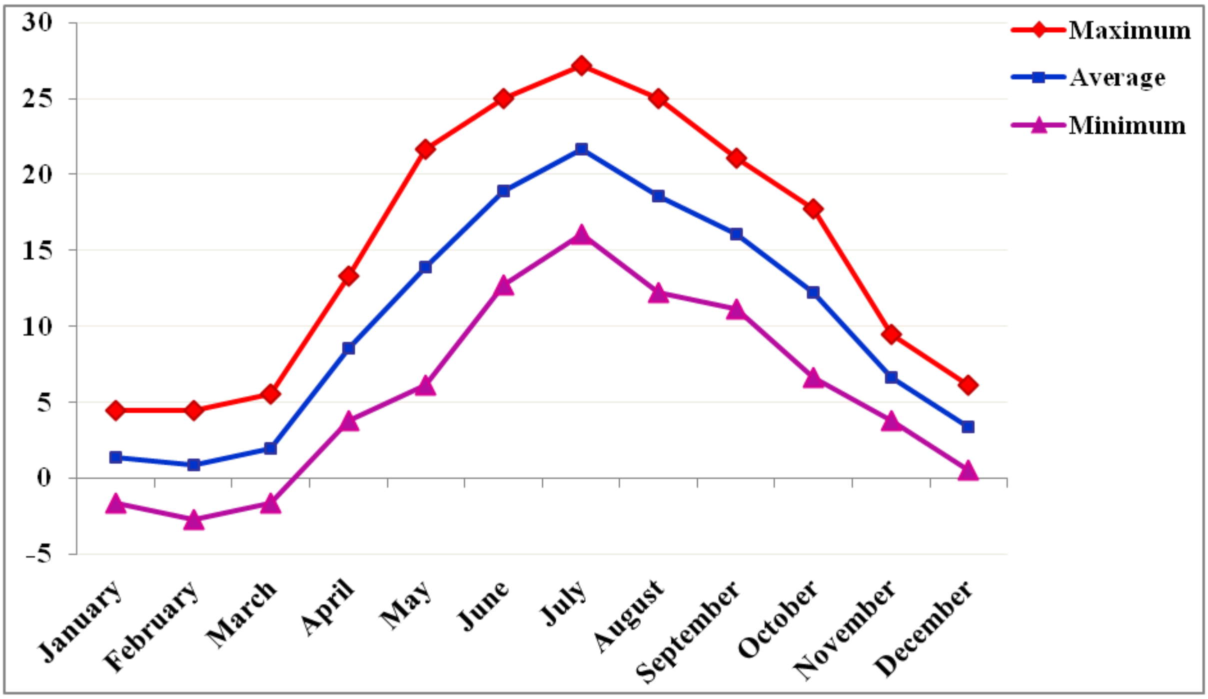


Fig. 3.5 Monthly minimum, maximum and average temperatures recorded at the town of Naran in the southern part of the valley (recorded at an altitude of 2450 m) for the years 1998 – 2008 (Source; Department of Metrology Islamabad, Pakistan)

Fig. 3.6 Picture showing avalanche near the village of Damdama (near the settlement 'B', is referred

to, on the area map, figures 3.1 and 3.2) in the Naran Valley; the snow has been excavated to make way for traffic

3.4 Biophysical Environment

Ecosystem studies of habitat types have not been undertaken extensively in Pakistan, especially in the Himalayan valleys. Champion *et al.*, (1965) described for the first time the forest types of Pakistan, using the following broad categories: swamps, dry sub tropical forests, tropical thorn forests, subtropical pine forests, Himalayan moist temperate forests, Himalayan dry temperate forests, subalpine forests, and alpine scrub. Beg (1975) defined major habitat types as tropical swamps, tropical thorn forests, tropical dry deciduous forests, subtropical semi evergreen forests, subtropical forests, moist temperate forests, dry temperate forests, subalpine forests, alpine vegetation and cold desert. All of these vegetation types, except the swamps, are represented in the northern part of the country (Champion & Harry, 1965, Beg, 1975).

The Naran Valley is situated on the extreme margin of the Western Himalayas and thus forms a part of the internationally recognized western Himalayan floristic province of the western Asiatic sub-region of Irano-Turania. Its geographical, geomorphological, geological, climatic and vegetational setting makes it somewhat transitional between the Himalayas, Hindu Kush and Karakorum ranges. This lends particular phytogeographical interest to the valley and its vegetation.

3.4.1 Vegetation

The vegetation of the western Himalayan Province is predominantly under the influence of monsoon winds and can be classified into different vegetational zones on the basis of temperature, humidity and altitude (Champion & Harry, 1965, Takhtadzhian & Cronquist, 1986). A brief description of the habitat types that occur within the Naran Valley and their associated vegetation is provided below.

3.4.1.1 Moist temperate

Evergreen forests with some mixture of deciduous broad-leaved trees occur across an altitudinal range of 2400-3100m asl; they are found as far north as the middle of the valley, mainly occupying the cooler, moister north facing slopes. These forests are dominated by conifers, in particular *Pinus wallichiana*, *Abies pindrow*, *Cedrus deodara* and *Picea* *smithiana*. The understory vegetation consists of both evergreen and deciduous species, amongst which the shrub species *Viburnum grandiflorum, V. cotinifolium* and *Sorbaria tomentosa* are important. Dominant herb species include *Achillea millefolium, Impatiens bicolor, Fragaria nubicola, Geranium spp., Viola spp.* and *Plantago spp.* (Fig. 3.7). This vegetation also provides a suitable habitat for the rare animal species.

Fig. 3.7 The Naran Valley showing moist temperate forests/habitats (in between the settlements 'A' & 'B', is referred to, on the area map, figures 3.1 and 3.2) at relatively low elevations and mostly confined to north facing slopes

3.4.1.2 Dry temperate

This habitat type is the most characteristic of the Hindu Kush mountain range, but also occurs in the inner ranges of the Himalayas and the Karakorum in the north-west. In the Naran Valley, this habitat is characterized by patchy shrubby species of *Artemisia, Ephedra, Cotoneaster, Rosa* and *Rubus spp.* at elevations of 2600-3100, particularly in the inner valley. Amongst the tree species of this zone *Juniperus excelsa* and a few evergreen species of *Pinus* *wallichiana*, *Cedrus deodara* and *Picea smithiana* are important. This habitat type receives usually low rainfall in summer and heavy snowfall in winter (Fig. 3.8) and is usually subjected to intense grazing and also partial use by Markhor (*Capra falconeri*) in the winter (Champion & Harry, 1965).

Fig. 3.8 Dry temperate vegetation/habitat, which mainly dominates in the middle section of the valley on southern slopes (picture was taken near the settlement 'G', is referred to, on the area map, figures 3.1 and 3.2)

3.4.1.3 Subalpine

This habitat type occupies a narrow zone between the coniferous tree line and the alpine pastures. The elevation range of this zone varies slightly from place to place, but is usually in the range 3100-3500 m. Important flora of this zone include *Betula utilis* at the tree line, along with species of *Juniperus*, *Rhododendron*, *Primula*, *Bergenia* and *Poa* (Fig. 3.9).

This habitat type is important for Snow Partridge (*Larwa larwa*) and Western Horned Tragopan (*Tragopan melanocephalus*).

Fig. 3.9 Subalpine vegetation/habitat occupies a relatively narrow zone and is replaced at higher altitudes by alpine grassland (picture was taken near the settlement ‘K’, is referred to, on the area map, figures 3.1 and 3.2)

3.4.1.4 Alpine pastures

This habitat type starts between 3300-3500 m where the coniferous tree line ends and the subalpine habitat merges in grass lands up to the altitude of 4500 m or above. This is a relatively productive habitat type and people use it for livestock grazing and collection of non timber products during the summer months. The vegetation is dominated by a number of herb species, including species of *Potentilla, Anemone, Gentiana, Poa, Polygonum, Iris* and *Aster*

(Fig 3.10). This habitat is typically inhabited by Snow Partridge (*Larwa larwa*) and Himalayan ibex (*Capra sibirica hemalayanus*).

Fig. 3.10 Alpine pastures above the tree line (picture was taken at an altitude of 3600m near the settlement 'E', is referred to, on the area map, figures 3.1 and 3.2)

3.4.1.5 Cold desert and permanent snow

These habitat types are found at the highest altitudes on only a few peaks in the valley. The vegetation of cold desert habitat is xerophytic in nature and emerges only for a very short growing period following snow melt. Typical plant species associated with this habitat type include *Gentianod* and *Polygonum spp.* Snow Partridge (*Larwa larwa*) and

Himalayan ibex (*Capra sibirica hemalayanus*) are found on the periphery of this habitat (Fig 3.11).

Fig. 3.11 Cold desert/permanent snow on the highest peaks in the valley. These habitats retain snow cover throughout much or all of the year and thus have an extremely short growing period (picture was taken above the settlement 'F' at an altitude of 4500m, is referred to, on the area map, figures 3.1 and 3.2)

3.4.2 Kunhar River

The Kunhar is the main river of the Naran Valley. It originates from Lake Lulusar and is joined by several other small tributaries (nalhas) at various locations on its journey, including the Gittidas Nalha, Jalkhad Nalha, Burwai Nalha, Wettar Nalha, Jora Nalha, Dadar Nalha, Shanak Nalha, Sapat Nalha, Kinarida Nalha, Barjalida Nalha and the Saiful Maluk

Nalha. The main sources of water to the main river and its tributaries are melting snow and natural springs, with a smaller contribution from rainfall during the summer (Fig 3.12).

Fig. 3.12 The River Kunhar flowing near the village of Soach in the Naran Valley (picture was taken from an altitude of 4000 m, above the settlement 'C' is referred to, on the area map, figures 3.1 and 3.2)

3.4.3 Lakes

The Naran Valley is also known as a 'land of lakes' due to the presence of nine lakes in the valley. The most important amongst these are Lake Lulusar, Lake Saiful Maluk, Dhodipatsar Lake, Anso Jheel (Lake), Jati Jheel and the Jalkhad Lake (Census Report 1998).

Further information on the two more spectacular and largest lakes, the Lake Lulusar and Lake Saiful Maluk, are given below.

3.4.3.1 Lake Lulusar

Lake Lulusar near the Babusar pass is a beautiful, natural lake surrounded by the mountains from all sides and located at an elevation of 3455m. It forms the source of the River Kunhar and also the upper limit of the Naran Valley. This is an irregular shaped lake about 300 m wide and 2.5 km long (Fig 3.13). The Naran Valley is blocked at the end of the lake by mountains but a pass allows a rough way to cross over into the Chilas Valley (a tributary valley of the Indus River). This is the 4,173 m high Babusar Pass which provides views of the Nanga Parbat (The Naked Mountain, 8,126 m).

Fig. 3.13 Lake Lulusar; the source of the River Kunhar and the end point of the Naran Valley, western Himalayas (near settlement 'L' is referred to, on the area map, figures 3.1 and 3.2)

3.4.3.2 Lake Saiful Maluk

Lake Saiful Maluk is one of the most famous and beautiful lakes in the Himalayas. It is about 500 m long and 460 m wide, situated at an elevation of 3220m, near Naran town in a tributary valley and in the shadow of the Malika Parbat (Queen of the Peaks, 5,290 m). It gives rise to the Saiful Maluk stream (nalah), which merges with the River Kunhar at the edge of Naran town. It is an important tourist spot in the valley and people come to see the spectacular scenery and hear the local legend about the prince Saiful Maluk who fell in love with a fairy named Badri Jamala (Fig 3.14).

Fig. 3.14 The Lake Saiful Maluk situated at a distance of about 6 km from the Naran town (settlement 'A' is referred to, on the area map, figures 3.1 and 3.2) is one of the region's most beautiful lakes and a famous tourist spot

3.4.4 Peaks

There are a number of peaks in the Naran Valley, amongst which the highest is the Malika Parbat which rises on the north eastern boundary of Lake Saiful Maluk, to an elevation of 5290 m (Fig 3.15). Other high peaks are Shikara and Bichfa (both having a height of 4877m), and Bogi and Raja with heights of 4852 m and 4720 m, respectively (Fig 3.16).

Fig. 3.15 The Malika Parbat (Queen of the Peaks, 529 m) is situated immediately to the north east of Lake Saiful Maluk

Fig. 3.16 The Bogi peak (4852 m) (picture was taken near the settlement 'J', is referred to figures 3.1)

3.5 Agro-ecology and important agricultural crops

The harsh climate in this high altitude valley means that the growing season is reduced to a very short summer and hence agricultural activities are limited. The whole area is mono-cropic i.e., only one crop can be grown in a year, and only summer (Kharif) crops are cultivated. The main crops are potatoes and peas. Recently with the help of Germany, the Government of Pakistan has established a research station at the upper Batakundi village, for the production and provision of potato seeds (tubers) to the local farmers (Fig. 3.17 & 3.18).

Fig. 3.17 View from Lalazar near Batakundi, taken in early August, 2009 showing crop fields of potatoes and peas (picture was taken near the settlement ‘D’, is referred to, on the area map, figures 3.1 and 3.2)

Other crops are maize, rye, wheat, red beans and cauliflower, but with less frequency and production. Fruit trees including pears, plums, walnuts and apples are also grown in the area but less frequently. A lack of financial support and poor communication and transport links are the main hurdles to improved practices of land development and agriculture. The River Kunhar and its tributaries provide water for irrigation in summer, whilst natural springs and streams are the main sources of drinking water (Iqbal, 1986) (Fig. 3.18).

Fig. 3.18 Crop fields at the Batakundi research station showing peas and potatoes at the end of July, 2010 (near settlement ‘E’, is referred to, on the area map, figures 3.1 and 3.2)

3.6 Demography of the main villages of the valley

The population of the Naran Valley is exclusively rural and mostly people live in temporary settlements and even in tents in the upper parts of the valley due to the prevailing high levels of poverty and harsh climate. The local economy is mainly based on farming and rearing of live stock. Although exact data on the population of this area are not available because most of the inhabitants are seasonal migrants or nomads and their number varies according to the season, it is believed that approximately 22,000 people inhabit the valley each year (Fig. 3.19).

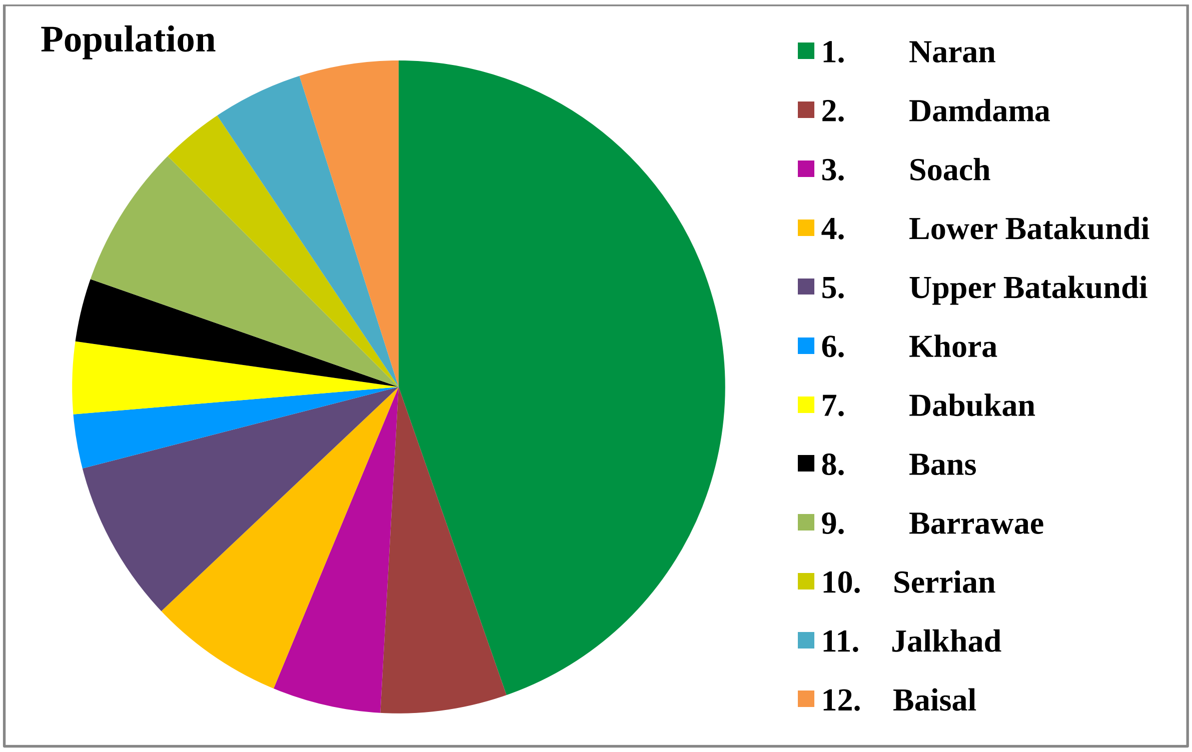


Fig. 3.19 Distribution of total human population of about 22,000 among the 12 main localities of the Naran Valley, western Himalaya, Pakistan

3.7 Main localities (villages of the Valley)

Severe winter weather compels the inhabitants of the Naran Valley to follow a nomadic lifestyle, with many people making temporary arrangements to reside at high altitudes during the summer months and returning to lower altitudes during the winter. The following sections provide brief descriptions of some of the more important villages/localities of the area.

3.7.1 Naran town

The name of the valley is attributed to the small beautiful Naran town situated at the junction of the River Kunhar and the Saiful Maluk stream (34° 54.423´North latitudes 073° 39.034´ East longitudes, 2451 m). About half of the population of the valley (10,000) reside in the Naran, which not only serves as a base for the whole valley but also as the entry point to the tributary valley of the Lake Saiful Maluk. From here one can ride a jeep or horse or hike on foot to several picturesque lakes, tributary valleys, landscapes and peaks. The people of Naran town are semi nomads and most of them migrate to the plains during the winter season. The economy of the residents is primarily based on agriculture, domestication of animals and trade in forest products, whilst some also own restaurants, hotels and shops. There are a few water mills and a small power station. Tourists come for picnics and to stay in the Naran during the summer season.

Fig. 3.20 Pictures giving glimpse of the ecotourism; Hotels near the Naran Village on the bank of the Saiful Maluk stream/tributary

3.7.2 The lower and upper Batakundi

The economy of these two villages (34° 55.180´north latitudes and 073° 46.620´ longitudes (lower) and 34° 55.250´ north latitude and 073° 46.660´ (upper), 2610 and 2540 m, respectively, is based on farming and rearing of live stock. Potatoes and peas are cultivated widely as both the villages occupy much of the plain area compared to other localities. The main source of irrigation is the River Kunhar, its tributaries and springs. Each village has two primary schools each for boys and girls.

Fig. 3.21 Terrace cultivation (after deforestation) near upper Batakundi village, July 2009 (picture was taken near the settlement ‘E’, is referred to, on the area map, figures 3.1 and 3.2)

3.7.3 Barrawae

Barrawae village (34° 56.344´ north latitudes 073° 52.034´ east longitudes, 2903 m) is located in a region that is under the ownership of Muzamil shah a lord (Syed) of the Kaghan. There are primary schools for boys and girls. The people are nomadic, dwelling in the area during the summer and returning to the lower villages of Kaghan, Mhandri, and Jarid etc. during the winter months (Fig. 3.22).

Fig. 3.22 Fields being prepared for potato crops near Barrawae village, June 2010 (picture was taken near the settlement ‘I’, is referred to, on the area map, figures 3.1 and 3.2)

3.7.4 Jalkhad

Jalkhad village (35° 00.065´ latitudes and 073° 56.333´ longitudes at 3120 m) is located between Barrarwae and the Baisal. This region is in use of the Pakistani Army, whilst the inhabitants include Gujars and Pathans. The economy of the local people is mainly based on livestock raising (goats and sheep), as the climate is less suitable for crop production in the upper parts of the valley, although people also cultivate potatoes and peas but on a smaller scale compared to the villages lower down the valley. The people migrate to the plain areas during the winter season.

3.7.5 Baisal

Located near Lake Lulusar at 3220 m (35° 02.322´ north latitudes and 073° 56.183´ longitudes), this settlement comprises a few grazers/nomads who live here in temporary shelters/tents during the summer. Lake Lulusar is located at a distance of about 5 km from Baisal towards the north (Fig. 3.23).

Fig. 3.23 The Tent Village of grazers at the Baisal 'L', referred to area map' (the last village of the valley, above 3200 m)

The names of other main villages referred to in this study are Damdama, Soach, Khora, Dabukan and Bans.

3.8 Ethnology

Various tribes including the Gujars, Syeds, Swati and Kashmiri inhabit the valley. The most important among these are the Gujars (descendents of the Indian Arians) who are famous for their individual culture, way of life, rituals and bravery. The Gujars are concentrated in the upper parts in most of the valleys in Pakistan where they cultivate rain-fed slopes, and are generally more aware of traditional knowledge of plant use and local ecology (Ahmad *et al.*, 2009). The Gujars were designated by the British as a Martial Race that were thought to be naturally strong in battle, and possessing qualities like courage, faithfulness, autonomy, physical strength, discipline and firmness. They are the original inhabitants of the Indo-Pak sub-continent (Chauhan, 1998). Their life is very harsh and, to some degree, comparable to the prehistoric people. They are very hard working people and easily face any ruthless situation, particularly natural hazards and climatic constraints. They migrate to the upper parts of the Naran Valley with their livestock in the summer and come back to the plains during the winter (Lyon, 2002). The Gujars have their own specific language called Gujri which is among one of the most ancient languages of the world. The origin of Gujri goes back to 400 B.C. and it has a rich vocabulary. It is also considered to be the mother tongue of the present day Urdu and Punjabi languages (Wayne, 1996).

Amongst the other main tribes in the Naran region are Swati (who came from the Swat Valley about 500 years ago) are descendants of the ancient Kushan dynasty, and Syeds who are the religious people of the area. These tribes in combination form the major population and have inhabited the Naran Valley since at least 300-400 years ago (Bellew, 1994). Most of the people speak the Gujri or Hindko languages.

3.9 Livelihoods

Human life in the Naran Valley is a continuous challenging effort for survival. Usually people have more than one type of occupation in order to maintain a sustainable livelihood. Usually every household keeps grazing live stock, the numbers and types of which vary from a few to hundreds. In the lower and middle valley the second most common profession is growing crops. Most of the people execute these two professions simultaneously. Having cultivable lands and a more moderate climate people grow crops in the lower valley which gradually decrease along the valley with altitudinal increase and disappear at the valleys upper boundaries. The people of the upper valley mainly rely on rearing livestock and collection of wild plants. Grazing livestock is dominant in the valley (Fig. 3.24).

Fig. 3.24 Herd of sheep and goats grazing on a southern slope immediately after snow melt. Rearing sheep and goats is one of the main sources of livelihood in the Naran Valley (picture was taken near the settlement 'D', is referred to, on the area map, figures 3.1 and 3.2)

3.10 Summary

As a whole, the Naran Valley occupies a highly important geo-climatic, geologic and geopolitical location. Geographically, it is located at the extreme west end of the Himalayan range, from where after the Hindu Kush range of mountains starts on the east side of the River Indus. Climatically, it is situated at the point where the summer monsoon is blocked by the lofty mountains of the lower Kaghan valley. Geologically, the area is very important as it is located on the extreme margin of the Indian Plate where it is still colliding with the Asian plate. Its geopolitical importance is also high as the north-eastern parts adjoin the disputed Kashmir region. Its special physiographic, climatic and geological history have contributed to make this area distinctive in floristic terms, but the tense geopolitical situation in adjacent border areas has limited intensive vegetation exploration. The present effort is the first ever systematic investigation of the area in terms of vegetation classification and ecosystem services.

Chapter 4 CLASSIFICATION AND ORDINATION OF VEGETATION ALONG ENVIRONMENTAL GRADIENT

4.1 Introduction

This Chapter is based on the data from the first field campaign and comprises a discourse about phytosociological methodology, statistical analyses, results and discussion. Data were collected using phytosociological techniques during summer 2009. Data matrices were analysed using three different computer programs i.e., MS EXCEL 2007, PC-ORD version 5 (McCune, 1986, McCune & Mefford, 1999) and CANOCO version 4.5 (Ter Braak, 1986, Ter Braak, 1987, ter Braak, 1989, ter Braak & Smilauer, 2002).

Classification of natural ecosystems into potential plant communities and habitat types is important for the long-term conservation of natural resources. Ecologists always try to understand the variation in species diversity along the environmental gradient like altitudinal gradient in mountainous ecosystems (Lomolino, 2001, Vetaas & Grytnes, 2002). Variation in species diversity along environmental gradients has been a major topic of ecological study in recent years and has been explained by reference to climate, productivity, biotic interaction and habitat heterogeneity (Givnish, 1999, Willig *et al.*, 2003, Currie & Francis, 2004). In mountainous regions altitude has a much greater effect on temperature and the rate of decrease is much more rapid in summer and this ultimately causes the altitudinal limits of plant species and vegetation types (Vázquez G & Givnish, 1998, Heaney, 1989). It is impossible to count each and every plant present for determining composition, abundance and cover of plant species. Keeping the objective and the vegetation pattern of the study area in mind, a number of samples can be taken from the area as representative of the whole region (Moore & Chapman, 1986). The most common quantitative sampling methods are the quadrat and lines transect methods. The two methods are used together when sampling an area contain heterogeneous landscape (Goldsmith *et al.*, 1986, Everson & Clarke, 1987b). Use of multivariate statistics has become very popular in community ecology in the last few decades. It helps ecologists to discover structure in the data set (Anderson *et al.*, 2006, Clymo, 1980). The development of recent computer technology has also provided new software packages for vegetation assessment e.g. PCORD, CANOCO etc. Ecologists have worked out vegetation classification and mapping in the developed world (Brown *et al.*, 1993a, Brown *et al.*, 1993b, Bork *et al.*, 1997, Chytry & Otypkova, 2003, Zhang *et al.*, 2008, Niedrist *et al.*, 2009, Zhang *et al.*, 2009) but in the developing world still number of areas need to be explored and mapped for their vegetation using modern ecological tools. A review of the literature showed that community classification based on these robust approaches had not been done for the Western Himalayan vegetation including the Naran Valley. The present project is the first to give a general account of the major plant communities, with the crucial target of understanding the factors responsible for distribution of plant species and to contribute to an improved knowledge of the vegetation of Pakistan. Secondly, (and also for the first time) the abundance of plant species (measured using phytosociological techniques) is linked to the use value of the same species (from ethnobotanical studies) in order to understand the provisioning services of the ecosystem, and to assess the anthropogenic pressures on the species by identifying the relation between abundance and uses. This study will also help to open a new gateway to understand conservation measures for specific species.

4.2 Materials and methodology for first field work

The first phase of field work was carried out during summer 2009 using phytosociological techniques. Quantitative attributes i.e. density, cover and frequency of each vascular plant species were measured along altitudinal transects using a quadrat method (Appendix 4.1). The whole valley (about 60 km long) was divided into 12 sampling localities at about 5 km intervals (here after indicated by the first 12 English alphabet letters A-L in analyses and figures) (Fig. 3.1, Fig. 4.1 & Appendix 4.2). For a better understanding of vegetation structure and diversity variation both altitude and aspect were kept in mind during sampling. To study both the northern (North western facing slopes; stations specified by capital letters A-L in analyses) and southern aspects (South eastern facing slopes; stations specified by small letters a-l in analyses), 12 altitudinal transects were established on hill side with each of these aspects perpendicular to the River Kunhar at each locality (site), with a total elevation range of 2450- 4100 m.

4.2.1 Sampling Procedure

A stratified random method was used to sample the area with rectangular quadrats of varied sizes for trees, shrubs and herbaceous vegetation respectively. Changes in quadrat size based on the minimal area method were introduced where necessary. Aspect and altitude have a great influence on vegetation structure in mountainous areas and hence a stratified random approach was employed to cover maximum data along such environmental gradients. The use of quadrat along transects is the best way to assess vegetation in such varying landscape (Everson & Clarke, 1987a, Cox, 1996, Goldsmith *et al.*, 1986). The following steps were sequentially met during vegetation sampling.

1) The whole valley was divided into 12 localities (sites) for quantitative sampling (Fig. 4.1)
2) Both southern and northern aspects (slopes) were selected at each locality (Fig. 4.1) (Total of 24 transects, 12 at each aspect).
3) Mature, accessible and least possible disturbed vegetation was sampled through quadrats at each of 24 transects/sites.
4) Ropes, steel rods and measuring tapes were used for making quadrats. The typical quadrat size used in this study was 10 x 5 m (for trees layer), 5 x 2 m (for shrub layer) and 1 x 0.5 m (for herb layer) (Fig. 4.2).
5) Each transect was started from the bed of natural stream (in most cases the River Kunhar) at each study site and was carried on along the full altitudinal gradient (bottom to peak or ridge of the mountain; perpendicular to River Kunhar).
6) Along each transect, plots (hereafter called stations/samples) were established at 200m elevation intervals (144 stations in total).
7) At each station 3 quadrats (1 each for tree, shrub and herb species) were used. Two replicate sub stations were also established at 100m distance on either side of the first one, at the same altitude with the same number of quadrats. Thus 9 quadrats were established at each station/sample (Fig. 4.3).

As a whole 1296 relevés/quadrats (432 each for tree, shrub and herb species) were recorded at a total of 144 stations. A summary of the sampling procedure is given in Fig. 4.1.

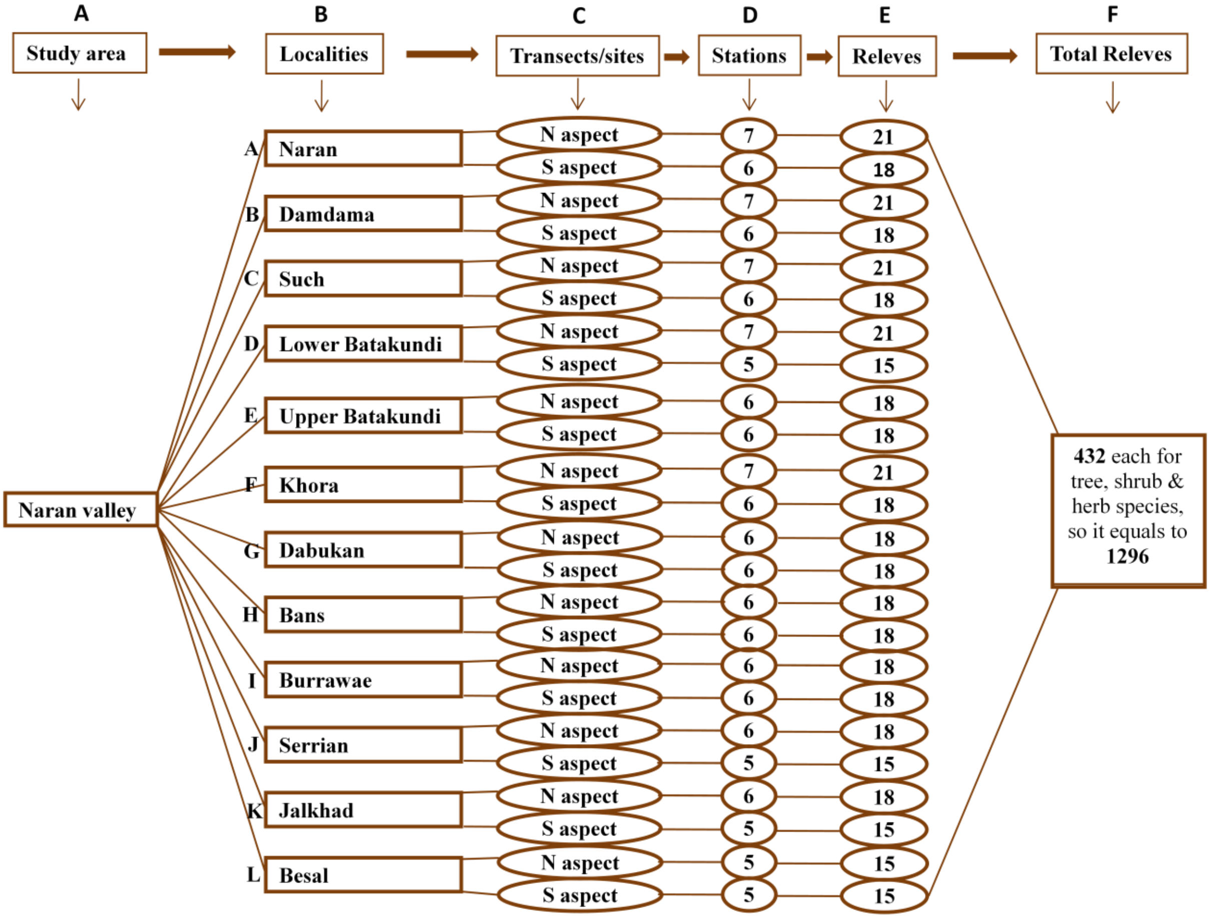


Fig. 4.1 Summary of the sampling procedure in the Naran Valley, Western Himalaya: Column wise; (A) The Naran valley {The study area; 60 Km long valley}; (B) 12 {A-L} names of sampling localities; (C) N aspect = North west facing slopes, S aspect=South east facing slopes {12 + 12 = 24 transects/sites}; (D) Stations = the number of sampling points (stations) at each 200 m elevation along each transect/site}; (E) Relevés/quadrats = the number of relevés/quadrats at each station (F) Total relevés = Total number of relevés/quadrats used in the field survey each for tree, shrub and herb species

4.2.2 Vegetation and floristic data collection

The vegetation was sampled in three layers i.e., trees, shrubs and herbs. Trees had a height of ≥ 5 m; shrubs were all woody species of height 1 and 5 m; the herb layer comprised all herbaceous species less than 1 m in height. The presence of all vascular plants was record on pre-prepared data sheets (1, 0 data) (Appendix 4.1). For the tree layer, the diameter of trees at breast height was measured using diameter tape. This enabled an assessment of tree cover values in the quadrats. For the shrub and herb layers abundance/cover values were visually estimated according to a regulated Braun–Blanquet scale later on modified by Daubenmire (table 4.1) (Braun-Blanquet *et al.*, 1932, Daubenmire, 1968). Absolute and relative values of density, cover and frequency of each vascular plant species at each station, were calculated using phytosociological formulae (table 4.4) (McIntosh, 1978).

Fig. 4.2 Measuring diameter of tree species through diameter tape in a 10 x 5 m quadrat

Table 4.1 Braun Blanquet covers classes modified by Daubenmire

Cover Class	Range of Percent Cover	Midpoint
1	0-5%	2.5%
2	5-25%	15.0%
3	25-50%	37.5%
4	50-75%	62.5%
5	75-95%	85%
6	95-100%	97.5%

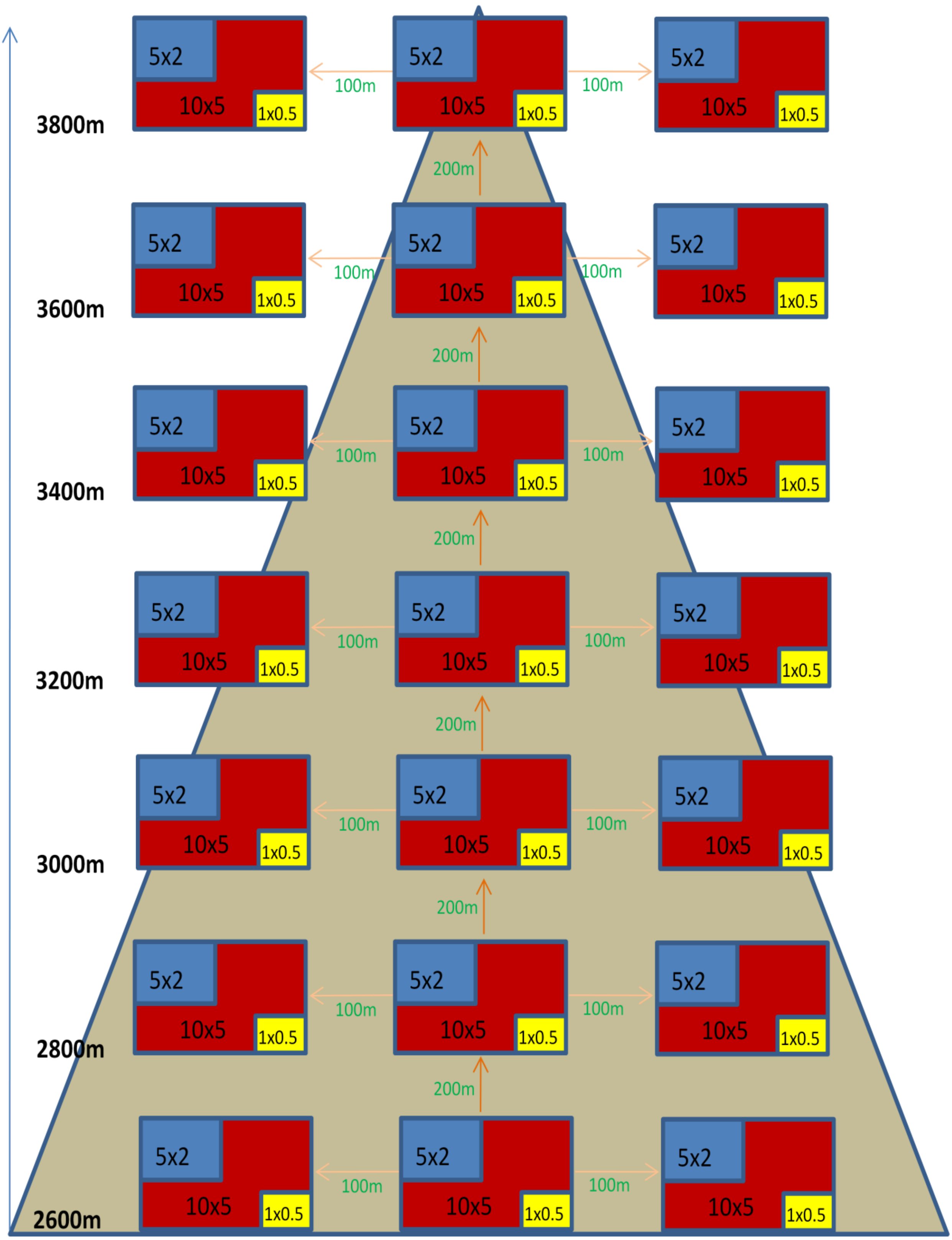


Fig. 4.3 Sketch of quadrat set up along each altitudinal transect on mountain slopes (a total of 24 transects) 12 each on northern and southern aspects: quadrat sizes, 10 x 5 = 50m^2 for the tree layer; 5 x 2 = 10m^2 for the shrub layer; 1 x 0.5 = 0 .5m^2 for herb layer.

4.2.3 Calculation of Importance Value Index and the concept of dominant species

In the past it was a common technique to classify plant communities based on the Important Value Index (IVI) values of the plant species. In this sort of characterization and classification in phytosociology, the species with highest IV are considered as dominant plant species and communities are attributed based on this. Even today it is a very common method of classifying plant communities. The present day revolution of computer based technology in every field of science has modified these older techniques. In this study, IV data are used mainly for ordination purposes and comparison with Use Value (UVs) data in Chapter 6. The Importance Values (IVs) were calculated by adding the values of relative density, relative cover and relative frequency and then dividing by 3. For full details of the IVI see Appendix 4.5.

4.2.4 Measurement of environmental variables

At each of the 144 relevés stations the following environmental data were also collected. Altitude data for each station at each of the 200 meter elevations along transects was obtained using a GPS (Garmin eTrex· HC series, vista HCx); Measurement of longitude and latitude were also recorded. Aspect (Slope) direction was recorded using the compass in the GPS. Soil pH was measured using a pH kit (Merck KGaA Germany). An iron rod of one meter length with pointed head was used to measure soil depth in three classes (Table 4.2). Grazing pressure (intensity) was recorded on a scale of 1- 5 by noticing the recent signs, intensity and trampling effects of grazing grazing live stock. For further detail of the environmental data see Table 4. 2 and Appendix 4.2.

Table 4.2 Assortment of various classes to environmental data and class codes

Class Code	Grazing Pressure category	Soil depth in cm	Aspect (Slope) of mountain
1	Very low/None	0-50	South facing (S)
2	Low	50-200	North facing (N)
3	Moderate	>200	
4	High		
5	Very high		

4.2.5 Identification of plant species and life forms

Herbarium specimens of all plant species were collected at each station and identified based on the Flora of Pakistan (Ali, *et al.,* 1972-2009). These specimens were dried, processed, mounted on standard herbarium sheets and submitted to the Herbarium, Department of Botany, Hazara University Mansehra Pakistan.

The plant life forms were specified according to the major divisions of the Raunkiaer life form classification (Raunkiaer, 1934) (Table 4.3).

Table 4.3 Raunkiaer Life form Classes; 1-5

Raunkiaer Classes	Description
1	**Phanerophytes:** Woody species with perenating buds emerging from aerial parts
2	**Chamaephytes:** Species with perenating buds born on aerial parts but close to the ground (no more than 25 cm above the soil surface).
3	**Hemicryptophytes:** All above ground parts of the plant die back in unfavourable conditions and buds are born at ground surface.
4	**Cryptophytes (Geophytes):** Plant species with buds or shoot apices which survive the unfavourable period below ground or water
5	**Therophytes:** Plant species survive unfavourable condition as seeds (annuals)

4.3 Data analysis

Data for 198 vascular plant species, 5 environmental variables and 144 stations/samples (1296 relevés) were analysed in three different computer programmes i.e., MS EXCEL 2007, PC-ORD version 5 (McCune, 1986, McCune & Mefford, 1999) and CANOCO version 4.5 (ter Braak, 1988, ter Braak, 1989, ter Braak & Smilauer, 2002). Step wise details for analyzing the data are provided below. As phytosociology is concerned with the vegetation, the environmental variables related with those sites need to be examined in a statistical framework (Lambert & Dale, 1964, Kent & Coker, 2002). Use of multivariate statistical analysis in ecology has enormously increased in the last few decades. Phytosociologists often need to test hypotheses regarding the effects of investigational factors on whole groups of species (Anderson *et al.*, 2006). The development of the above mentioned computer packages are the latest advancements in the field of community ecology which provides a new approach to vegetation classification and ordination (Gilliam & Elizabeth, 2003, Hettrich & Rosenzweig, 2003). These analyses have been elucidated according to the methods and techniques suggested by Greig-Smith, (1983), Mueller-Dombois & Ellenberg, (1974) and Rieley & Page, (1990).

4.3.1 Qualitative and quantitative attributes analyses using MS EXCEL 2007

MS EXCEL 2007 was used for a range of basic computations.

4.3.1.1 Computation of species attributes

Absolute and relative values of qualitative characteristics (presence/absence) and quantitative attributes (Density, Cover & Frequency) of vascular plants present in different sized quadrats (9 quadrats) at each of the 144 stations (each at 200 m elevation intervals) along 24 altitudinal gradients were calculated using various formulae (Curtis & McIntosh, 1950, McIntosh, 1978). MS EXCEL was also used for the calculation of constancy and percent constancy of the species in each community as specified by PCORD. For details see table 4.4.

Table 4.4 Formulae used for the measurement of various phytosociological attributes

S. No	Species attributes	Formulae
1	Density	No. of individuals of a species in all quadrats / Total area sampled
2	Relative Density	Density of a species x 100 / Total density of all species
3	Cover	Total cover (m^2) of a species in a quadrat / Total Area sampled (Quadrat area)
4	Relative Cover	Total cover (m^2) of all plants of a species x 100 / Total cover (m^2) of all plants of all the species
5	Frequency	No. of quadrats in which a species occurs x 100 / Total No. of quadrats used during sampling
6	Relative Frequency	Frequency of a species x 100 / Total frequency of all species
7	Importance Value	Relative density + Relative cover + Relative frequency / 3
8	Constancy	No. of samples (per community) in which a sps occurs x 100 / Total No. samples constitute a community
9	Presence	No. of communities in which a species occurs x 100 / Total No. communities or stands
10	Fidelity	See table 4.5

4.3.1.2 Organizing data for PC-ORD and CANOCO

After calculation of qualitative and quantitative attributes for each of the 144 stations using the formulae given in table 4.4, two groups of data matrices were produced in line with the requirements of the PC-ORD and CANOCO programmes. The first group included species matrices (for all 198 plant species recorded in the quadrats), for both species qualitative characteristics (presence/absence data) and quantitative characteristics (density, cover, frequency, relative density, relative cover, relative frequency and Importance Values) at 144 stations. The second group comprised the environmental data for each station. All the environmental variables were treated as independent variables while quantitative attributes of plant species were considered as dependent variables.

4.3.1.3 Graph production

MS EXCEL was used to graphically display the floristic and climatic data, including plant habit form, Raunkiaer life form, 19 most representative families and change in species diversity and richness with altitude.

4.3.2 Vegetation analysis using PC-ORD

Community ecologists often analyze data by classification and ordination in order to explain and understand plant community distribution. Computer based classification assisted by a multivariate statistical approach was used. PC-ORD version 5 was used to find the groups of stations/habitat types and plant species. The objectives were to bring the data sets to a low dimensional space for further interpretation, to identify plant communities, habitat types and their respective indicator species. Various classification techniques were applied i.e., Cluster Analysis (CA), Two Way Cluster Analysis (TWCA) and Indicator Species Analysis (ISA), (Dufrêne & Legendre, 1997) were used for classifying plant communities. Numerical classification as an explorative method was used to identify pattern and order in the data, leading to data reduction. Further details of each of the classification methods used are as follows.

4.3.2.1 Cluster Analysis

A general objective of the plant community analysis was to identify and explain the vegetation pattern in the valley. The first method used was hierarchical agglomerative clustering of the 144 stations (samples) for all of the 198 plant species based on qualitative data i.e. presence/absence (Greig-Smith, 2010). This method proceeded from the individual items i.e., samples or species and gradually combined them into groups, in terms of their similarity. It was hierarchical in the manner that each of the small clusters belongs to a bigger and further diverse cluster. Cluster Analysis (CA) identified significant habitat and plant community types based on Sorensen's (Bray Curtis) distance. Sørensen's similarity distance is applied to presence/absence data and measured with the formula;

$$QS = 2C/A+B$$

Where A and B are the number of species in stations A and B and C is the number of species shared by the two stations (Sorensen, 1948, Dalirsefat *et al.*, 2009). Major assemblies defined within the dendrogram were attributed as habitat and community types; their formation was subsequently confirmed further, using ordination techniques (section 4.3.4).

The clustering procedure was carried out with the following rationale;

i. To identify groups of stations with similar floristic composition, which should represent the environmental gradients identified by DCA and then CCA analyses.
ii. To identify the plant communities (groups) and their distribution patterns.
iii. To outline a relationship that provides the base for the results of ordination techniques.

4.3.2.2 Indicator Species Analysis

One of the specific objectives of the plant community analysis was to categorize and illustrate the value of different species as representative of environmental conditions. For this purpose the second classification method used was Indicator Species Analysis (ISA). This combines information on the concentration of species abundance in a particular group and the faithfulness (fidelity) of occurrence of a species in that particular group (defined by an environmental variable). It constructs indicator values for each species in each group which are tested for statistical significance using a Monte Carlo technique. Using ISA, the species matrix for all stations (198x144) was defined five times for each environmental variable i.e., aspect, altitude, soil depth, grazing pressure and soil pH, from the environmental matrix (144 stations x 5 environmental variables). Each species was evaluated for its ability to categorize among all the treatments of environmental variables. Indicator Species Analysis provided suggestions of how well the presence of a species was indicating a station/sample type (Dufrene & Legendre, 1997).

4.3.2.3 Mantel test

Before commencing the field studies, it was hypothesized that variation in aspect (north- and south-facing slopes) and altitude would have an impact on the diversity of both plant species and also on plant communities quantitatively as well as qualitatively. To test the significance of this hypothesis the mantel test was used. This is a utility in PCORD that estimates the strength of the relationship between two matrices. It was run to quantify the correlations between the floristic and environmental distance matrices. The value of the Mantel statistic can vary from −1 to +l. The Mantel statistic points out the extent of overall spatial autocorrelation between the values of a quantitative attribute at different stations and the environmental variables of those stations (Legendre & Fortin, 1989, Mantel, 1967). Nevertheless, two variables may be correlated due to a third, common variable, thus before the ultimate decision is made on whether the original two variables are significantly correlated, the third variable is removed. In the first step the species data matrix was checked alongside the environmental variable data matrix. There was a significant correlation between both the matrices. To further authenticate the test the significance free of other variable effects, the species data matrix was examined in relation with one environmental variable at one time i.e. altitude, aspect, soil depth, grazing pressure and soil pH.

4.3.2.4 Species Area Curves

Species Area Curves (SAC) are used to approximate the adequate sample size, maximum number of plant species and the causal driving forces on vegetation in a region. SACs are also important to understand the biodiversity, and for producing measures for its conservation (He & Legendre, 1996, Legendre *et al.*, 2005). This method was used to calculate the average number of species at each of the stations. Species area and compositional curves were used in order to evaluate whether the sample size was sufficient to achieve adequate presentation of species composition in relation to the full sample (the study area). To evaluate such adequacy and associate it with causal variables, Species Area Curve

(SAC) as a PC-ORD utility was run for all the sampled species and stations. Using the importance value (IV) and Sørensen distance, Species Area Curves were constructed following the method of McCune and Mefford (1999). SAC was calculated for all 144 stations (sampling plots) which showed standard deviations as an assessment of the variability of the data (Turner & Tjørve, 2005, Grandin, 2006).

4.3.3 Naming plant communities

The naming of the plant communities was based on indicator (characteristic) species. A threshold level indicator value of 20-25% (p value ≤ 0.05) for the index was chosen as the cut off for identifying significant indicator species identified by Indicator Species Analysis (ISA) as recommended by Dufrene and Legendre (1997). A smaller number of indicator species were identified for naming the communities; these were the species highly associated with those specific communities. Indicator species of a specific community were reassessed as having constancy of 30% in the stations/sites of that community (Calculated in EXCEL) (Ter Braak & Barendregt, 1986, Dufrene & Legendre, 1997, Bergmeier, 2002, Dai *et al.*, 2006) (for detail results see Appendix 4.4 & 4.5). Beside the indicator value and constancy, the indicator species were also checked for fidelity i.e., species with fidelity between 3 and 5 from fidelity classes 1-5 (table 4.5) were only considered as characteristic species (Mueller-Dombois & Ellenberg, 1974, Kent & Coker, 1994, Malik & Husain, 2006, Malik & Husain, 2008).

Table 4.5 Criteria for determining Fidelity (Faithfulness) classes

Fidelity Class	Description
5	**Exclusive species:** Completely or almost completely confined to one community
4	**Selective species:** Found most frequently in certain community but also rarely in other communities
3	**Preferential species:** Present in several communities more or less abundantly but predominantly in one certain community and there with great deal of vigour
2	**Indifferent species:** Without a definite affinity for any particular community
1	**Accidental species:** Species which is rare and accidental intruders from another community or relics of a preceding community

4.3.4 Ordination analyses to identify ecological gradients using CANOCO

Ordination is a multivariate statistical method that summarizes community data by constructing a low dimensional space in which similar samples and species come closer together whilst dissimilar ones goes further apart. It produces effective low dimensional summaries from field data by convenient and objective means. Ordination procedures provide two kinds of information i.e., on community pattern through indirect gradient analysis and structure through direct gradient analysis. The literature shows that the former ordination method is commonly used by European ecologists while the latter is more widely used in North America (Greig-Smith, 1983, Tüxen & Whittaker, 1973, Ter Braak, 1987, Jongman *et al.*, 1995, Digby & Kempton, 2010, Gauch, 2010).

Keeping the objectives of the present project in mind, both of the ordination techniques i.e. indirect and direct environmental gradient analyses were performed using CANOCO version 4.5 (Ter Braak, 1986, Ter Braak & Barendregt, 1986, Terbraak & Prentice, 1988). All data were used in the gradient analysis. Using indirect methods i.e., Correspondence Analyses (CA), Principal Component Analyses (PCA) and Detrended Correspondence Analysis (DCA) the vegetation data were treated without the input of environmental data in order to assess the faithfulness of various assemblages of samples (stations) and species. DCA provided more robust and interpretable results than CA and PCA and hence was adapted as a tool for further indirect gradient analysis.

4.3.4.1 Detrended Correspondence Analysis

Among the indirect techniques, DCA is the most used method. It is highly valued by ecologists as it is carried out without the input of environmental data and hence results are free from distortion (Hill & Gauch Jr., 1980, ter Braak, 1988). Species abundance data matrices i.e., density, frequency, cover and Importance Values were used for DCA procedures. The results describe the ecological gradient for the community and habitat types identified by a Cluster Dendrogram (hierarchical classification).

4.3.4.2 Canonical Correspondence Analysis

Based on an extensive review of the literature on ordination techniques it was clear that CCA is the most robust and widely used direct ordination gradient exploration technique and hence this was adopted for the present studies. Direct gradient analyses (RDA, CCA and

DCCA) were performed that treated floristic and environmental data matrices together in CANOCO. CCA was found to be the most meaningful as a direct gradient analysis procedure. Its application to the data further authenticates the results of DCA (Kent & Coker, 1994, Greig-Smith, 1983, Dufrene & Legendre, 1997, McCune & Grace, 2002). Abundance data of all the 198 species and at all of the 144 stations along with environmental data matrices were analysed using canonical correspondence analyses (CCA) with the following objectives.

i. To evaluate the significance of relationships among floristic and environmental data.
ii. To reconfirm whether the Cluster and DCA based pattern of plant communities was due to measured environmental variability or something else.
iii. If yes then to examine and determine the obvious plant communities across the different environmental conditions.
iv. To identify the strength and interrelationship within different environmental variables.

4.3.4.3 Data attribute plots and Diversity Indices

Ecologists use a number of diversity indices for measuring plant species diversity in different habitat types and plant communities. CANODRAW a utility of CANOCO was used to generate data attribute plots (in graphic forms) of indicator/characteristic species. It also provided the opportunity to utilize the index of number of species, Shannon Weiner index, index of species richness, evenness and sample variance, etc. Diversity indices were calculated at the community level through data attribute plots under the DCA function of CANODRAW.

4.4 Results

The phytosociological segment of the work resulted in the quantification of plant species, communities and environmental gradients. Detailed results are presented under the following sub headings; (1) floristic composition of the Naran Valley, (2) classification of plant communities and habitat types, (3) communities identified by Cluster Analysis, Indicator Species Analysis and confirmed through Ordination Analyses (DCA & CCA), (4) environmental gradients of the floristic data, (5) species richness and diversity along environmental gradients and species area curves, (6) correlation between floristic attributes and environmental variables, (7) Raunkiaer life form classification, (8) environmental gradient and Raunkiaer life forms, (9) diversity among plant community.

4.4.1 Floristic composition of the Naran Valley

A total of 198 plant species belonging to 150 genera and 68 families were recorded at the 144 stations (1296 relevés) (Appendix 4.3). The division into major taxonomical groups (Table 4.6) indicates that dicotyledonous angiosperms are the most abundant.

Table 4.6 Taxonomic divisions of recorded plant species

Taxonomic distribution	**No. of Families**	**No. of Species**
Dicot	53	161
Monocot	9	23
Subtotal of *Angiosperms*	**62**	**184**
Gymnosperms	3	8
Subtotal of *Spermatophyta*	**65**	**192**
Pteridophyta (Ferns and allies)	3	6
TOTAL NO. OF PLANT SPECIES	**68**	**198**

Based upon plant growth habit, 12 trees, 20 shrubs and 166 herbs (mostly flowering plants) comprised 6, 10 and 84% respectively, of the plant diversity of the vegetation of the Naran Valley (Fig. 4.5). The most abundant plant family was Asteraceae (Compositae) with seventeen species and a 25% share of all species. Rosaceae represented by fourteen species (with a 21% share) was the second most species rich family in the study area. Lamiaceae, Ranunculaceae, Poaceae and Polygonaceae were represented by 13, 12, 11 and 10 plant species respectively. The remaining families all had less than 10 species each (Fig. 4.4).

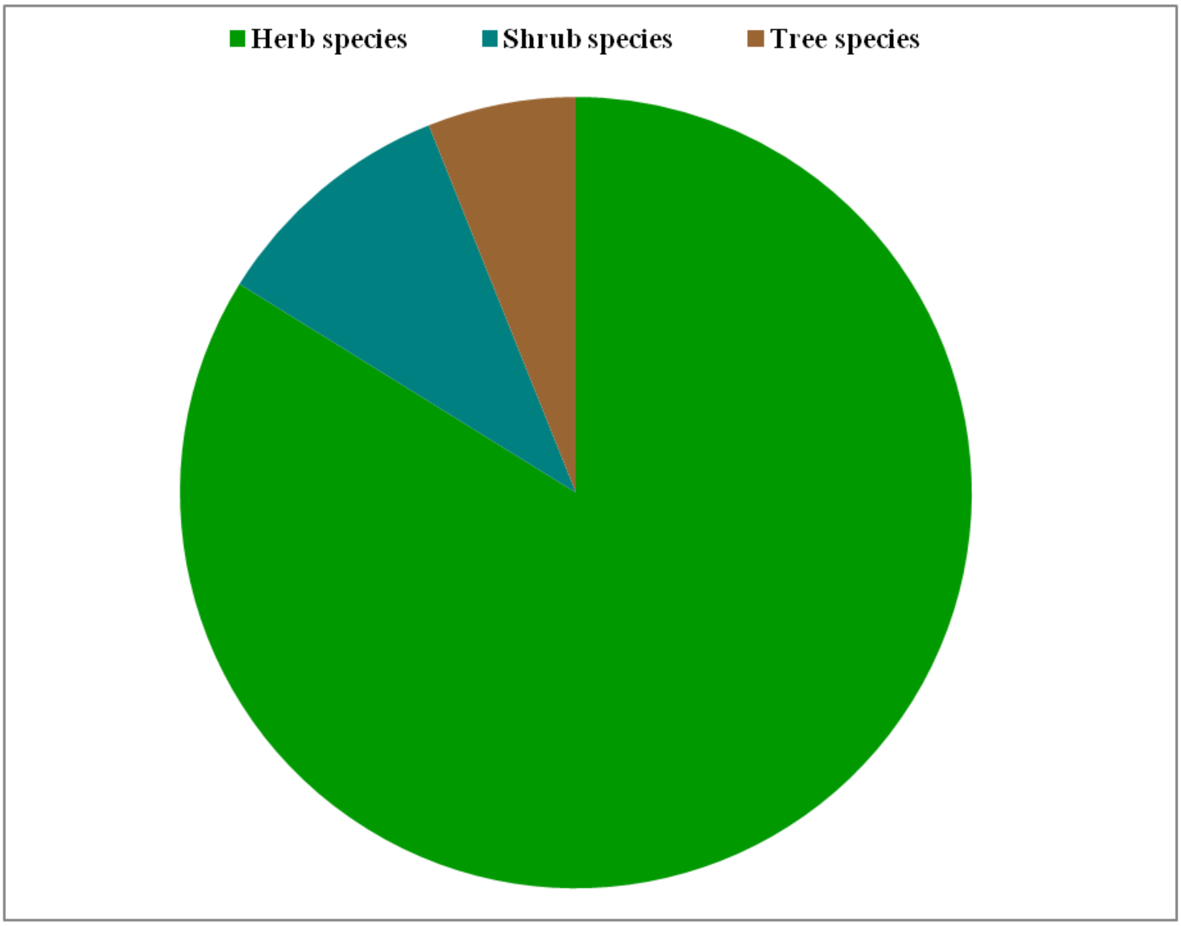


Fig. 4.4 Percent share of various habit forms of vegetation of the Naran Valley

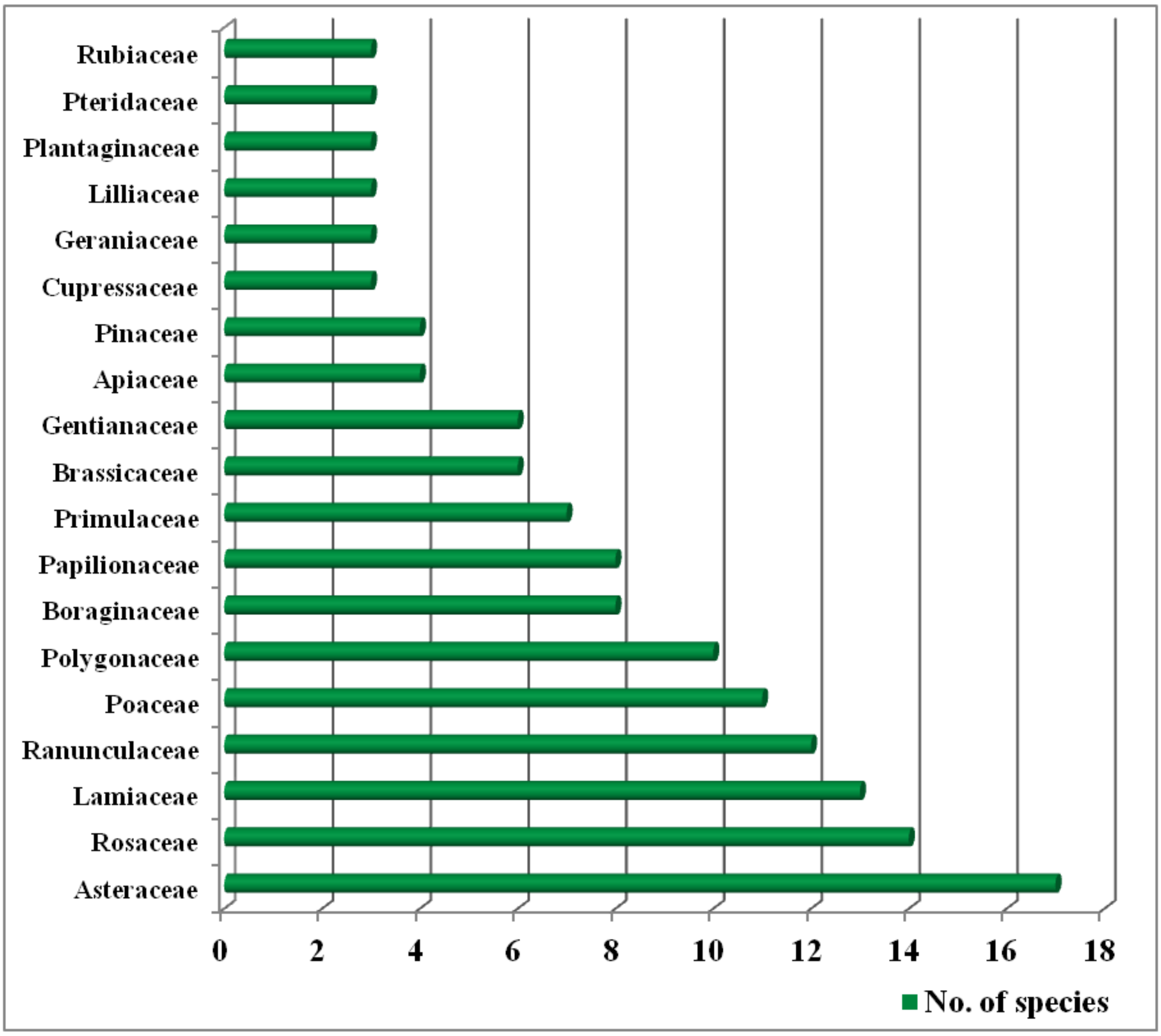


Fig. 4.5 Top 19 plant families represented by highest number of species in the study area which share 66.6% of the total specie.

4.4.2 Classification of plant communities and habitat types

4.4.2.1 Classification using Cluster Analyses

Clustering brought together the stations/samples to form five groups of communities/habitats which can be clearly seen in two main branches of the dendrogram; (i) the lower altitude (2450-3300 m) dominated by temperate vegetation and (ii) the higher altitude (3250-4100 m) dominated by subalpine and alpine vegetation. Three groups (community/habitat types) are assembled in the first half of the dendrogram and two in the second one (hereafter each group will be termed a plant community) respectively (Fig. 4.6).

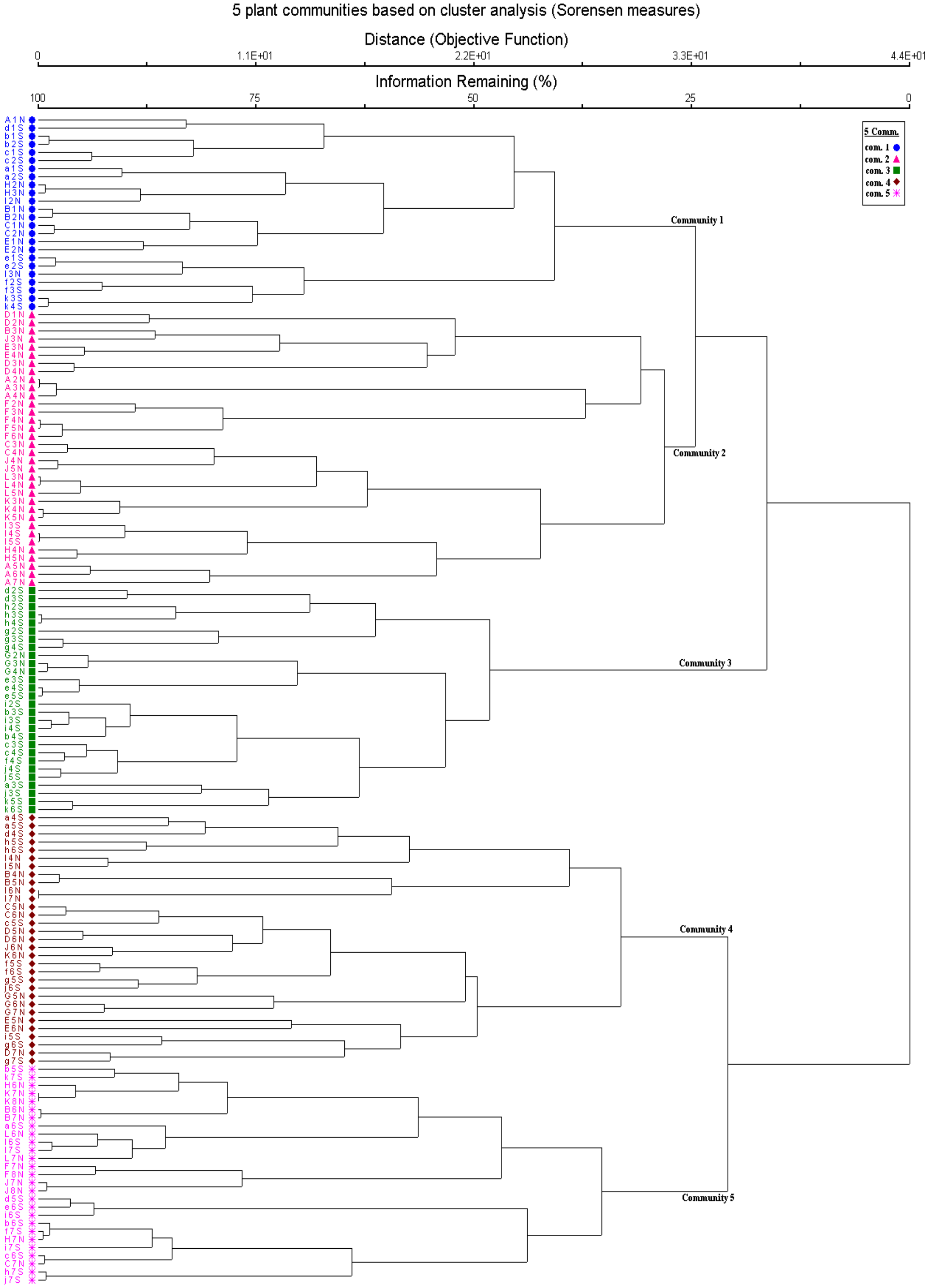


Fig. 4.6, Cluster dendrogram of 144 stations based on Sorensen measures showing 5 plant communities/habitat types (each station name refers to Fig. 4.1 and appendix 4.2)

Five plant communities identified as a result of grouping of stations are designated as Community 1, 2, 3, 4, and 5 in the cluster and ordination graphs.

4.4.2.2 Results of Indicator Species Analyses

After finding the general vegetation pattern and community classification, Indicator Species Analysis (ISA) was carried out to classify the species matrices based on the number and abundance of species in a particular group and the faithfulness (fidelity) of occurrence of species to a particular group (defined by an environmental variable). It also gave the indicator values for each species in each group. These values were tested for statistical significance using a Monte Carlo method. During indicator species analysis, main matrix (species matrix) was defined number by number by the values of environmental variables i.e., aspect, altitude, soil depth, grazing pressure and soil pH from the second matrix (environmental variable matrix). Running ISA (1000 runs) each species was evaluated for its ability to differentiate among all the providing categories (treatments) of the environmental variables (in this case soil depth, aspect and altitude). Indicator Species Analysis presented an indication of how well the presence of a species indicates a station type. Results of ISA were later on confirmed through CCA, indicating that among the five main communities constructed by the cluster analysis, one community occurred at lower altitudes (under the influence of higher soil depth and lower altitudes), two of the communities were restricted to either north or south facing slopes (under the influence of aspect as an environmental variable) and two of them were limited to high elevations irrespective of aspect (i.e., above about 3250 m) (Appendix 4.4). In common with the ISA, the Canonical Correspondence Analysis (CCA) (Table 4.14; Fig. 4.19 & 4.20) showed the strength of each environmental variable by testing the significance of that particular variable using a Monte Carlo procedure. Both of these analyses show that aspect, altitude and soil depth are the most important environmental variables. Only data attribute plots produced through CCA are included in the description of each community type while full details are provided in section 4.4.4. A brief summary of the Indicator Species Analyses (ISA) is given in the Table 4.7 with full details provided in Appendix 4.4.

Table 4.7 Top 4 indicator (characteristic) plant species of each of the 5 plant communities based on constancy, Fidelity and Indicator Species Analysis

Com. 1	***Pinus wallichiana-Sambucus wightiana*** (Valley bottom or lower altitude plant community) Total no. of stations formed the community = 24	MONTE CARLO test of significance of observed maximum indicator value for Species based on 4999 permutations. Random number seed: 2324 (Groups were defined by values of Soil depth classes; **Max grp = 3 = greatest soil depth**)							
	Indicator (characteristic) species of the community	Const	% const	Fid. class	Max grp	Obs IV	Mean	S. Dev	p * value
	Pinus wallichiana Jackson	11	46	4	**3**	32	9.7	3.31	0.0004
	Sambucus wightiana Wall. Ex Wight & Arn	23	96	3	**3**	59	16.4	3.79	0.0002
	Impatiens bicolor Royle	14	58	3	**3**	50	15.3	4.06	0.0002
	Plantago lanceolata L.	14	58	3	**3**	30	14.1	3.6	0.0024
Com. 2	***Abies pindrow-Betula utilis*** (middle altitude (2800-3300 m) N-aspect plant community) Total no. of stations = 34	MONTE CARLO test of significance of observed maximum indicator value for Species based on 4999 permutations. Random number seed: 527 (Groups were defined by values of Aspect; **Max grp = 1 = Northern aspect**)							
	Abies pindrow Royle	14	41	3	**1**	34	12	2.5	0.0002
	Betula utilis D. Don	10	29	4	**1**	24	8.8	2.1	0.0002
	Salix flabellaris Andersson in Kung	10	29	3	**1**	20	8.1	2.1	0.0004
	Achillea millefolium L.	15	44	4	**1**	25	11.6	2.5	0.0006
Com. 3	***Juniperus excelsa-Artemisia brevifolia*** (middle altitude (2800-3300 m), S-aspect plant community) Total no. of stations = 28	MONTE CARLO test of significance of observed maximum indicator value for Species based on 4999 permutations. Random number seed: 527 (Groups were defined by values of Aspect**;** **Max grp = 0 = Southern aspect**)							
	Juniperus excelsa M.Bieb	19	68	4	**0**	35	13.1	2.5	0.0002
	Artemisia brevifolia L.	27	96	3	**0**	50	23	3.1	0.0002
	Eremurus himalaicus Baker	22	79	4	**0**	35	12.8	2.6	0.0002
	Dryopteris stewartii Fras.-Jenk.	22	79	3	**0**	40	15.4	2.6	0.0002
Com. 4	***Rheum australe-Sibbaldia cuneata*** (higher altitude (3200-4000 m), timber line community) Total no. of stations = 31	MONTE CARLO test of significance of observed maximum indicator value for Species based on 4999 permutations. Random number seed: 2673 (Groups were defined by values of Altitude at m.s.l; **Max grp = 38-41 = 3800-4100 m i.e., higher altitudes**)							
	Rheum australe D.Don	13	42	4	**39.5**	20.3	10.7	5.05	0.0588
	Sibbaldia cuneata O. Kuntze	16	52	3	**38.5**	19.7	10.4	4.56	0.0584
	Bergenia stracheyi (Hook. f. & Thoms) Engl	13	42	4	**39**	14.7	10.6	5.91	0.0914
	Iris hookeriana Foster	12	39	4	**39**	20	10.9	5.4	0.0702
Com. 5	***Aster falconeri-Iris hookeriana*** (highest altitude (3700-4100 m); Alpine plant community) Total no of stations = 27	MONTE CARLO test of significance of observed maximum indicator value for Species based on 4999 permutations. Random number seed: 2673 (Groups were defined by values of Altitude at m.s.l; **Max grp =40-41= above 4000 m i.e., highest altitudes**)							
	Aster falconeri (C. B. Clarke) Hutch	13	48	**5**	**41**	43.2	10.4	6.31	0.0056
	Iris hookeriana Foster	25	93	**4**	**41**	20	10.9	5.4	0.0702
	Ranunculus hirtellus Royle ex D. Don	6	22	**1**	**41**	67.1	11.5	8.39	0.0022
	Rheum australe D.Don	20	74	**4**	**40**	20.3	10.7	5.05	0.0588

4.4.3 Community types identified by cluster analysis, indicator species analysis and confirmed through ordination analyses (DCA and CCA)

All the community names were given on the basis of the most indicative/faithful species of the specific community. Criteria for selecting indicator or faithful species were based on four different tests i.e., constancy more than 30%, fidelity class 5-3 (based on fidelity classes), indicator value more than 25% and p value less than 0.05 (based on Indicator Species Analysis; ISA) (Dufrêne & Legendre, 1997)

Details of each of the community/habitat types are as follow.

4.4.3.1 Pinus wallichiana-Sambucus wightiana Community

This association can be described as a **Valley bottom or lower altitude plant community** (indicator species identified by high Soil Depth classes; Com. 1 in Appendix 4.4 & 4.5; Table 4.7, 4.8, 4.13 & 4.14; and Fig. 4.17, 4.18, 4.19 & 4.20). This community is found on either side of the River Kunhar at altitudes from 2450 m up to an upper elevation of 2900 m. The tree and shrub layer is characterised by *Pinus wallichiana* and *Sambucus wightiana* which are diagnostic (indicator) species. Other dominant species of this layer are *Cedrus deodara*, *Abies pindrow* and *Artemisia brevifolia*. Characteristic species of the herb layer are *Impatiens bicolor*, *Plantago lanceolata* and *Onopordum acanthium* L., with *Trifolium repens* and *Hypericum perforatum* L. as sub-dominants and *Dactylis glomerata* L., *Urtica dioica* L., *Bistorta amplexicaulis*, *Verbascum thapsus* and *Viola canescens* as common species (Fig. 4.7 & 4.8). In many places along the valley, this community also contains cultivated plants. These were recorded *in situ* but not included in the classification and included potato, peas, and maize etc. The most important environmental variables determining the occurrence of this community are high soil depth which is linked with associated co-variables like relatively high temperature, higher soil moisture, high grazing and other anthropogenic pressures. This plant community is located at lower altitudes and is thus under pressure from a range of anthropogenic activities including cutting of woody plants for fuel wood, expansion of agricultural land, grazing and multipurpose plant collection. These lower altitude communities are easily accessible by local people who live in the valley during the summer months and who utilize the local plant resources.

Table 4.8 Top indicator (Characteristic) species of Community 1, based on constancy, fidelity and ISA; Community name is given with the bold highlighted species

Total No of stations in the formation of community= 28		**Constancy**		**Fidelity class**	**MONTE CARLO test of significance using ISA**		
S. No	Indicator Species	Cons tancy	% Cons		Max group (defined by high soil depth class = 3)	Observed Indicator Value %	p * value
1	***Pinus wallichiana* Jackson**	16	57	4	3	32	0.00045
2	***Sambucus wightiana* Wall. Ex Wight & Arn**	26	93	3	3	59	0.00021
3	*Impatiens bicolor* Royle	15	54	3	3	50	0.00022
4	*Plantago lanceolata* L.	15	54	3	3	30	0.00023
5	*Onopordum acanthium* L	16	57	3	3	34	0.00123

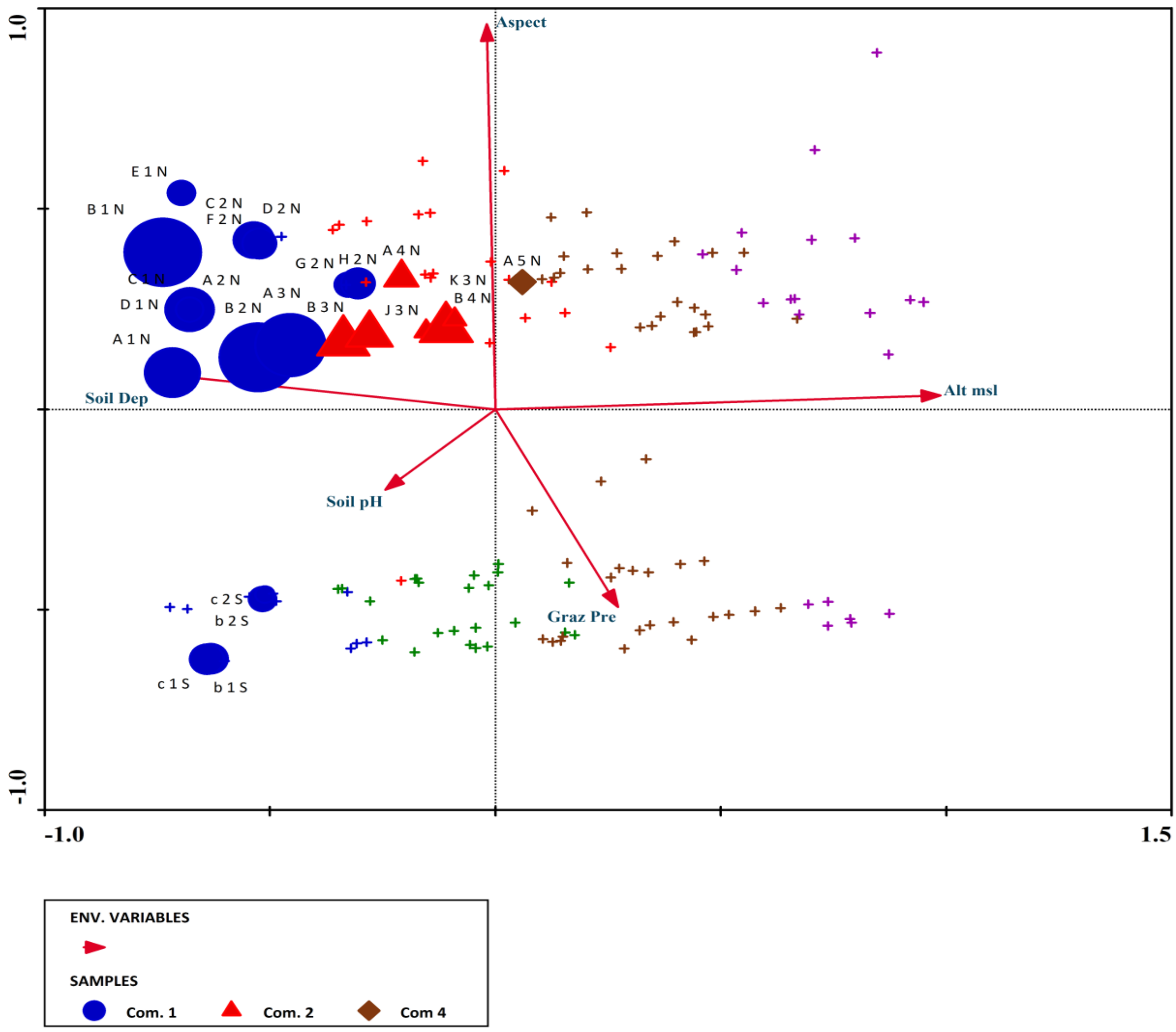


Fig. 4.7 Data attribute plot of *Pinus wallichiana;* the first indicator species of Community 1 characteristic of valley bottom or lower altitude habitats.

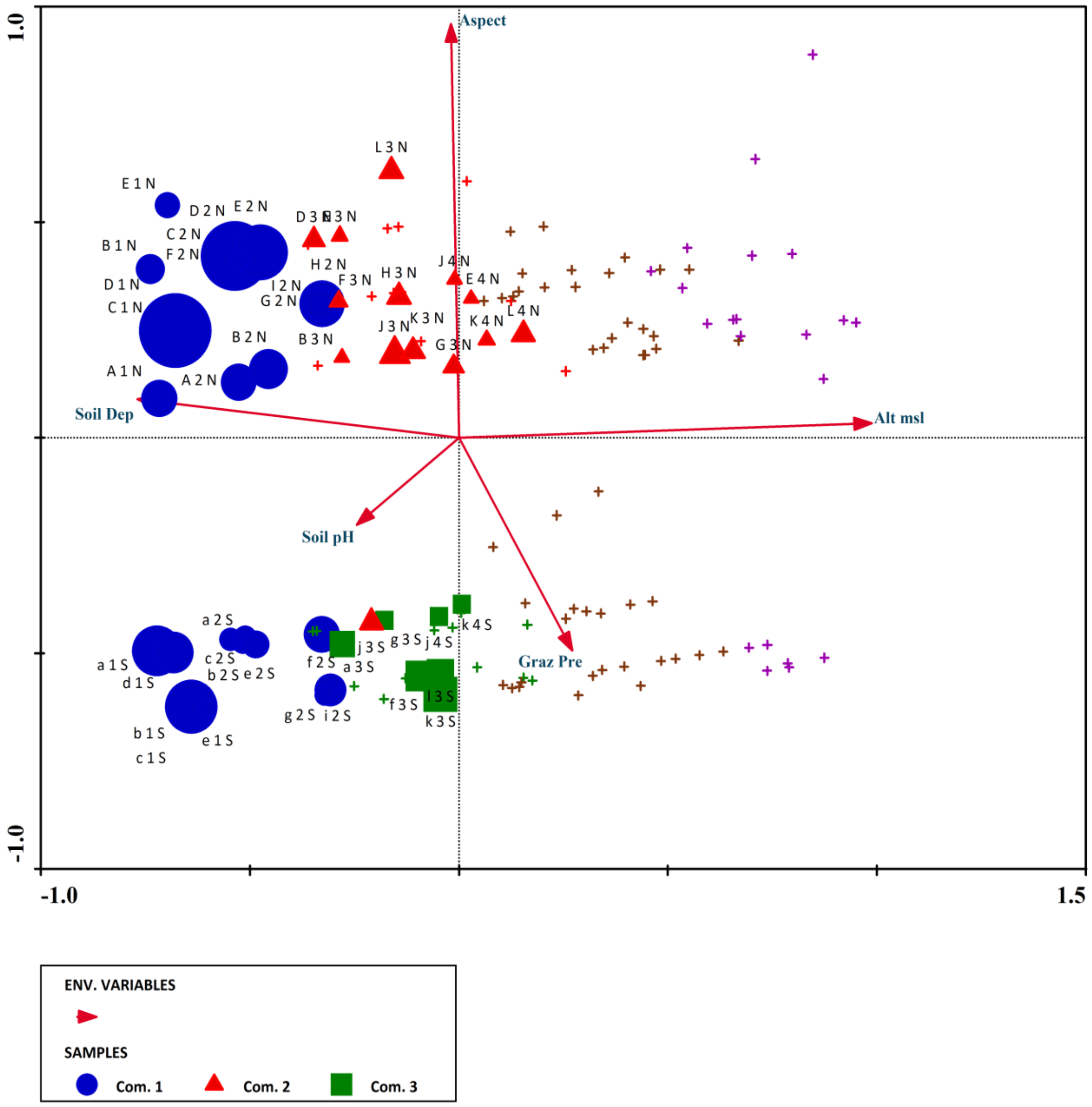


Fig. 4.8 Data attribute plot of *Sambucus wightiana;* the second indicator species of Community 1.

4.4.3.2 Abies pindrow-Betula utilis Community

This **middle altitude (2800-3300 m) northern aspect plant community** (indicator species identified by the northern aspect; Com. 2 in Appendix 4.4 & 4.5; Table 4.7, 4.9, 4.13 & 4.14; and Fig. 4.17, 4.18, 4.19 & 4.20) is characterised by two indicator species of the tree layer, namely *Abies pindrow* and *Betula utilis*, whilst the shrub layer is characterised by *Salix flabellaris.* In the herb layer, *Achillea millefolium* and *Fragaria nubicola* are the characteristic species. Other prominent species of this community which are almost restricted to north or north-west facing slopes are *Picea smithiana*, *Cedrus deodara*, *Impatiens bicolor*, *Oxyria digyna*, *Cynoglossum glochidiatum*, *Poa alpina* and *Valeriana pyrolifolia (*Fig. 4.9 & 4.10). Shade-loving plants are a characteristic feature of this community since the hill slopes receive less direct sunlight compared to Community 3 on the south-eastern facing slopes (S-aspect). Furthermore, the shade effect is increased by the greater canopy closure of the tree and shrub layers. The main influencing environmental variable in the formation of this community is the aspect (NW facing) that is associated with co-variables such as relatively high soil depth, low grazing pressure and high soil moisture (due to both shade effects and soil depth). The main anthropogenic impacts are timber removal and plant collection for various purposes. Similarly some natural hazards like heavy snowfall following summer snowmelt can lead to significant water and glacial erosion, which also affect the development of this community.

Table 4.9 Top indicator (Characteristic) species of Community 2, based on constancy, fidelity and ISA; Community name is given with the bold highlighted species

Total No of stations in the community = 24		**Constancy**		**Fidelity class**	**MONTE CARLO test of significance using ISA**		
S. No	Species name	Cons.	% Cons.		Max group (defined by aspect; 1=N)	Observed Indicator Value %	p * value
1	***Abies pindrow* Royle**	16	67	3	1	34	0.0002
2	***Betula utilis* D. Don**	11	46	4	1	24	0.0002
3	*Salix flabellaris* Andersson in Kung	08	33	3	1	20	0.0004
4	*Achillea millefolium* L.	12	50	4	1	25	0.0006

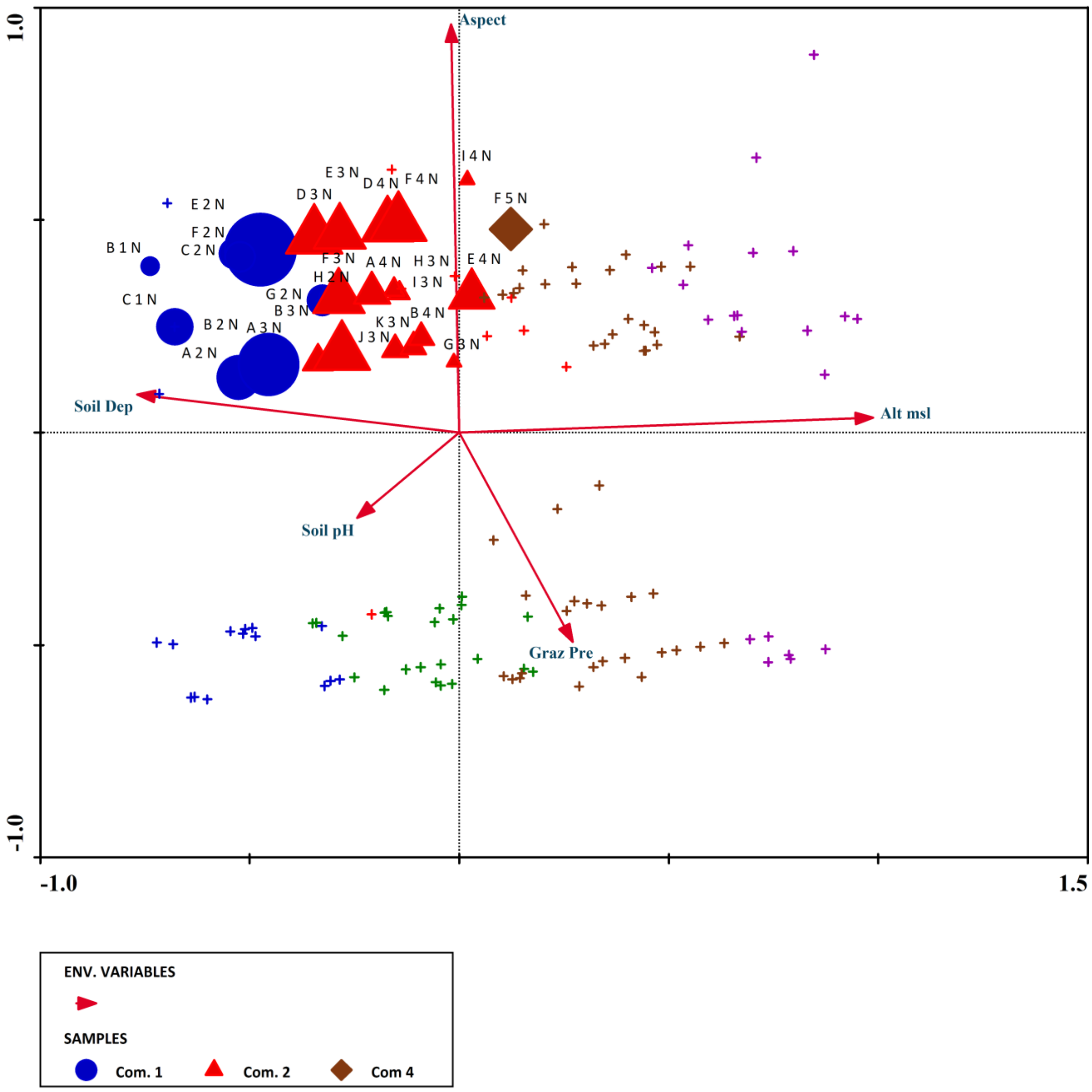


Fig. 4.9 Data attribute plot of *Abies pindrow;* the first indicator species of Community 2 at middle elevation (2800-3300 m) northern aspect habitats.

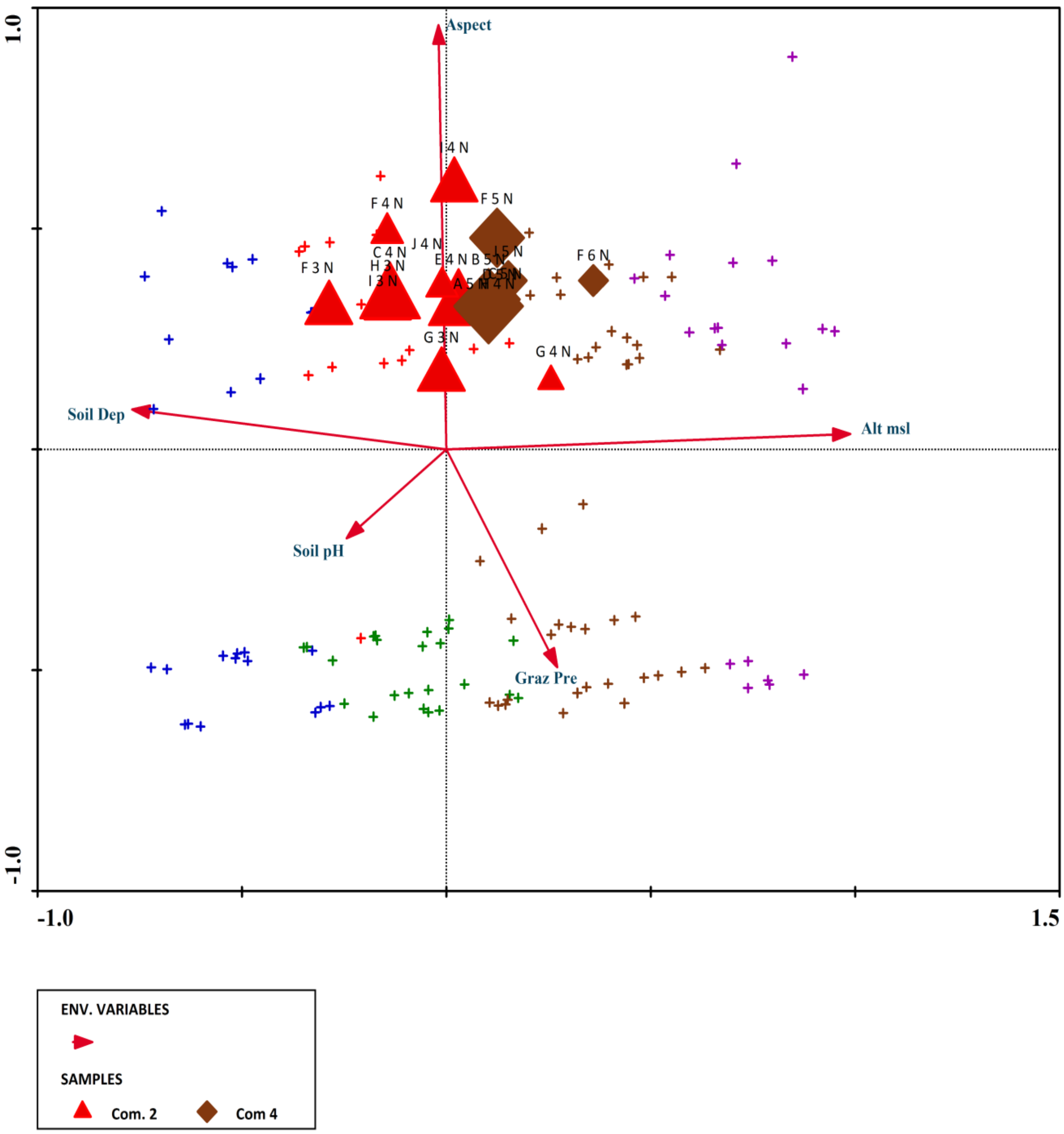


Fig. 4.10 Data attribute plot of *Betula utilis;* the second indicator species of Community 2 at middle elevation (2800-3300 m) northern aspect habitats.

4.4.3.3 Juniperus excelsa-Artemisia brevifolia Community

This community can be described as a **middle altitude (2800-3300 m) southern aspect plant community** (indicator species identified by the values of aspect; Com. 3 in Appendix 4.4 & 4.5; Table 4.7, 4.10, 4.13 & 4.14; and Fig. 4.17, 4.18, 4.19 & 4.20). *Juniperus excelsa, Artemisia brevifolia, Eremurus himalaicus, Dryopteris stewartii* and *Taraxacum officinale* are the distinguishing (indicator species) of this community. A tree layer is almost completely absent with only a few trees with a shrubby growth-form occurring e.g., *Juniperus excelsa (*Fig. 4.11 & 4.12). The shrub layer is the dominant woody strata and is characterized by *Artemisia brevifolia, Juniperus communis, Cotoneaster microphyllus* and *Rosa webbiana.* Characteristic species of the herb layer are *Androsace rotundifolia, Clematis montana, Malva neglecta, Hypericum perforatum, Onopordum acanthium* and *Verbascum thapsus.* This community shows its best development on south-east facing slopes at middle altitudes where it is exposed to direct solar radiation owing to slope orientation and the absence of a tree layer. Other associated influencing factors are a relatively high grazing pressure and the early melting of snow cover. In contrast to Community 2 on slopes with a north-facing aspect, the main human pressure on this community is in the form of grazing as the snow melts earlier from south facing slopes and the seasonal grazers move onto these areas early to utilize the snow-free vegetation as soon as possible. Other associated disturbances are trampling effects of grazing animals and erosion by snow melt.

Table 4.10 Top indicator (Characteristic) species of Community 3, based on constancy, fidelity and ISA; Community name is given with the bold highlighted species

Total No of stations in the community = 34		**Constancy**		**Fidelity class**	**MONTE CARLO test of using ISA**		
S. No	Species name	Cons.	% Co ns.		Max group (defined by aspect; 0=S)	Observed Indicator Value %	p * value
1	***Juniperus excelsa* M.Bieb**	13	57	4	0	35	0.0002
2	***Artemisia brevifolia* Wall ex DC**	21	91	4	0	50	0.0002
3	*Eremurus himalaicus* Baker	16	70	4	0	35	0.0002

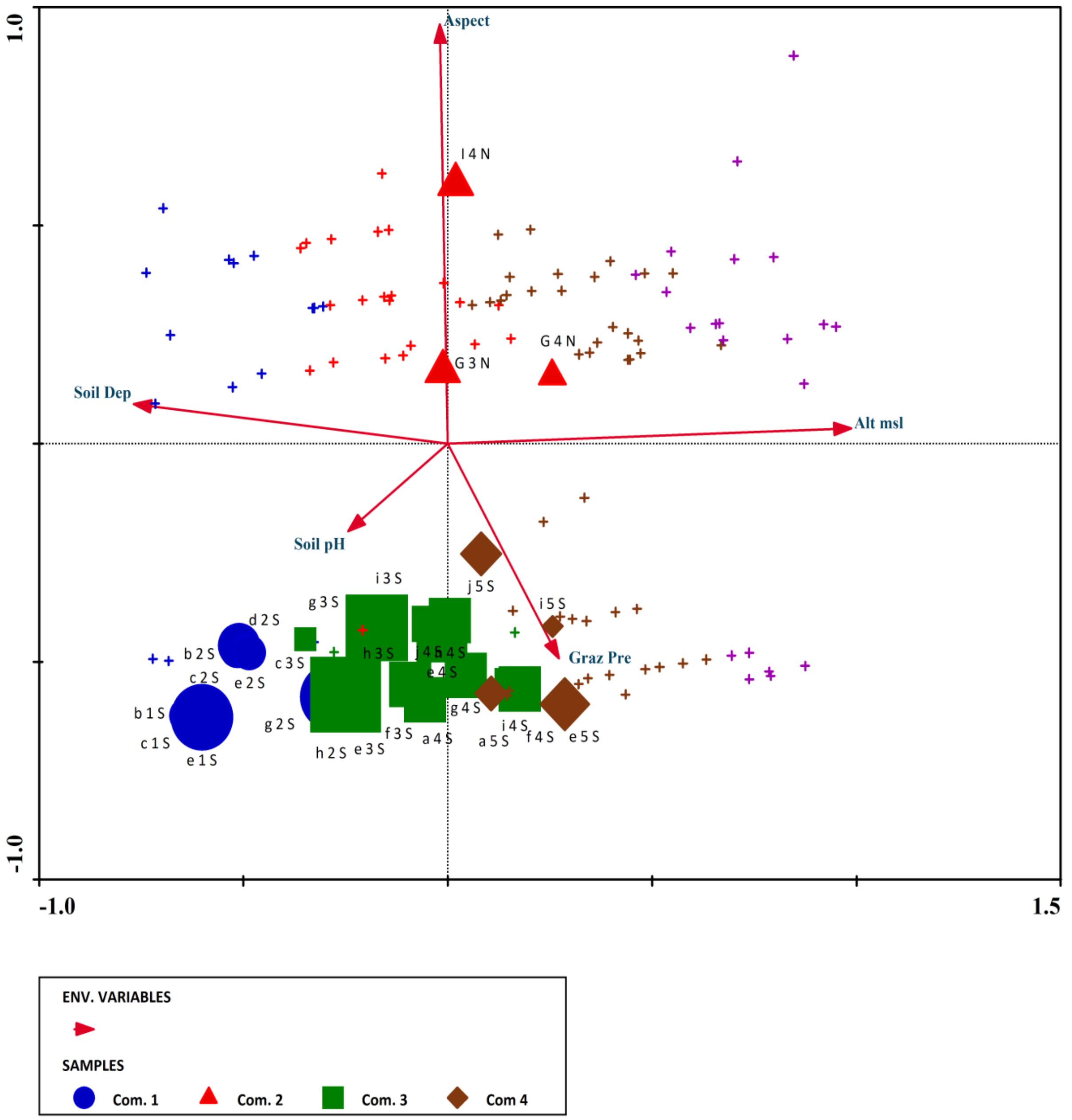


Fig. 4.11 Data attribute plot of *Juniperus excelsa;* the first indicator species of Community 3 at middle elevation (2800-3300 m) southern aspect habitats

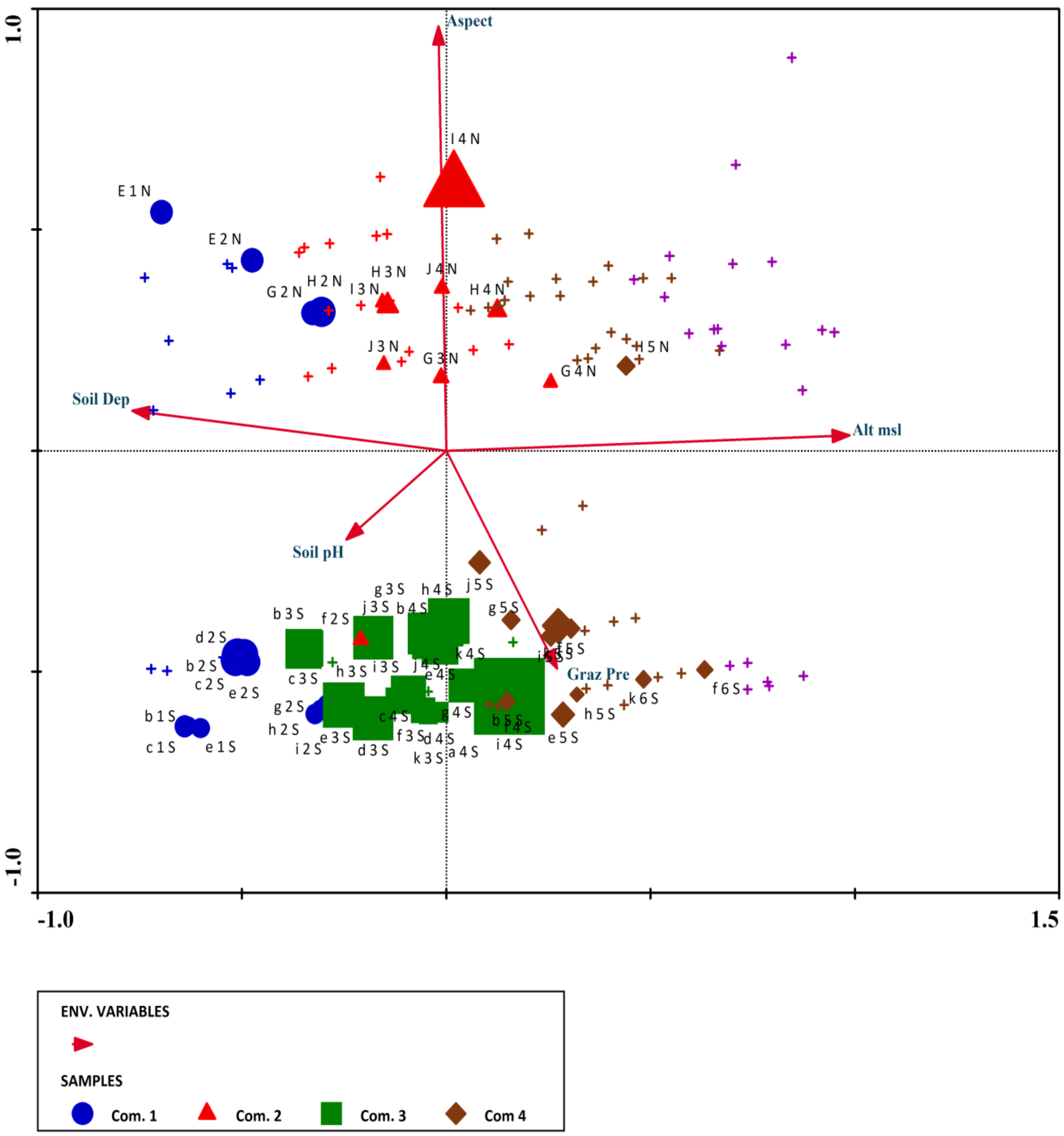


Fig. 4.12 Data attribute plot of *Artemisia brevifolia;* the second indicator species of Community 3 at middle elevation (2800-3300 m) southern aspect habitats

4.4.3.4 Rheum australe-Sibbaldia cuneata Community

This community forms a **high altitude (3300-4000 m) timber line plant community** (indicator species identified by the values of Altitude; Com. 4 in Appendix 4.4 & 4.5; Table 4.7, 4.11, 4.13 & 4.14; and Fig. 4.17, 4.18, 4.19 & 4.20). It is comprised of subalpine and alpine vegetation and characterized by alpine species including *Rheum australe, Sibbaldia cuneata* and *Iris hookeriana* (Fig. 4.13, 4.14). The vegetation is dominated by herbaceous species, although some shrub species occur at relatively lower altitudes (3300-3500 m) i.e., *Juniperus communis, Juniperus squamata, Rhododendron hypenanthum* and *Berberis pseudumbellata.* Other dominant herb species are *Bergenia stracheyi, Poa alpina, Thymus linearis, Bistorta affinis* and *Aconitum violaceum.* This community develops in between the timberline and alpine pastures at higher altitudes, irrespective of slope aspect and overlaps with Community 5 (alpine pastures) at most of the stations, especially in the upper part of the valley. The main anthropogenic pressures on this community are medicinal plant collection, fodder collection and grazing.

Table 4.11 Top indicator (Characteristic) species of Community 4, based on constancy, fidelity and ISA; Community name is given with the bold highlighted species

Total No of stations in the community = 28		**Constancy**		**Fidelity class**	**MONTE CARLO test of significance using ISA**		
S. No	Species name	Const.	% Const.		Max group (defined by altitude = m.a.s.l.)	Observed Indicator Value %	p * value
1	***Rheum australe* D.Don**	22	47	3	3950	22	0.0488
2	***Sibbaldia cuneata* O. Kuntze**	28	60	4	3850	20	0.0484
3	*Iris hookeriana* Foster	24	51	4	3900	19	0.0502

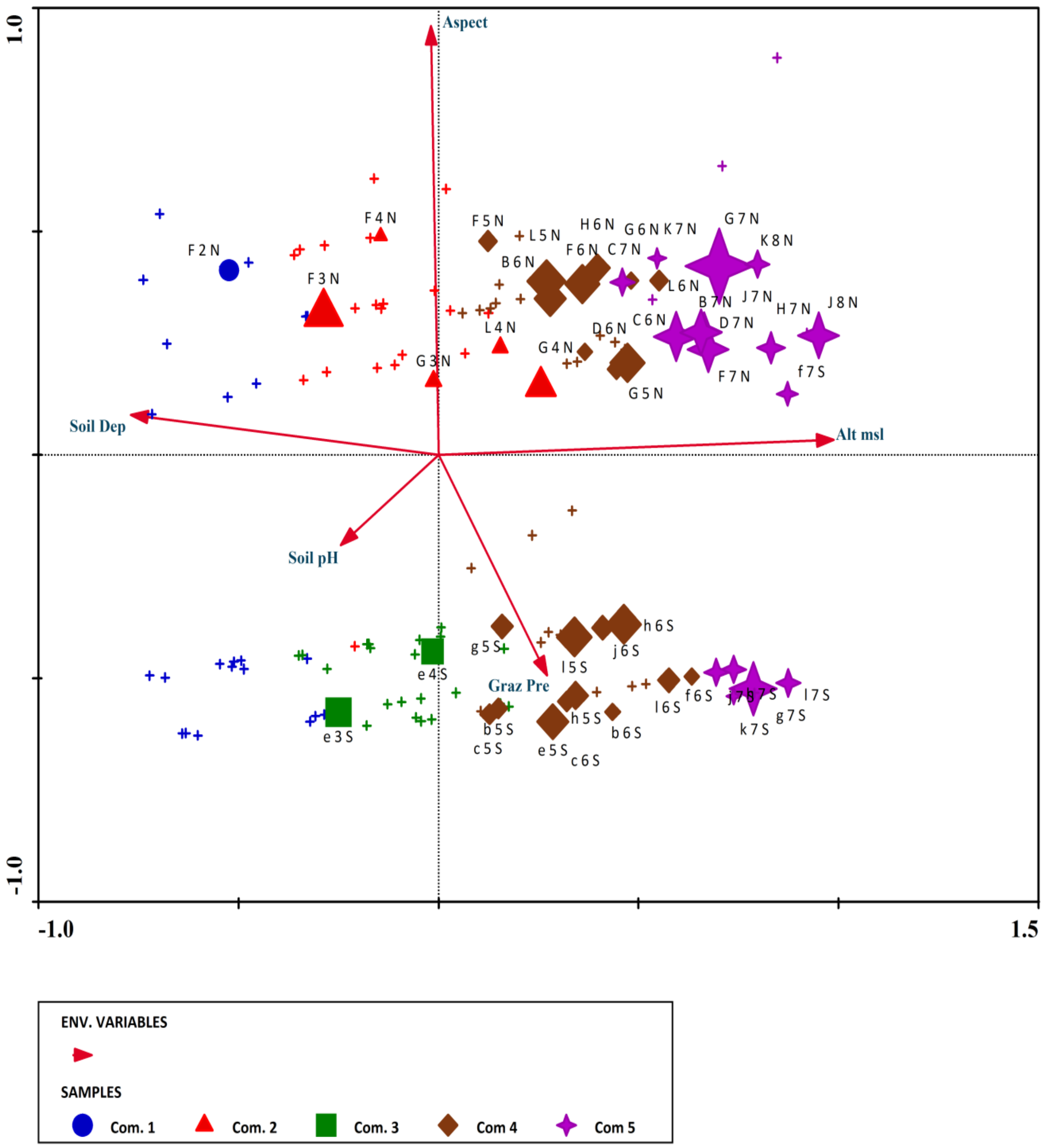
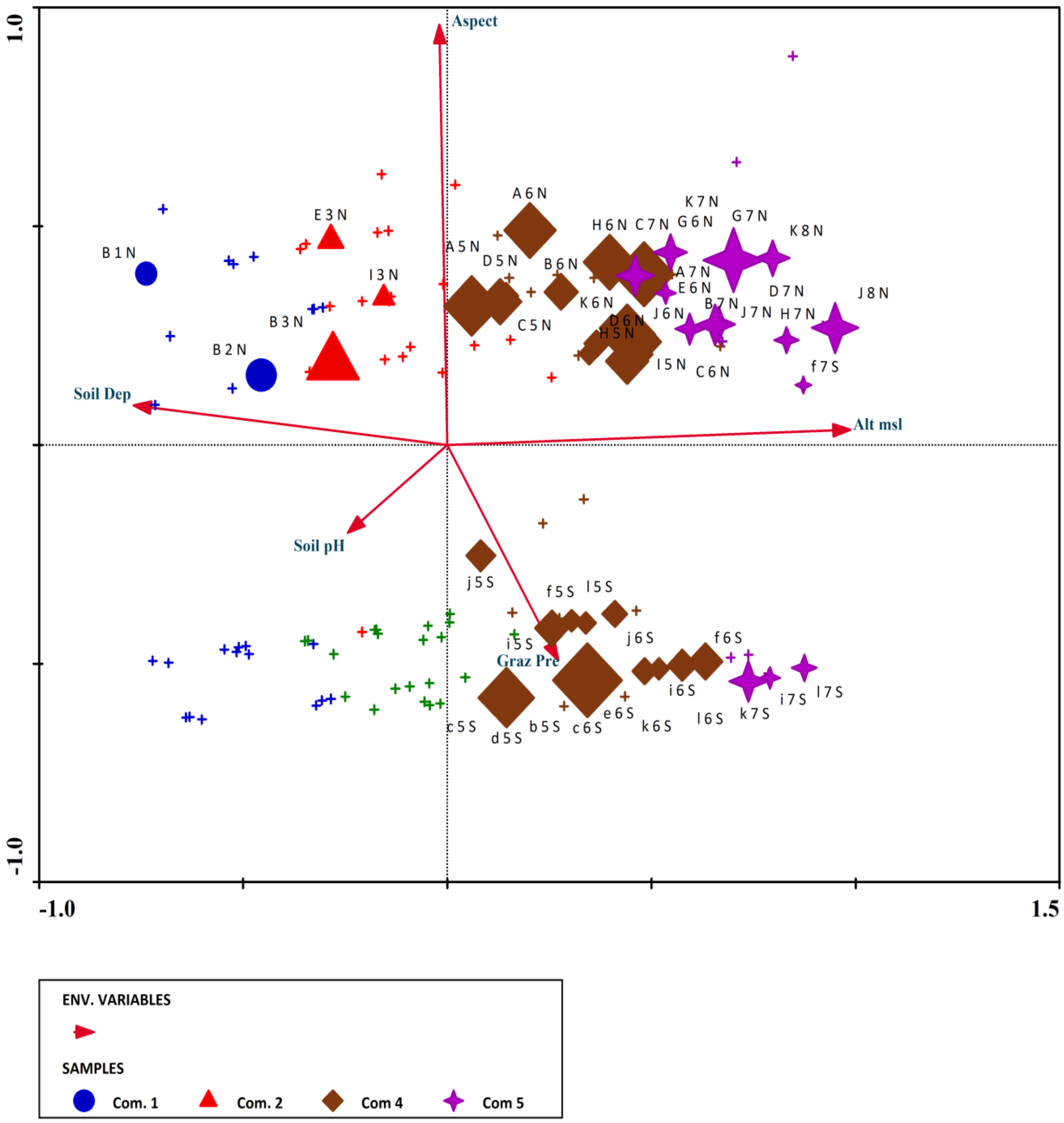


Fig. 4.13 Data attribute plot of *Rheum australe;* the first indicator species of Community 4 at high altitude (3300-4000 m) timber line (subalpine) habitats



1.0
-1.0
-1.0
1.5
Aspect
Alt msl
Soil Dep
Soil pH
Graz Pre
ENV. VARIABLES
SAMPLES
Com. 1
Com. 2
Com 4
Com 5

Fig. 4.14 Data attribute plot of *Sibbaldia cuneata;* the second indicator species of Community 4 at high altitude (3300-4000 m) timber line (subalpine) habitats

4.4.3.5 Aster falconeri-Iris hookeriana Community

This is a **high altitude (above 3700 m) alpine plant community** (indicator species identified by the values of elevation from sea level; Com. 5, in Appendix 4.4 & 4.5; Table 4.7, 4.12, 4.13 & 4.14; and Fig. 4.17, 4.18, 4.19 & 4.20). *Aster falconeri, Iris hookeriana* and *Ranunculus hirtellus* are the characteristic species. Other diagnostic alpine species are *Anemone tetrasepala, Gentiana carinata* and *Rheum australe* (Fig. 4.15 & 4.16). Tree and shrub layer species (Phanerophytes and Chamaephytes) are completely absent from these alpine pastures. Due to the high altitude and location at the summer snow line, extremely low temperatures are a feature throughout the growing season. These harsh environmental conditions are exacerbated by xeric conditions and a very short growing season from August through September. This high altitude plant community has low species richness in comparison with the other four communities. Soil depth is shallow and grazing is the main anthropogenic pressure on the flora. Seasonal grazers utilize these alpine pastures as soon as they are freed from snow cover.

Table 4.12 Top indicator (Characteristic) species of Community 5, based on constancy, fidelity and ISA; Community name is given with the bold highlighted species

Total No of stations in the community = 28		Constancy		Fidelity class	**MONTE CARLO test of significance using ISA**		
S. No	Species name	Cons.	% Cons.		Max group (defined by altitude = m.s.l.)	Observed Indicator Value %	p * value
1	***Aster falconeri* (C. B. Clarke) Hutch**	10	48	5	4100	43	0.0056
2	***Ranunculus hirtellus* Royle ex D. Don**	7	33	**5**	4100	63	0.0022

3	*Iris hookeriana* Foster	15	71	4	4000	19	0.0502

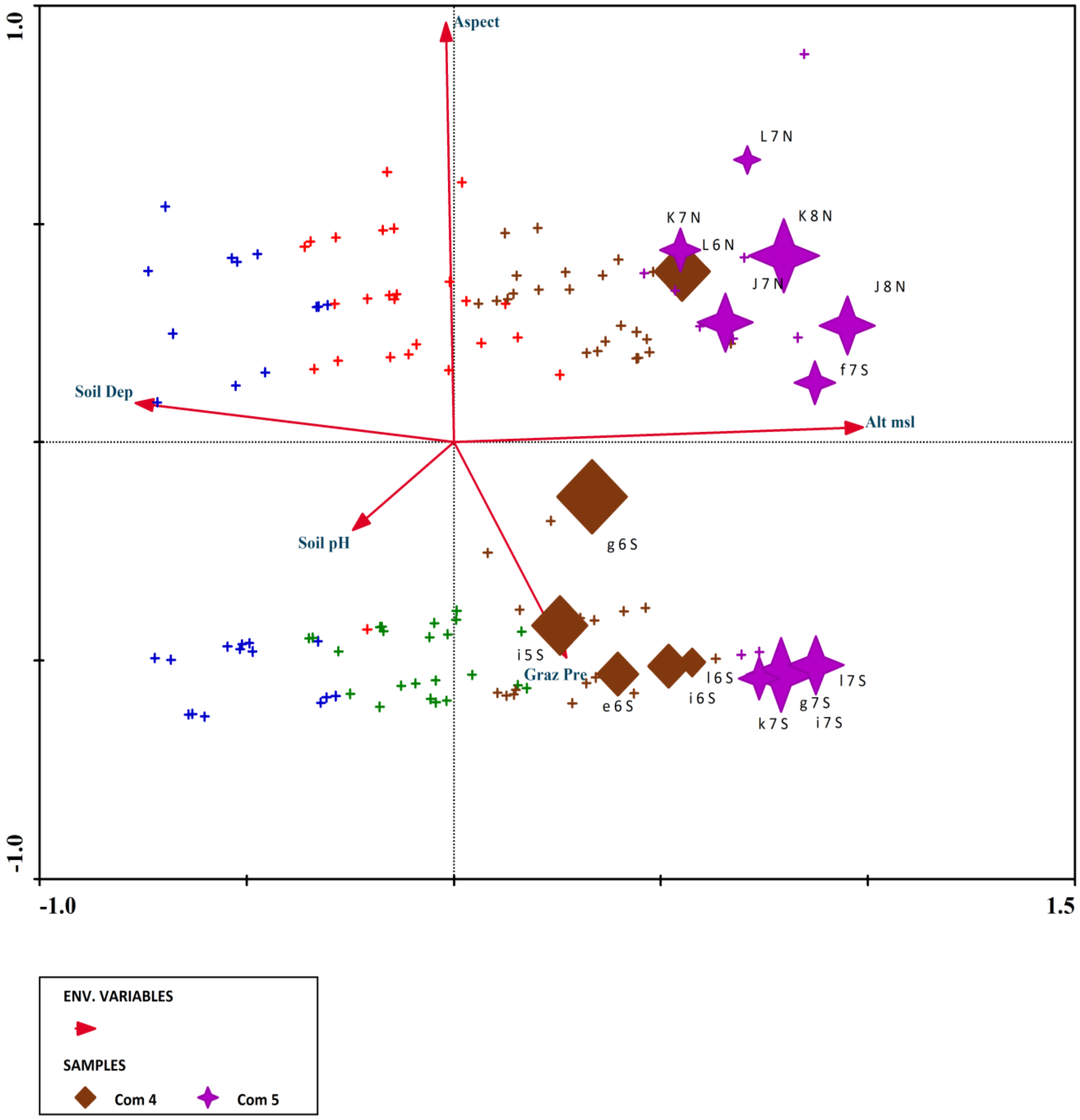


Fig. 4.15 Data attribute plot of *Aster falconeri;* the first indicator species of Community 5 at high elevations (above 3700 m) alpine habitats

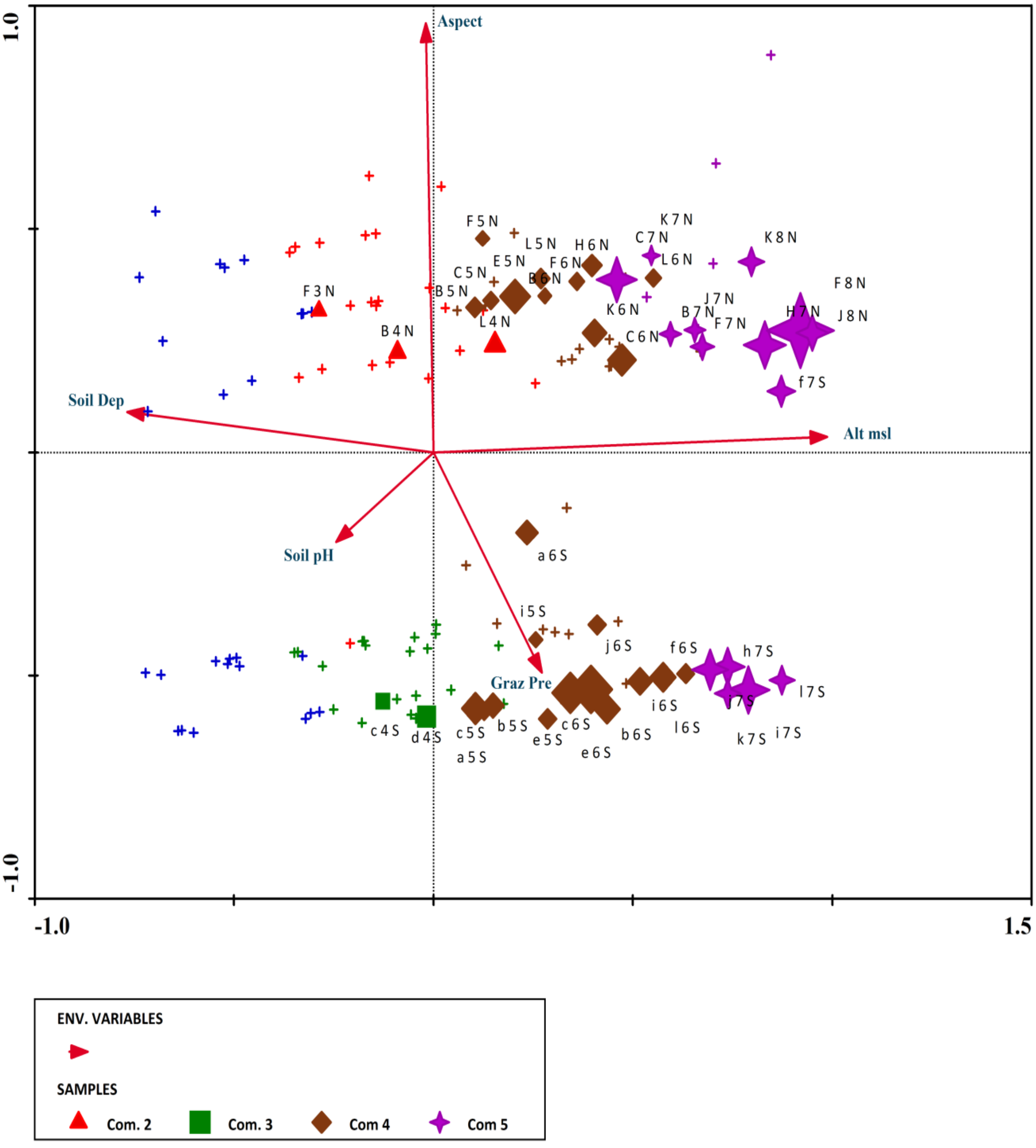


Fig. 4.16 Data attribute plot of *Iris hookeriana;* the second indicator species of Community 5 at high elevation (above 3700 m) alpine habitats

4.4.4 Environmental gradient of the floristic data

CANOCO gives ecologists a choice through ordination analyses whether to explore environmental gradients indirectly using a species matrix or directly using both species and environmental data matrices. The results obtained using both methods are provided below.

4.4.4.1 Indirect gradient ordination

Initially, indirect ordination analyses including Correspondence Analysis (CA), Principal Components Analysis (PCA) and Detrended Correspondence Analysis (DCA) were applied to the vegetation data (plant species matrix) in order to elucidate the environmental gradients. Due to the long gradient length of the 1st axis i.e., 4.797 SD (Average standard deviation of species turnover), DCA seemed the most decisive among the indirect ordination methods (Table 4.13). The first two DCA axes describe 10.1% of the variance of the species data. CANODRAW a utility of CANOCO was used to plot the data as an ordination plot. The classification results were used to categorize the ordination results for better visual interpretation. The stations/samples scores on the first two ordination axes, along with the classification results for the five plant communities are plotted in Fig. 4.17 & 4.18. The DCA diagram illustrates the environmental gradients and facilitates interpretation of the cluster dendrogram. The plant species ordination diagram further supports the influence of these gradients on species composition, diversity and community structure (Fig. 4.18).

Table 4.13 Description of the first four axes of the DCA for the vegetation data (using the matrix species with their Importance Values (IV))

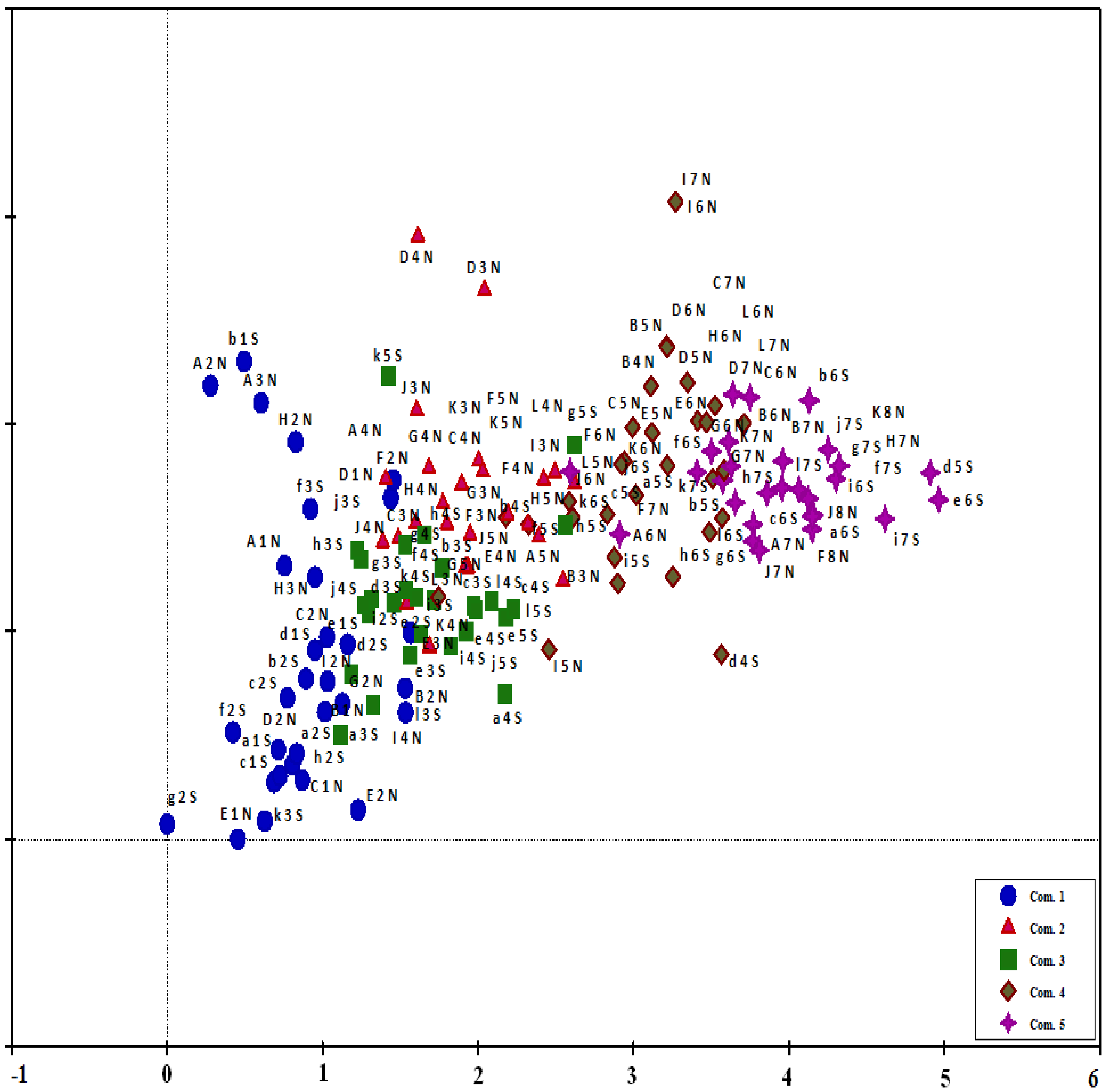
All the species (198) and all the stations/samples (144) were included					
Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigen values	0.643	0.405	0.263	0.215	9.673

Lengths of gradient	4.797	3.649	3.256	3.411	
Cumulative percentage variance of species data	6.6	10.8	13.6	15.8	

The 1st DCA axis separates the lower altitude habitats from those of higher altitudes. Communities 1, 2 and 3 occupy the left-hand side of the DCA diagram, whilst Communities 4 and 5 are located on the right-hand side. This also reflects the altitudinal and latitudinal gradient complex of the valley i.e., stations at the opening of the valley are concentrated on the left part of the diagram (lower latitudes) and the more distant stations (higher latitudes) are grouped mostly towards the right hand side of the diagram (Fig. 4.17).

The 1st axis of the species ordination diagram also reveals environmental gradients amongst the plant species and communities. Plant species of mesic habitats with temperate elements (at lower altitudes and latitudes) are grouped to the left of the first axis (Com. 1). Plant species of cool habitats of forests (at lower-middle altitudes with a northern aspect) and more xeric habitats (at lower-middle altitudes with a southern aspect) are plotted in the middle of the diagram (Com. 2 & 3), whilst sub-alpine and alpine species of a xeric nature (occurring at high altitudes and on relatively shallow soils) (Com. 4 & 5) are located on the right hand side (Fig. 4.18). As a whole, the 1st axis of the DCA reveals an altitudinal and latitudinal gradient and climatic gradient complex from inclined, mesic-cool temperate sites with trees and shrubby (woody) vegetation to more dry-cold subalpine and alpine sites, with herbaceous vegetation (left to right). Plant species diversity (β -diversity) and richness also decrease along this axis (left to right).

The 2nd ordination axis of the DCA differentiates the vegetation according to aspect (north and south facing) i.e., by grouping the communities of north-aspect slopes to the upper and south-aspect to the lower side of the plot diagrams. Again most of the stations with woody vegetation are grouped in the upper left half of the DCA diagram whilst herbaceous species are grouped in the right half of the diagram. As a whole the 2nd DCA axis reveals a geomorphologic and physiographic gradient complex from habitats of more exposed (unshaded) land surfaces with relatively thin soils (southern aspect slopes) to habitats of shady surfaces with relatively deep soils (northern aspect slopes) (Fig. 4.17 & 4.18).



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1
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4
5
6
Com. 1
Com. 2
Com. 3
Com. 4
Com. 5
I7N
I6N
D4N
D3N
C7N
D6N
L6N
B5N
H6N
L7N
B4N
D5N
b1S
A2N
A3N
k5S
J3N
D7N
C6N
b6S
K3N
F5N
L4N
g5S
C5N
E5N
E6N
B6N
K8N
H2N
A4N
G4N
C4N
K5N
G6N
B7N
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I3N
F6N
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I6N
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k7S
i6S
e6S
j3S
H5N
k6S
c5S
b5S
C3N
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b4S
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J8N
J4N
A6N
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a4S
D2N
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a2S
a3S
I4N
c1S
h2S
C1N
g2S
E2N
E1N
k3S

Fig. 4.17 Detrended Correspondence Analysis (DCA) diagram showing distribution of 5 plant communities and habitat types among 144 stations (three letters code in the plot indicate each station's and is referred to Appendix 4.2 & Fig. 4.1 for details)

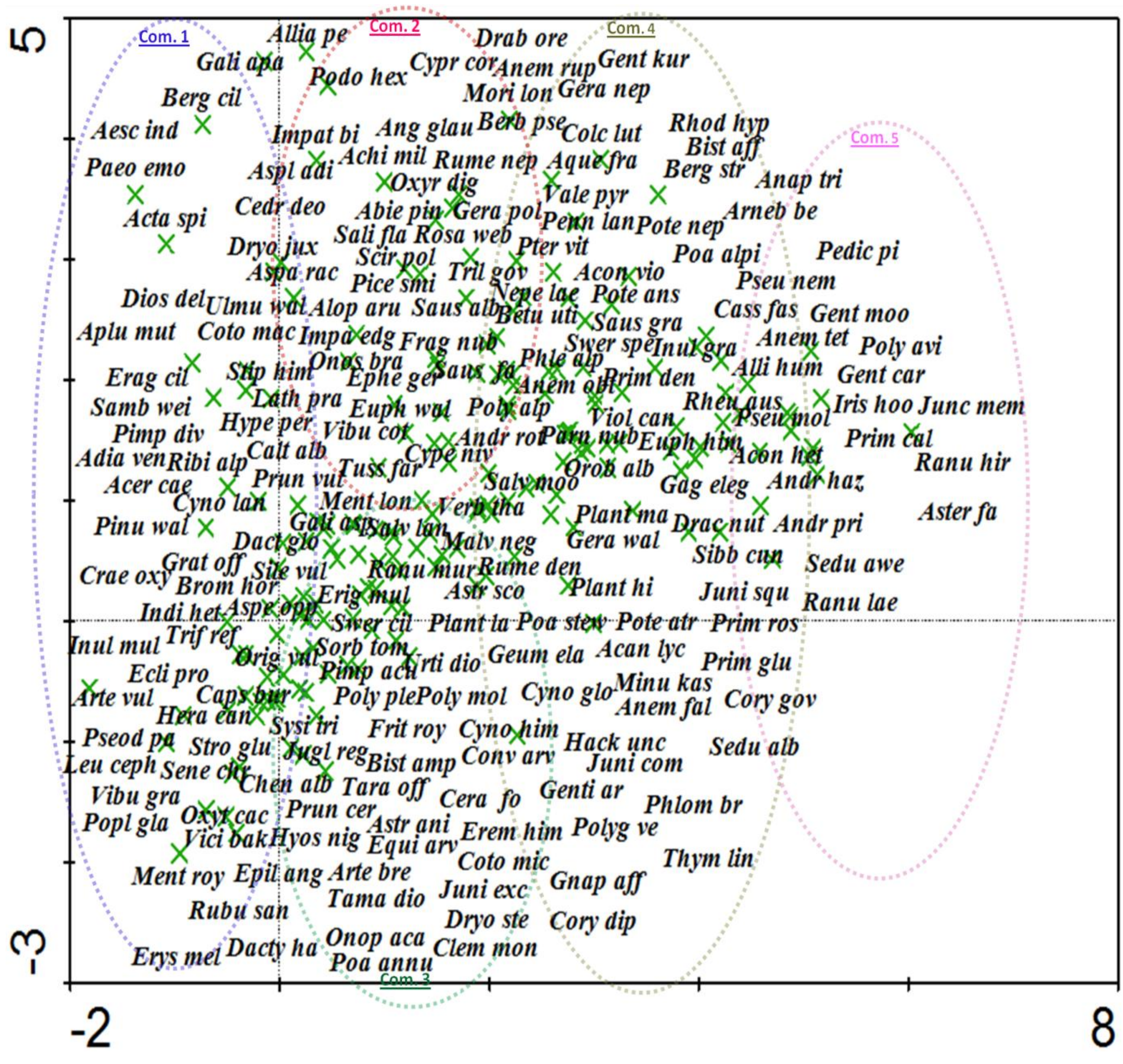


Fig. 4.18 Detrended Correspondence Analysis (DCA) diagram showing distribution of 198 plant species among 5 plant communities along the gradient

4.4.4.2 Direct gradient ordination

Direct gradient procedures were carried out to analyse both species and environmental matrices together. In order to test whether the community formation was aligned with the measured environmental variables direct gradient procedures, i.e. RDA, CCA and DCCA were tested on the available species and environmental data. As it was hypothesized that aspect and altitude were the main driving forces of vegetation variation in the valley, the low p value ($p \leq 0.002$) showed that the results were highly significant in terms of test statistics. Input of environmental data through CCA identifies the main driving environmental variable for the constitution of a specific community type. To test whether a community is established under the effect of a specific environmental variable, the results of the CCA were matched with an Indicator Species Analysis performed through PC-ORD (Appendix 4.4).

The CCA diagram (bi-plot) showed that both the composition and abundance of plant species were a reflection of the differences in the environmental variables, mainly aspect and altitude i.e., Communities 2 and 3 were distinguishable under the influence of aspect and Communities 4 and 5 (Com. 4 & 5) were distinguished by the effect of high altitudinal range (p value ≤ 0.002). Community 1 was separated under the cumulative effect of greater soil depth and lower altitudinal range. The CCA ordination procedures for stations and species indicated that the first axis was primarily correlated with altitude and soil depth; the second axis was correlated mainly with aspect; whilst partially with aspect, soil depth, altitude and grazing pressure. The strongest ecological gradient of the 1st axis can be clearly recognized from the stations and species CCA diagrams (Table 4.14; Fig. 4.19 & 4.20). The stations + environmental bi-plots and species + environmental bi-plots confirm each other by establishing habitat and community relations with the environmental data. Pearson's correlations with ordination axes for the CCA plot pointed out a significant correlation of axis with the geo-climatic variables (i.e. altitude and soil depth). The Pearson's correlations with CCA ordination axis indicate that the first axis ($e = 0.\ 0.531$) was principally correlated with the altitude ($r = 0.987$) and soil depth ($r = -0.796$). The second axis ($e = 0.252$) was correlated mainly with aspect ($r = 0.997$). The third axis ($e = 0.096$) was correlated partially with grazing pressure ($r = -0.514$).

Table 4.14 Summary of the first four axes of the CCA for the vegetation data (Using abundance (Importance Value (IV) data)

All the 198 plant species, all the 144 stations/samples & all of the 5 environmental variables were included in analysis					
Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigenvalues	0.531	0.253	0.098	0.071	9.673
Species-environment correlations	0.923	0.878	0.660	0.635	
Cumulative percentage variance of species data	5.5	8.1	9.1	9.9	
Species-environment relation	52.5	77.5	87.2	94.3	
Summary of Monte Carlo test (499 permutations under reduced model)					
Test of significance of first canonical axis		**Test of significance of all canonical axes**			
Eigenvalue	0.531	Trace			1.011
F-ratio	8.017	F-ratio			3.222
P-value	0.0020	P-value			0.0020

The CCA ordination procedures for stations and species indicated that the first axis was primarily correlated with altitude and soil depth; the second axis was correlated mainly with aspect; whilst the third axis was correlated partially with aspect, soil depth, altitude and grazing pressure. Overall, the stations and species ordination diagrams utilized the first two axes (Table 4.14; Fig. 4.19 & 4.20).

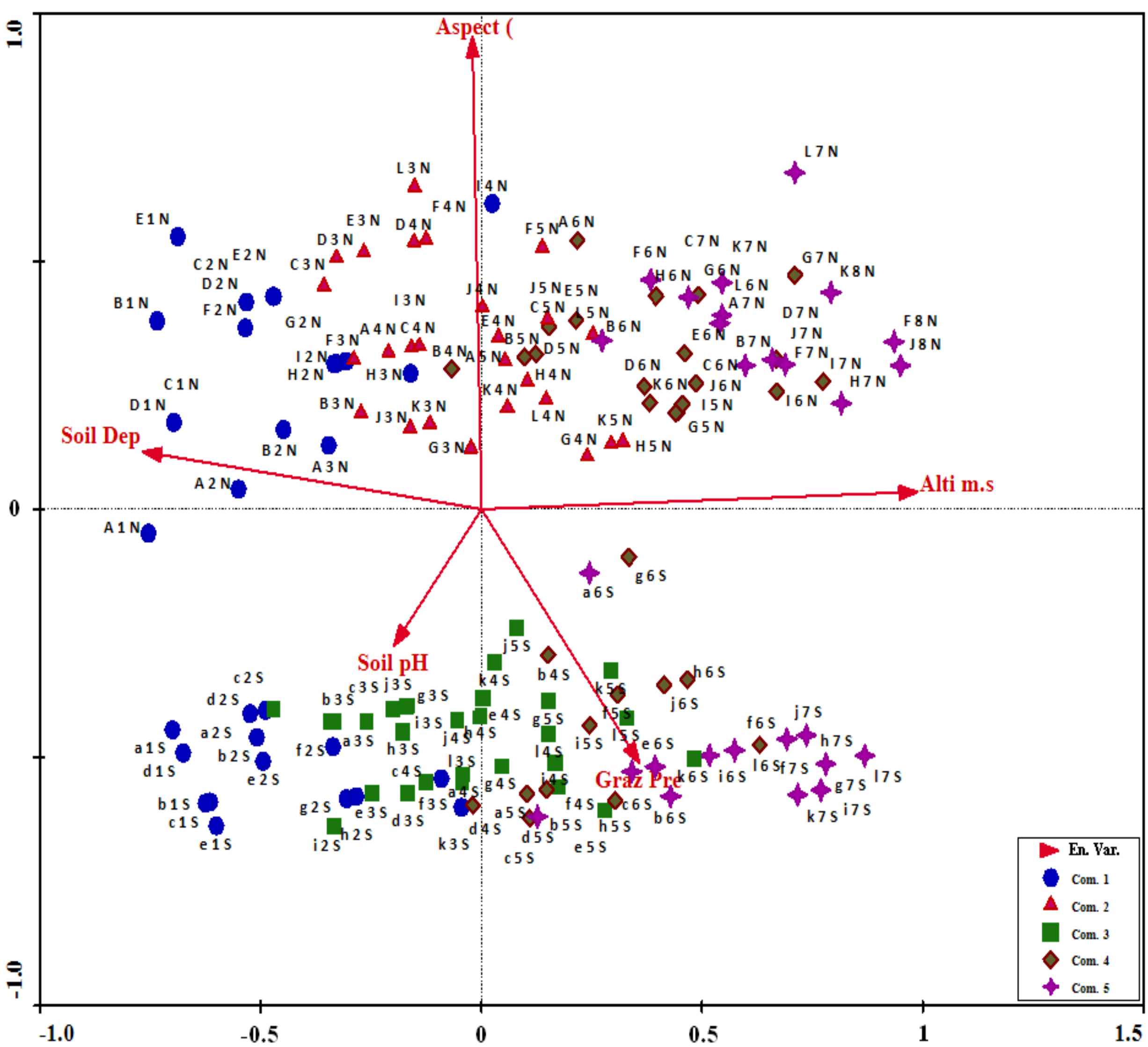


Fig. 4.19 Canonical Correspondence Analysis (CCA) diagram showing distribution of 5 plant communities among 144 stations in relation to various measured environmental variables (three letters code in the plot indicate each station's name and is referred to Appendix 4.2 & Fig. 4.1 for details)

Fig. 4.20 Canonical Correspondence Analysis (CCA) diagram showing distribution of 198 plant species among 5 plant communities and the measured environmental gradients

Beside the species and sample bi-plots, data attribute plots of each of the indicator species were also prepared to support and represent the diagrammatic proof of their preference to a specific community. CCA data attribute plots of indicator/characteristic species reconfirmed the results of the indicator species analyses (a classification technique) (Figures of data attribute bi-plots can be observed under the section 4.3.3).

4.4.5 Species richness and diversity along environmental gradients and species area curves

The DCA and CCA analyses show that the main influencing environmental variables are altitude, aspect (slope direction) and soil depth and that both species richness and diversity vary along these gradients. Analysis of the elevation gradient showed that species richness was higher at lower altitudes and lower at higher elevations. Species β-diversity gradually decreased along the altitudinal gradient as soil depth and temperature decreased. Similarly species richness on slopes with a northern aspect was slightly higher than that of slopes with a southern aspect (Figs. 4.21 & 4.22)

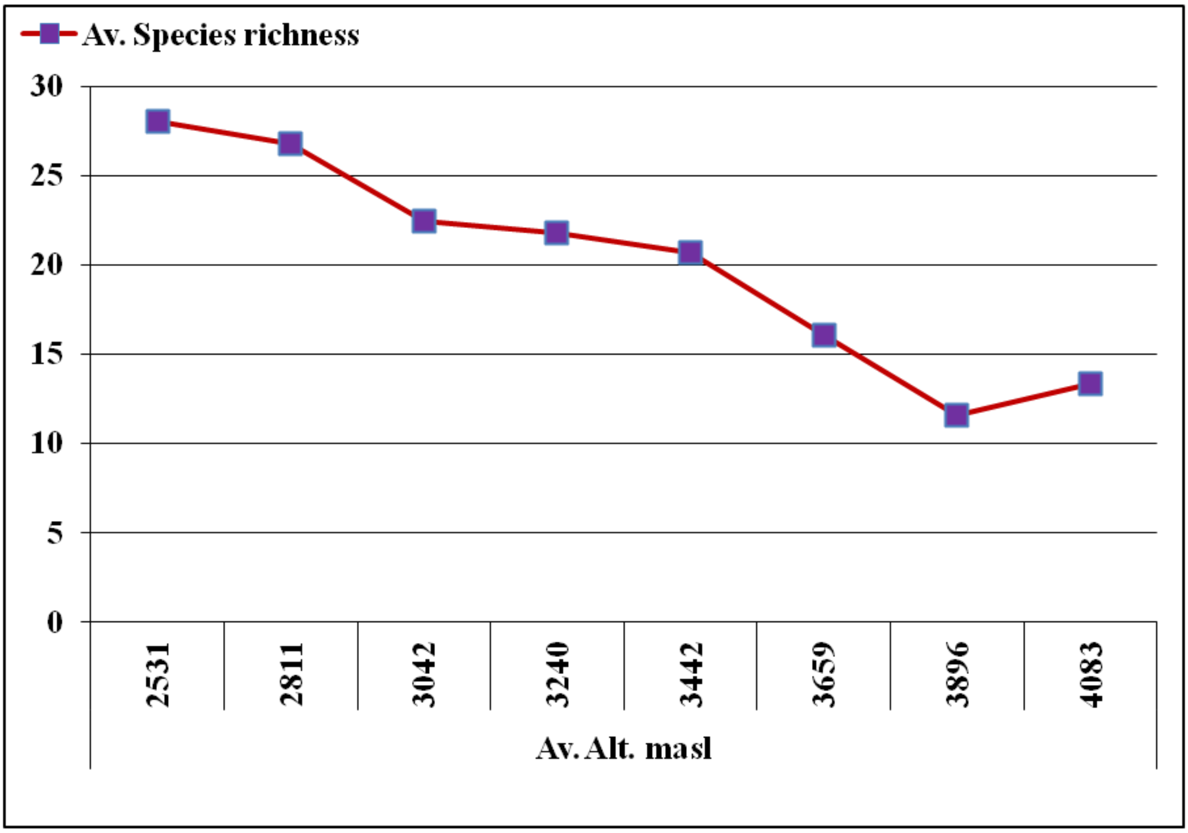


Fig. 4.21 Average β-diversity of plant species along the altitudinal gradient

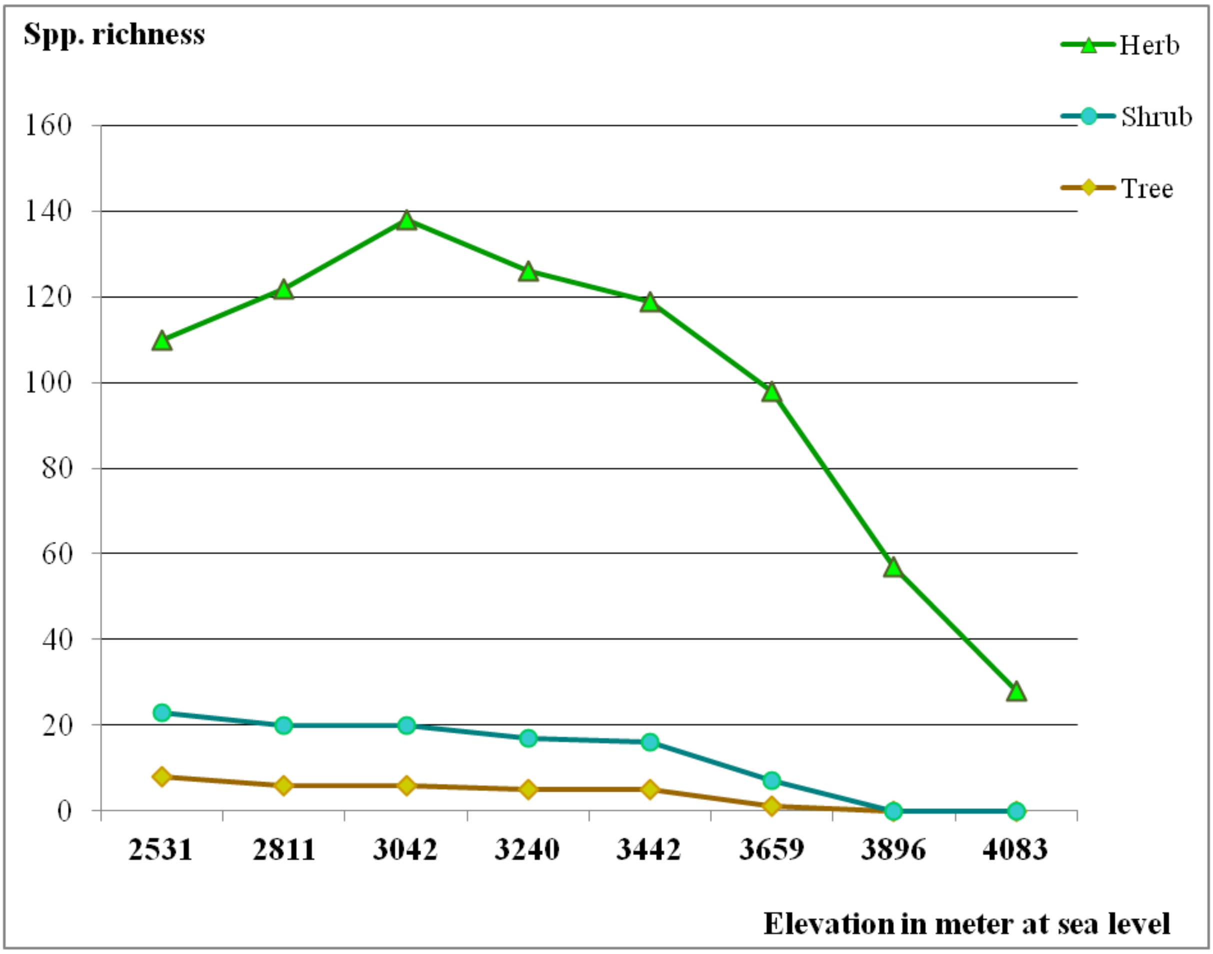


Fig. 4.22 Species richness of herb, shrub and tree species along the elevation gradient

The number of species increases with an increase in the number of sampling plots, providing species area curves for evaluation of ecological pattern. To make sure the adequacy of sample size used in community data Species area curves were calculated using PCORD. Fig. 4.23 shows the species curves climbing to the region of stability, whereas the distance curves go down to zero. The curve of average distance integrated the statistics on species presence-absence and abundance to determine a subsample size that gave a constant species composition. For our data set the average number of species started from 20 at station 1 (with average distance 0.7651) to 197 at station 143 (with average distance 0.0054). Average Sorensen distance between species and plots turned down around 10% after about 12 stations were sampled, is representative of adequate sample size for measuring community composition.

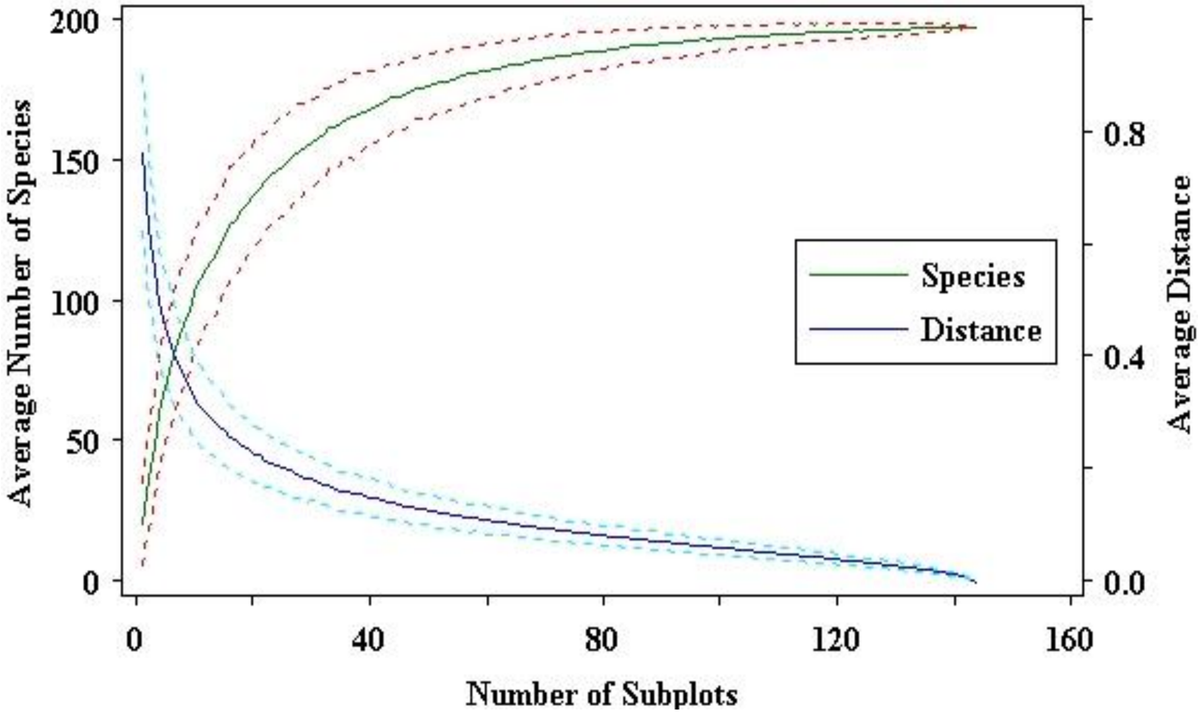


Fig. 4.23 Species area and compositional curves based on IVI data for all 198 plant species and 144 stations

4.4.6 Correlation between floristic attributes and environmental variables

Examining the correlation between species data matrices and environmental data matrices through the Mantel test resulted in highly significant correlations. The environmental distance matrix produced a significant Mantel correlation (p = 0.00000). Treating floristic matrix one by one with each of the environmental matrices showed the highest correlations with altitude, aspect and soil depth. The correlation with grazing pressure was weakly significant and non-significant with soil pH (Table 4.15).

Table 4.15 Results of the Mantel statistics executed between florestic & environmental data matrices

S. No	Main matrix i.e., {144 Samples (rows) x 198 Species (columns)} examined with second matrix of;	t	r	p value
1	144 Samples (rows) x 5 Env. variables (columns)	22.7673	0.4828	0.0000
2	144 Samples (rows) x 1 Env. variable (Altitude)	22.7260	0.4821	0.0000
3	144 Samples (rows) x 1 Env. variable (Aspect)	17.2970	0.1632	0.0000
4	144 Samples (rows) x 1 Env. variable (Soil depth)	13.2412	0.3061	0.0000
5	144 Samples (rows) x 1 Env. variable (Graz. pressure)	2.2217	0.0619	0.0265
6	144 Samples (rows) x 1 Env. variable (Soil pH)	1.6440	0.0383	0.1005

The Mantel test also showed a statistically significant correlation (p=0.00000000) at the community level (Table 4.16).

Table 4.16 Results of the Mantel statistics executed between community floristic & environmental variables data matrices

Matrices details	T	r	p value
Main matrix: 5 communities (rows) 198 Species (columns) Second matrix: 5 communities (rows) 5 Environmental variables (columns)	2.4527	0.7707 62	0.014348 99

4.4.7 *Raunkiaer life form classification*

Based on the Raunkiaer system of classification, 198 plant species were placed in 5 life form classes (Fig. 4.24). The Hemicryptophytes (51 %) dominate the flora of the study area followed by Phanerophytes and Cryptophytes (Geophytes) with 15 and 13 % dominance respectively. Therophytes and Chamaephytes are represented by smaller numbers (12 & 10% each). Most of the Phanerophytes especially tree species are widely distributed on northern aspect slopes whilst shrubs are more dominant on southern aspect slopes. Woody plants are dominant at lower altitudes (2450-3200 m), with a much smaller proportion occurring at middle and high altitudes (3200-3800 m). One of the highly selective Phanerophytic indicator species of middle altitude is *Betula utilis* which occurs only on northern aspect slopes at an altitudinal range of 3000-3400 m.

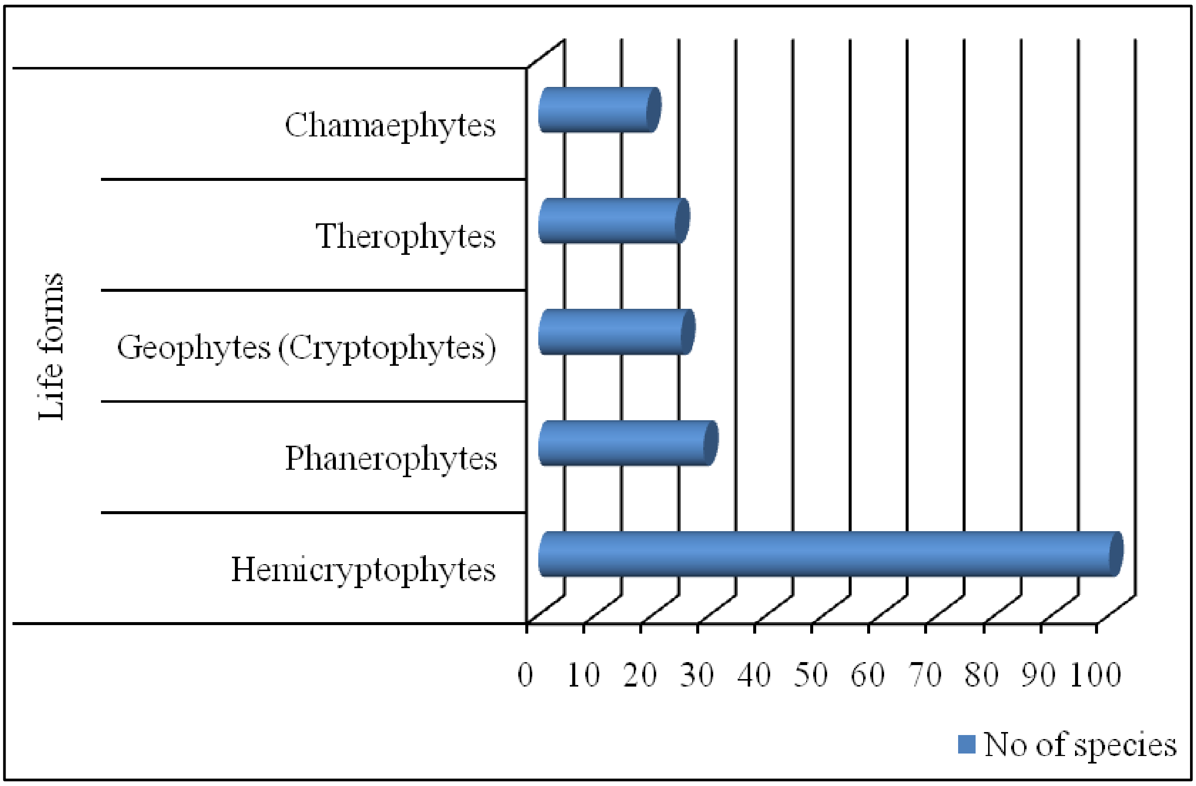


Fig. 4.24 Raunkiaer life form classification categories

4.4.8 Environmental gradient and Raunkiaer life forms

DCA analyses of Raunkiaer life forms show a clear gradient (length of the 1st axis 5.076 SD) from lower altitude habitats of woody phenerophytic and chamaephytic vegetation (trees and shrubs) through to hemicryptophytic, cryptophytic (geophytic) and therophytic herbaceous vegetation at higher altitudes (Table 4.17 & Fig. 4.25).

Table 4.17 Description of the first four axis of the DCA for the vegetation data (using Raunkiaer life form species matrix in 144 stations)

Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigen values	0.653	0.378	0.308	0.259	10.346
Lengths of gradient	5.076	3.767	4.097	3.607	
Cumulative percentage variance of species data	6.3	10.0	12.9	15.4	

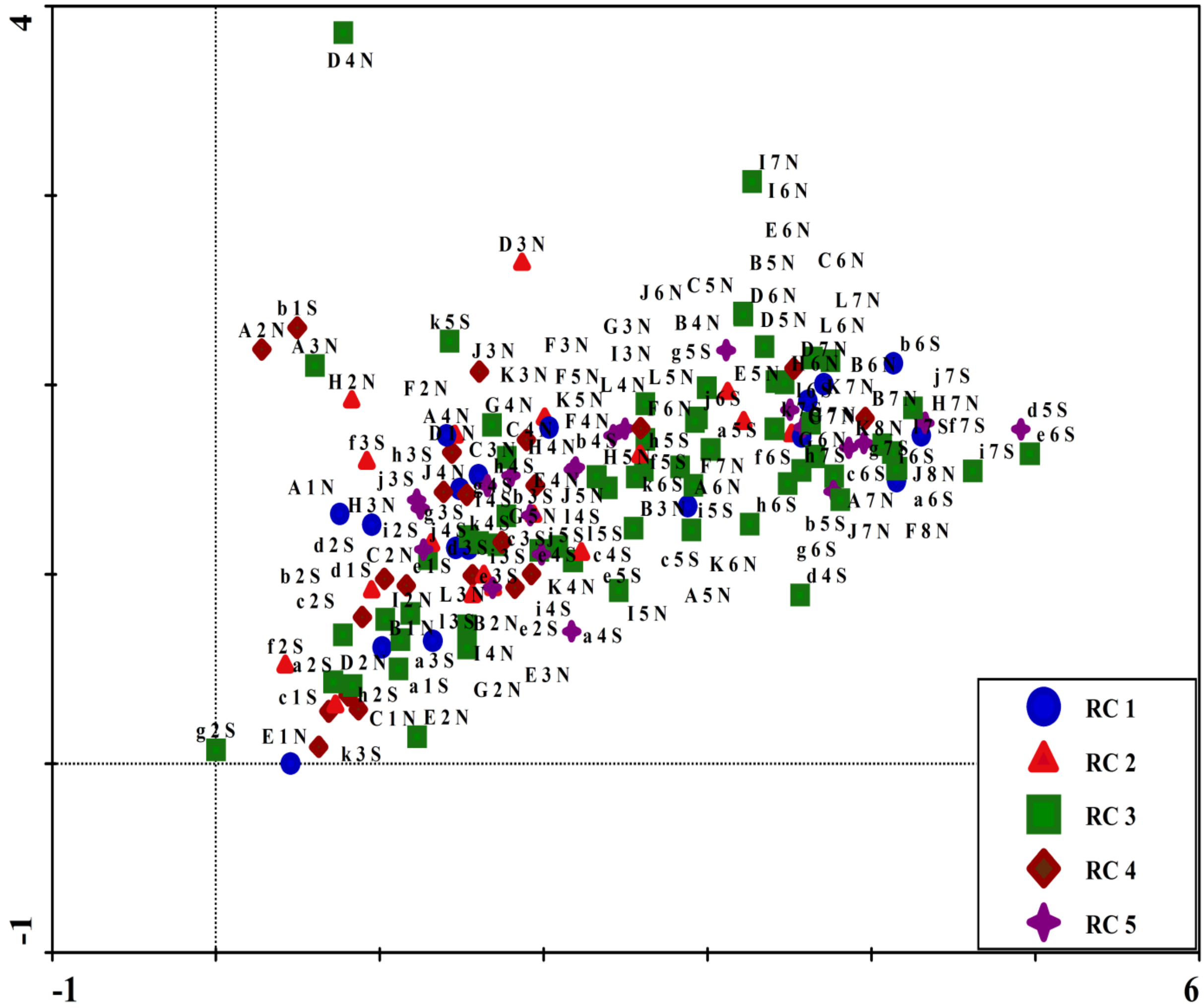


Fig. 4.25 Detrended Correspondence Analysis (DCA) diagram showing 5 Raunkiaer life forms distribution among 144 stations/habitat types

The CCA diagram (bi-plot) shows that the Raunkiaer life forms of plant species were a manifestation of the variation in the environmental gradients, mainly elevation i.e., Raunkiaer Classes (RC) 1, 2 and 5 were obvious under the influence of lower altitudes and higher soil depth whilst Class 3 and 4 (the hemicryptophytes and cryptophytes) were evident at higher to highest altitudes under the effect of elevation range (p value ≤ 0.002). Aspect has a partial effect on life form distribution as Classes 1, 2 and 3 are inclined mainly to slopes with a northern aspect and Class 5 to the southern ones whilst there is limited effect of aspect on the distribution of class 4 (Geophytes). Furthermore class 3 (the hemi-cryptophytes) are more inclined to northern aspect as compared to the southern slopes. The CCA ordination diagram for species further indicated that the first axis was primarily correlated with altitude and soil depth whilst the second axis was correlated mainly with aspect and to a lesser extent with grazing pressure (Table 4.18 & Fig. 4.26).

Table 4.18 Summary of the first four axes of the CCA for the vegetation data (Using Raunkiaer life forms in sps matrix along all144 stations and environmental variables)

When all the 198 plant species, all the 144 stations/samples & all of the 5 environmental variables were included in analysis					
Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigenvalues	0.536	0.267	0.101	0.076	10.346
Species-environment correlations	0.921	0.875	0.631	0.615	
Cumulative percentage variance of species data	5.2	7.8	8.7	9.5	
species-environment relation	51.4	77.0	86.6	94.0	
Summary of Monte Carlo test (499 permutations under reduced model)					
Test of significance of first canonical axis		**Test of significance of all canonical axes**			
Eigenvalue	0.536	Trace			1.044
F-ratio	7.544	F-ratio			3.099
P-value	0.0020	P-value			0.020

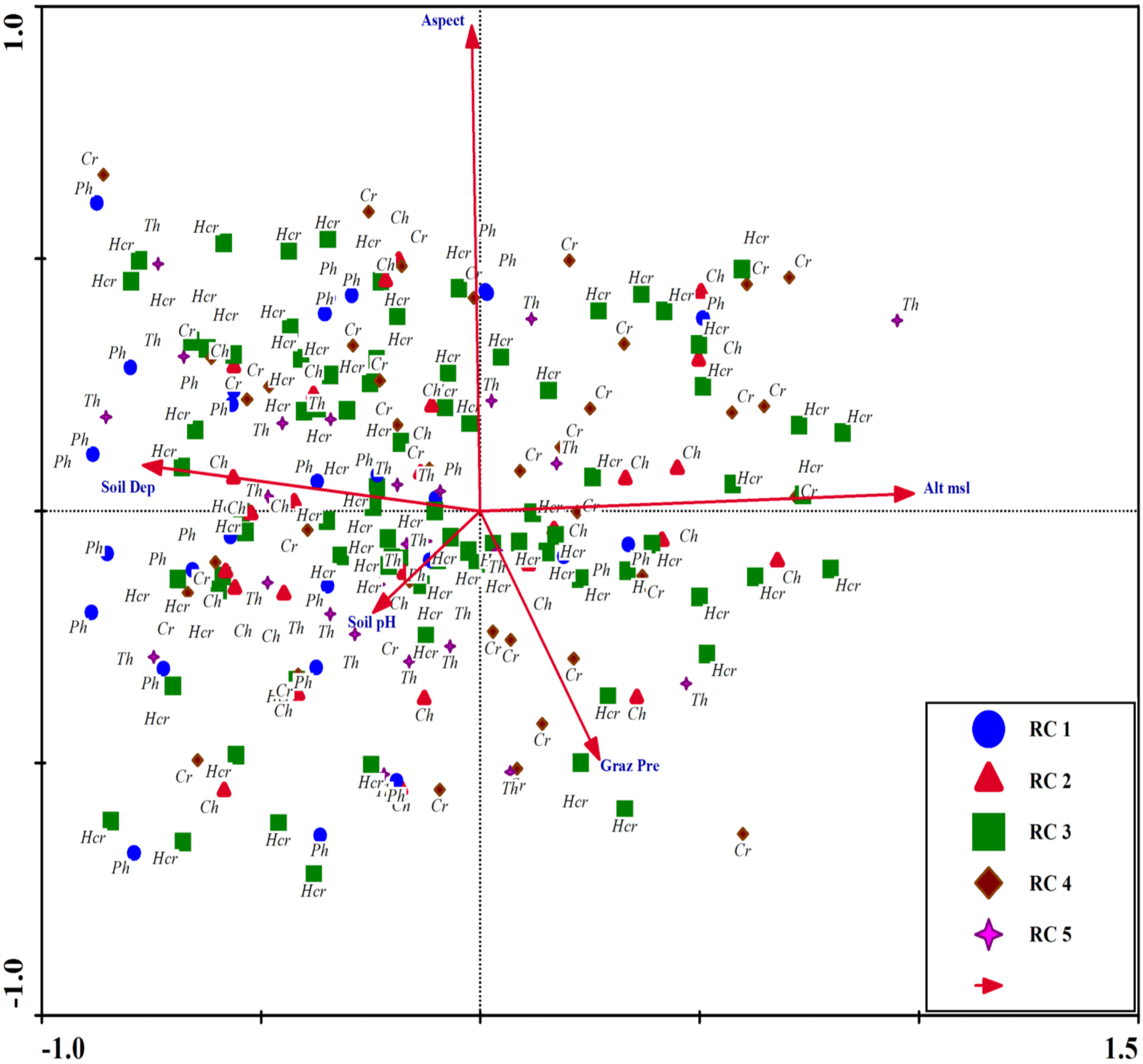


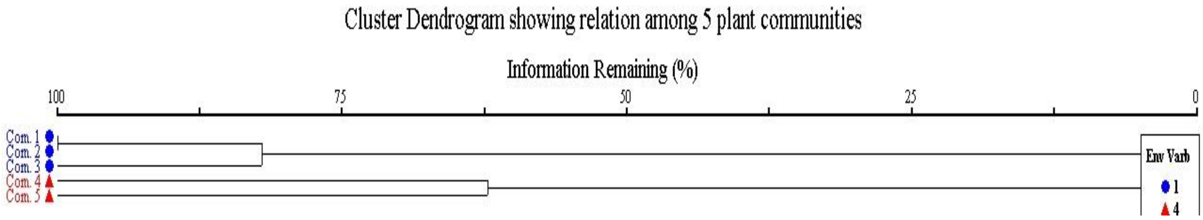
Fig. 4.26 Canonical Correspondence Analysis (CCA) bi-plot, showing the distribution of 5 Raunkiaer life forms among 198 plant species and 5 measured environmental variables

Overall the Naran Valley shows a gradient from Phanerophytic and Chamaephytic forms of vegetation to Hemicryptophytic forms (Left to right in the DCA and CCA plots) (Figs. 4.25 & 4.26) at higher altitudes.

4.4.9 Diversity among plant communities

4.4.9.1 Diversity and classification

Cluster analysis based on the Importance Value Index (IVI) showed similarities among the five plant communities based on habitat types. The cluster divided the five communities into two groups based on elevation i.e., a lower altitude group (Community 1, 2 & 3) and a higher altitude (Community 4 & 5) group.



4.4.9.2 Diversity analysis and ordination

The first sort of diversity index based on species richness was the calculation of species number per community (Fig. 4.27). The highest number of plant species was reported in Community 2 at middle altitude northern aspect habitats followed by lower altitude valley bottom habitats (Community 1). The high diversity of these habitat types can be attributed to high soil depth with high moisture retaining capacity and relatively high temperature at these somewhat lower altitudes. The lowest number of species scored in the index was for the Community number 5 at peak elevations above the tree line.

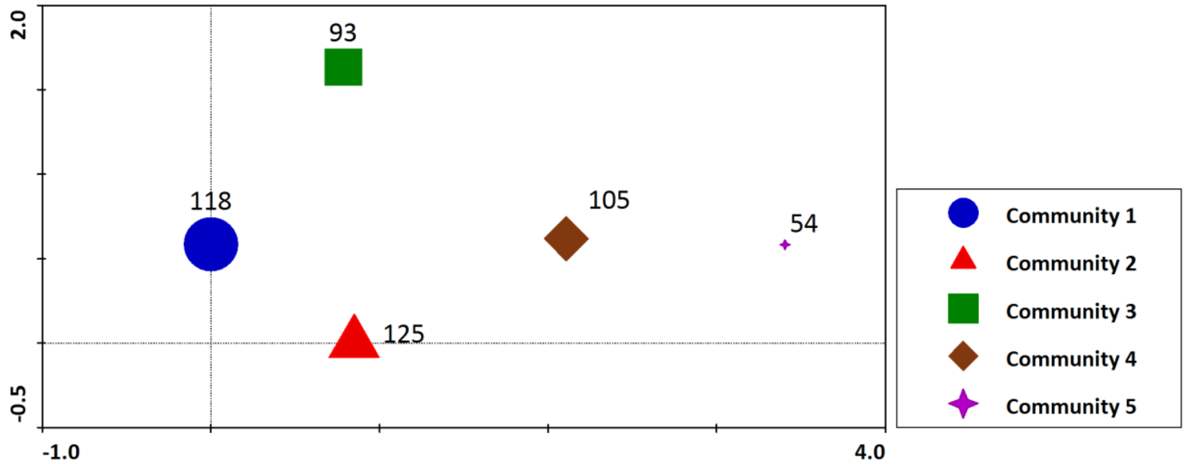


Fig. 4.27 Index of species Number (alpha diversity) among all community types through DCA data attribute plots along the gradients

The Shannon Diversity index values range between 3.3 and 4. Being constituted of both Northern and Southern aspect stations, Community 1 has the highest value of 3.98 among all the groups while Community 5 has the lowest value due to narrow ecological amplitude (Fig. 4.28). High values of this index are due to the inclusion of a considerable number of stations in a single community.

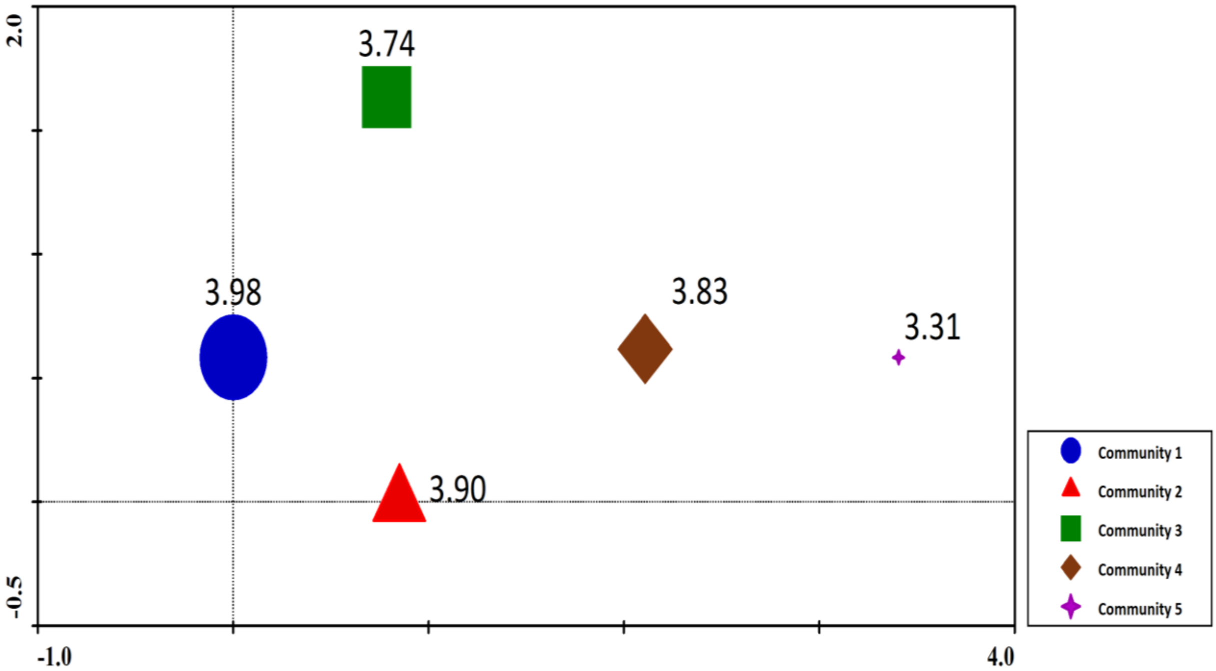


Fig. 4.28 Shannon Weiner diversity index at community level through DCA data attribute plots show the gradient of the community

The N2 index is the reciprocal of Sampson diversity index and is available in the CANODRAW utility of CANOCO. This index showed the highest value for Community 2 followed by Community 1 (Fig. 4.29).

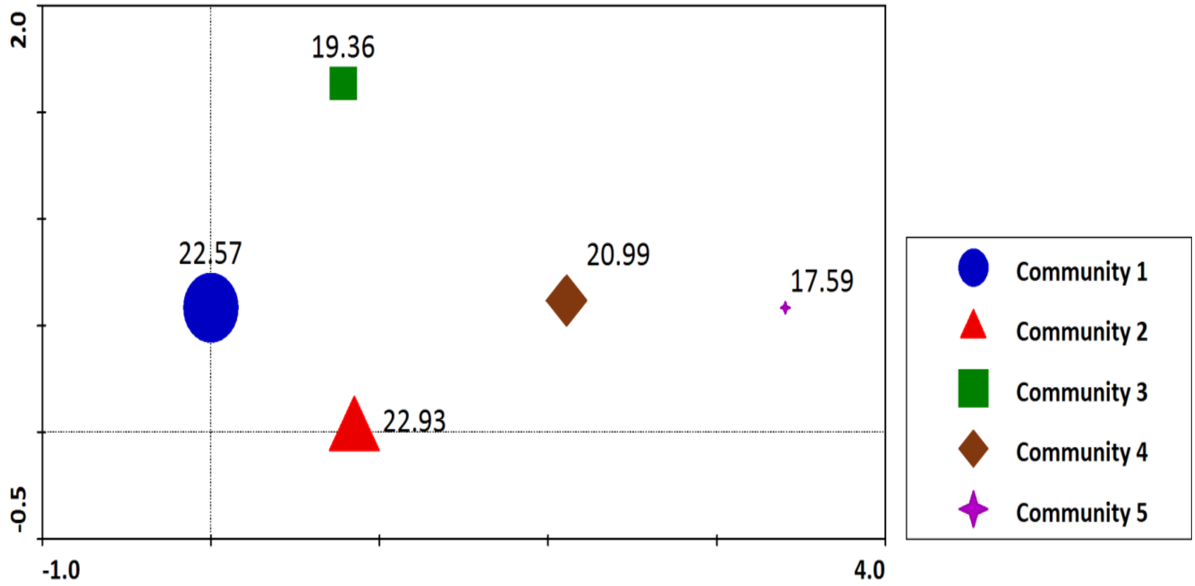


Fig. 4.29 N2 diversity index at community level through DCA data attribute plots along the gradient of the community

Index of sample variance showed the highest variance for Community 2. As the altitudinal pattern (Fig. 4.22) showed that species richness is optimum at the middle altitude especially on north facing slopes, this index reconfirmed that phenomenon through sample variance index (Fig. 4.30).

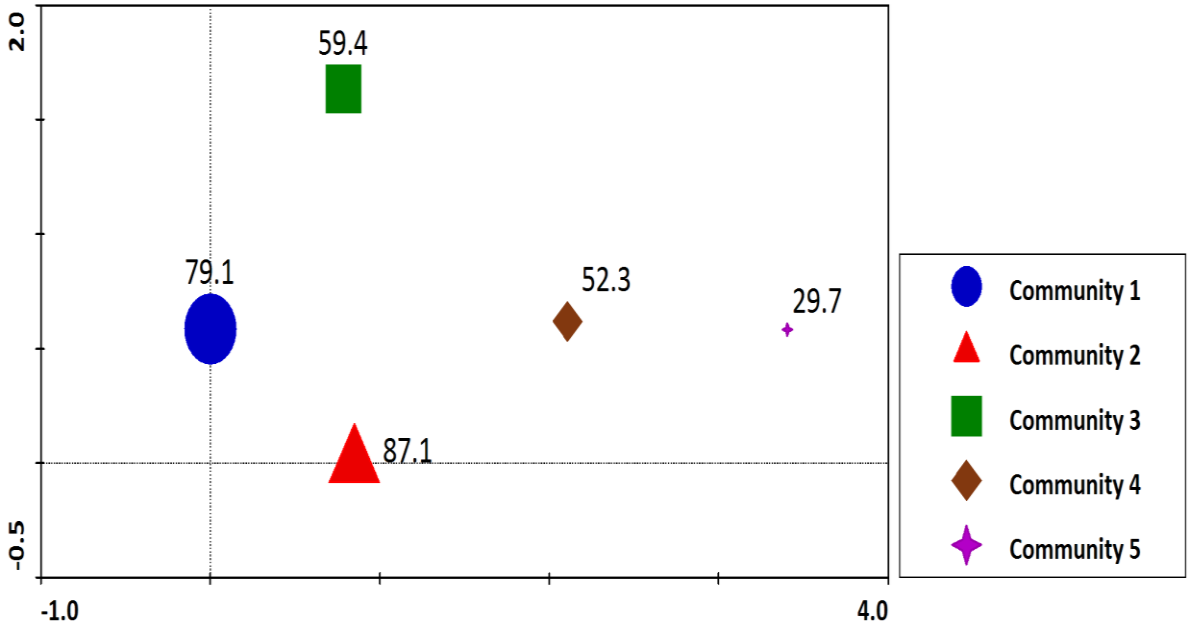


Fig. 4.30 Index of Sample Variance among all community types through DCA data attribute plots along the gradient

4.5 Discussion

Mountain ecosystems all over the world usually have diverse biological communities due to their rapidly changing landscape, climate and geo-climatic history (Herben *et al.*, 2003, Fosaa, 2004). The distribution of individuals of the same and different plant species in a community is the function of micro environmental pattern, time and biotic relationships. Plant species assemble in a community in a definite fashion and hence can assist in vegetation quantification and evaluation. Classification of natural ecosystems into potential plant communities and habitat types is important for the long-term management of natural resources (Mucina, 1997, Ewald, 2003). Classification and ordination also overcome problems of comprehension by summarizing field data in a low-dimensional space with similar samples and species near together and dissimilar ones far apart (Greig-Smith, 2010).

4.5.1 Vegetation composition, diversity and richness

Vegetation composition and classification shows that at lower altitudes along the River Kunhar temperate elements can be found, these then changes from temperate to subalpine and alpine types under the effect of high altitude. At the opening of the valley characteristic species of moist temperate vegetation of the adjacent Kashmir Hills and Siran valley (from the south) can be observed e.g., *Pinus wallichiana, Aesculus indica, Prunus cerasoides, Indigofera heterantha, Viburnum grandiflorum, Viburnum cotinifolium, Paeonia emodi, Bistorta amplexicaulis* and *Trifolium repens* etc (Nafeesa *et al.*, 2007, Ahmad *et al.*, 2009, Dar & Malik, 2009, Shaheen *et al.*, 2011). As one moves from south to north in the valley (along the latitudinal gradient), these moist temperate species disappear slowly and gradually and the valley is dominated by dry temperate elements i.e., *Artemisia brevifolia, Bistorta affinis, Anemone tetrasepala, Hackelia uncinata, Thymus linearis, Verbascum thapsus* etc. Predominantly, Community 1 and to some extent Communities 2 and 3 include the species of temperate vegetation (moist and dry) as these communities are found at lower altitudes. Nevertheless, the major part of the vegetation is comprised of subalpine and alpine types due to the high elevation of the mountains. Specifically, Communities 4 and 5 and a major portion of Communities 2 and 3 are made up of alpine and subalpine flora. Characteristic species of these subalpine and alpine habitats are *Betula utilis, Juniperus communis, Juniperus squamata Rhododendron hypenanthum, Rheum australe, Sibbaldia cuneata, Iris hookeriana, Aster falconeri and Ranunculus hirtellus.* Due to the influence of a harsh cold climate at high elevations, the growing season is very short and prevails from June to September. For the rest of the year most of the valley, especially the subalpine and alpine zones (zones between the timberline and the snowline) remain buried under deep snow. The classification and ordination analyses both reveal an altitudinal and latitudinal gradient complex within the vegetation of the Naran Valley, from mesic-cool temperate stations characterised by the presence of woody species of trees and shrubs, to more dry-cold stations with herbaceous vegetation dominated by subalpine and alpine flora. Species diversity and richness are optimal at the middle altitudes (2800-3300 m), in contrast to the lower altitudes (2400-2800 m) where direct anthropogenic activities have their greatest impact. At high altitudes (3400-4100), diversity reaches a minimum mainly due to xeric conditions and short growing season but also the high grazing pressure. Important indicator species in the study area which are typical of the Himalayan range (Takhtadzhian & Cronquist, 1986) include *Pinus wallichiana, Abies pindrow, Cedrus deodara, Picea smithiana, Fragaria nubicola, Rhododendron* species, *Viola* species, and *Clematis* species. Several other studies have shown that the forest areas of the Hindu Kush close to the western Himalaya also host these woody species across altitudinal ranges of 2400 to 3500 m, (Chaudhri, 1963, Miehe *et al.*, 2009, Dong *et al.,* 2010). Due to shallow soils, and harsh climatic conditions at high altitudes the vegetation is dominated by herbaceous species. An increase in herbaceous vegetation with increasing altitude is a common pattern in the temperate zone of both the Himalaya (Grytnes & Vetaas, 2002, Vetaas & Grytnes, 2002, Ren *et al.*, 2006, Anthwal *et al.*, 2008, Zhang *et al.*, 2009) and the Karakorum ranges (Eberhardt *et al.*, 2007, Khan & Khatoon, 2007). At higher altitudes in the Karakorum mountains (above 3500m asl) alpine pastures are characterised by species such as *Juniperus spp., Thymus linearis, Minuartia spp., Androsace spp., Gentiana spp., Geranium spp., Poa spp., Sibbaldia spp.* and *Rheum spp.,* indicating close similarity with Communities 4 and 5 in the Naran Valley.

Floristically, given its position at the extreme western edge of the Himalaya, the vegetation of the Naran Valley bears greater similarities to the vegetation of the Hindu Kush and the Karakorum ranges in terms of species richness and composition, than to the rest of the Eastern Himalaya, presumably as a result of geologic, physiographic and climatic similarities. This change in vegetation pattern is gradual from the south east (opening of the valley) towards the north western end of the valley. Characteristic species of this transitional belt of the Western Himalaya, the Southern Karakorum and the eastern Hindu Kush include *Cedrus deodara, Picea smithiana, Ephedra gerardiana, Thymus linearis* and *Cotoneaster* *microphyllus* (Oommen & Shanker, 2005, Kharkwal *et al.*, 2005b, Chawla *et al.*, 2008). Alpine and sub alpine habitats where altitude becomes the most influential limiting factor further strengthen the floristic affinities with these mountain systems with a number of characteristic shared species in the genera *Juniperus, Poa, Sibbaldia, Geranium, Rhodiola, Rheum, Androsace, Iris, Primula, Potentilla* and *Polygonum* (Sheikh *et al.*, 2002, Qureshi *et al.*, 2007, Wazir *et al.*, 2008, Ali & Qaiser, 2009a).

4.5.2 Floristic affinities with other regions in terms of community pattern and environmental gradients

Floristically the Naran Valley occupies an significant location in the western Himalayan Province of the Irano-Turanian Region as it falls in a transitional zone between moist temperate (from South East) and dry temperate (North West) vegetation zones (Takhtadzhian & Cronquist, 1986). The pattern of the plant communities in the valley is largely determined by aspect and altitude. Four plant communities i.e., Communities 2, 3, 4 and 5 can be separated mainly on the basis of these two variables, whilst Community 1 is established under the combined effect of lower altitude and greater depth of soil (the third most important variable). Deeper soil is closely related to the low elevation and higher soil moisture. Predominantly, Community 1 reflects the latitudinal gradient of vegetation from moist temperate to dry temperate along the valley on either side of River Kunhar at lower altitudes. Similar to our Community 1, Nafeesa *et al.*, (2007) reported *Pinus wallichiana* communities in the Pir Chanasi Hills; Kashmir (at the same altitude) although their study used a classical approach to vegetation description based on importance value indices. Saima *et al.*, (2009), also reported *Pinus wallichiana* communities similar to Community 1 but with different dominant species from the Ayubia National Park, Abbottabad. Both of the above mentioned studies use the dominant species with high importance value for naming the communities, hence why they named different communities with the same species name. In the Naran Valley, Communities 2 and 3 contain a mixture of temperate and subalpine plant species, which are strongly influenced by aspect (slope orientation) i.e., northern aspect slopes exhibit a vegetation change from moist temperate to subalpine and alpine, and south facing slopes from dry temperate to alpine vegetation along the altitudinal gradient. Such effects were also observed by a number of authors in other mountain systems around the globe while observing slope and aspect driven mechanisms of species zonations (Radcliffe, 1982, Wang *et al.*, 2006, Warren, 2008, Hegazy *et al.*, 2011). Community 2 is almost confined to slopes with a northern aspect at middle altitudes; it is dominated by tree species and shade loving herbs. In contrast, Community 3 differs from Community 2 in its position on south-facing slopes and the dominance of shrub species, in particular *Juniperus excelsa*, as opposed to trees. Eberhardt *et al.*, (2007) and Wazir *et al.*, (2008) reported a similar association of *Juniperus excelsa* with *Ephedra* species on rocky slopes of the Chapursan valley in the Hindu Kush and Karakorum Range respectively. They also identified herbaceous alpine associations which resemble our Community 4. In our project area, Communities 4 and 5 are comprised almost entirely of subalpine and alpine species. At higher altitudes, shorter summers, deep snow, low temperatures, intense solar radiation and cold winds result in relatively xeric conditions for plant growth and hence the *β*-diversity gradually decreases both along the altitudinal and the latitudinal gradients in the valley. At high altitudes, the vegetation bears a close correspondence to the subalpine and alpine flora of the adjacent Hindu Kush and the Karakorum mountain ranges. Common characteristic species include *Betula utilis*, *Juniperus communis, Juniperus squamata, Rhododendron hypenanthum, Rheum australe, Sibbaldia cuneata, Iris hookeriana, Aster falconeri* and *Ranunculus hirtellus* (Sheikh *et al.*, 2002, Eberhardt *et al.*, 2007,).

4.5.3 Diversity among plant communities/habitat types

Short summers, deep snow, low temperatures, strong solar radiation and cold speedy winds in the valley in common and higher altitude and special slope orientation in particular results xeric condition for plant growth and hence the -diversity is gradually decreasing both along the altitudinal and latitudinal gradients of the valley. Although drawing a sharp line in any natural ecosystem of mountains is difficult as the rapid micro climatic and edaphic variations overlap each other due to number of driving agencies and historical perspectives but based on some indicator species vegetation zonation and association can be established. Both at station and community level the plant species richness and diversity is strongly influenced by elevation, aspect and soil depth. Various diversity indices including number of species, Shannon Weiner, sample variance and N2 show maximum values for the middle altitude northern aspect plant community (Community 2) followed by the lower valley (Community 1) and the subalpine (Community 4) and middle altitude southern aspect plant community (Community 3). Similar patterns of diversity across altitudinal gradients have been observed in other studies in the Himalayan region (Tanner *et al.*, 1998, Vázquez G & Givnish, 1998, Kharkwal *et al.*, 2005a).

4.5.4 *Life form categorization and phyto-climatic gradient*

The life form of vegetation in a region is always indicative of plant-environment interactions. The station data designated a phyto climatic gradient from the mild monsoon belt at the mouth of the valley to the harsh dry alpine zone at the end of the valley. Classification and ordination analyses of Raunkiaer life forms further indicate the nature of the habitat types that gradually turn from moist temperate to dry temperate ecosystems along the valley and to alpine along the elevation gradient. At the mouth of the valley, species richness especially of Phanerophytes and Chamaephytes is higher as the soil depth is high, altitude is lower, the snow melts earlier compared to the upper reaches of the valley, and most importantly monsoon winds also cause a considerable summer rainfall as compared to the inner valley. The inner valley and the northern sections are dominated by herbaceous vegetation of Cryptophytes and Hemi-cryptophytes where the monsoon winds have no reach. This dry type of climatic gradient exhibited by sparse vegetation runs along the valley and leads westward to the Hindu Kush and northward to the Karakorum mountain systems where cryptophytic (geophytic) and hemicryptophytic elements prevail predominantly. Such life forms can also be found in high elevation zones of other Himalayan regions (Malik & Husain, 2006, Malik & Husain, 2008, Wazir *et al.*, 2008, Saima *et al.*, 2009).

4.5.5 *Anthropogenic gradient and different plant communities*

In the Naran Valley various anthropogenic activities have an influence on the vegetation. These include multipurpose plant collection, forest cutting, expansion of agricultural land and grazing pressure. Communities 1, 2 and 3 were influenced by all of these factors, whilst Communities 4 and 5 were mainly affected by grazing and plant collection. More detailed information on the utilization of plant species will be provided in Chapters 5 and 6. Grazing pressure was most severe in Communities 3, 4 and 5 which are mainly comprised of herb and shrub species. Community 3 occurs on south eastern facing slopes where the snow melts earlier compared to the north facing slopes and hence grazing occurs over a longer period. Communities 4 and 5 occur at higher altitude and are utilized by grazers during the summer. Anthropogenic pressure on the natural vegetation has been observed in adjacent hilly areas of the Hindu Kush and the Karakorum mountain ranges (Peer *et al.*, 2001, Inam-ur-Rahim & Maselli, 2004, Kukshal *et al.*, 2009,). A detailed discussion of anthropogenic gradients will take place in the next chapter, but here it is worth mentioning that local people also collect and utilize a number of medicinal plant species, some of which they sell in the local markets. Similar use has been reported in other studies from the adjacent mountains parts (Kassam *et al.*, 2011, Khan *et al.*, 2011a) and also other parts of the world (Jones, 2000, Maurer *et al.*, 2006, Chowdhury & Koike, 2010, Chowdhury & Koike, 2010).

4.5.6 Overall approach and novelty of the classification of the vegetation of the region

Due to the rugged topography and remote locations, intensive vegetation sampling is a challenging task anywhere in the Himalayan region. Previous plant community studies in this part of the world have often focused on subjective classification of plant communities, with community names being given on the basis of dominant species with high importance values. In this project we have adopted more robust multivariate statistical approaches for classification and ordination of plant communities which can only be found in a few previous community studies. The approach to naming the communities in this study is based on a statistical approach, namely Indicator Species Analysis (ISA), used in conjunction with constancy and fidelity measurements (Bergmeier, 2002), techniques which again which have not been widely applied in studies of Himalayan vegetation. The use of statistical packages reduces the complexity of the data by classifying vegetation and relating the results to abiotic (environmental) components (ter Braak, 1988, Dufrene & Legendre, 1997, McCune & Mefford, 1999). Such approaches have rarely been used in vegetation studies in the developing world. The results of the Cluster Analysis (CA) and Indicator Species Analysis (ISA) recognized five plant communities and their indicator species. DCA and CCA identified the altitudinal and latitudinal gradient complex from inclined, mesic-cool temperate, woody vegetation, to more dry-cold subalpine and alpine stations of herbaceous vegetation. The ISA and CCA elucidated that aspect, altitude and soil depths were the strongest explanatory variables. The Mantel test showed the significance between floristic and environmental data matrices. Species area curves authenticated the adequacy of the sample size.

The results further revealed that at the southern end (start) of the valley, at lower altitudes, Community 1 comprised of some characteristic species of the moist temperate vegetation of the adjacent eastern Himalayan valleys e.g., *Pinus wallichiana, Aesculus indica, Prunus cerasoides, Indigofera heterantha, Viburnum grandiflorum, Viburnum cotinifolium, Paeonia emodi, Bistorta amplexicaulis* and *Trifolium repens* etc. A similar plant community has also been observed in adjacent moist temperate locations elsewhere in the Himalaya (Dasti *et al.*, 2007, Malik & Husain, 2008, Wazir *et al.*, 2008, Saima *et al.*, 2009). In the inner valley, where the monsoon winds have no or greatly reduced influence, moist temperate vegetation disappears gradually along the latitudinal gradient, and dry temperate elements i.e., *Artemisia brevifolia, Bistorta affinis, Anemone tetrasepala, Hackelia uncinata, Thymus linearis* and *Verbascum thapsus* become more dominant (Peer *et al.*, 2001). At the northern end of the valley and on the high peaks, the climatic conditions are increasingly xeric, with similarities to the Tibetan Plateau of the Karakorum Mountains (Eberhardt *et al.*, 2007, Khan & Khatoon, 2007, Marston, 2008).

Thus the vegetation of the Naran Valley appears to exhibit transitional characteristics between the contrasting moist and dry temperate zones of the Sino-Japanese and Irano-Turanian floristic regions. On the basis of the definition of ecotone provided by Lloyd *et al.*, (2000), as ‘a zone where directional spatial change in vegetation is more rapid than on either side of the zone’ we advocate that the Naran Valley occupies a transitional floristic position between these two regions. Studies of adjacent mountain ranges e.g., the Karakorum and the Hindu Kush (Haserodt, 1980, Nüsser & Clemens, 1996, Sheikh *et al.*, 2002, Eberhardt *et al.*, 2007, Chawla *et al.*, 2008), add weight to this valley’s transitional location on the edge of the moist temperate zone of the Western Himalayan Province and adjacent to the dry temperate zone of the eastern Hindu Kush and the southern Karakorum. At the same time our study establishes the strong alpine floristic elements within the vegetation, with the overall dominance of herbaceous species (84%). Such vegetation features can be expected in the Himalaya (Zobel & Singh, 1997) and signify that most North Western parts of the Himalaya like the Naran Valley become increasingly more identical to the Hindu Kush and the Karakorum than to the southern and eastern Himalayas.

Chapter 5 EVALUATION OF PROVISIONING ECOSYSTEM SERVICES PROVIDED BY NATURAL VEGETATION

5.1 Introduction

This chapter mainly focuses on ecosystem services with special reference to medicinal uses of the plant species and medicinal families valued by indigenous people. This chapter covers methodology, data collection, analyses, results and discussion of qualitative and quantitative data regarding the provisioning services of plants obtained through questionnaires during the second field work period (May-August, 2010).

The benefits obtained by humans from nature are termed Ecosystem Services (Butler & Oluoch-Kosura, 2006, Seppelt *et al.*, 2011). Natural ecosystems provide human societies with vital supporting services, such as water and air purification, climate regulation, waste decomposal, soil fertility and regeneration, and continuation of biodiversity. The Millennium Ecosystem Assessment (2003) and other studies of ecosystem services have classified these services into four broad categories (Table 5.1) – provisioning, regulating, supporting and cultural (De Groot *et al.*, 2002, MA, 2003, Mooney *et al.*, 2004, Mooney *et al.*, 2004, Carpenter *et al.*, 2006, Boyd & Banzhaf, 2007, Jordan *et al.*, 2010). These services are produced by complex interactions between the biotic and abiotic components of ecosystems. Provisioning services are in the form of food, grazing land and fodder for livestock, fuel wood, timber wood, and medicinal products. These ultimately contribute to agricultural, socio economic and industrial activities (Kremen, 2005, Boyd & Banzhaf, 2006, Zobel *et al.*, 2006). All kinds of ecosystem services, whether provisioning, regulating, supporting or cultural, are closely allied to plant biodiversity (Pereira *et al.*, 2005, Gamfeldt *et al.*, 2008). Vegetation on mountain hill slopes regulates supply of good quality water and prevents soil erosion and floods. Vegetation also enhances soil formation, fertility and nutrient cycling. Culturally people utilize plants in a number of ways like aesthetics, religion, education and naming.

People extensively utilize the predominant herbaceous flora of the Naran Valley region, due to its location and the lack of basic facilities combined with the long-established culture of keeping grazing live stock and multipurpose plant collection. This sort of utilization can cause over-exploitation of the vegetation and risks to the continuation of plant biodiversity. In order to develop appropriate systems for the sustainable use of plant resources, it is crucial to understand how traditional uses of plants influence biodiversity in these ecosystems. This study therefore sought to, not only study the natural vegetation of the

Naran Valley, but also its use by the indigenous people of the valley in an assessment of the ecosystem services provided by the vegetation, with the overall aim of identifying plant species at risk of overuse and loss. Information on the ecosystem services provided by the vegetation to local people was obtained using questionnaire analyses.

Table 5.1 Provisioning Ecosystem Services provided by natural vegetation in the region after slight modifications to broader categories specified by the Millennium Assessment (MA) (Kremen, 2005, Wallace, 2008)

S. No.	Ecosystem Service (ES) Category	Sub Categories	Ecosystem service providers
1	**Provisioning Services**	i. Food ii. Fodder and grazing land iii. Medicine iv. Timber v. Fuel vi. Ornamental resources	i. All biodiversity ii. Vegetation iii. All biodiversity and minerals iv. Tree species v. Trees, shrubs, rarely herbs vi. All biodiversity and landscape
4	**Cultural Services**	i. Cultural diversity ii. Knowledge systems iii. Recreation, ecotourism and aesthetics	i. All biodiversity ii. Traditional knowledge about the local resources iii. Sceneries like lakes, peaks & meadows give the opportunities for swimming, boating, hiking, skiing,

5.2 Methodology for ethnobotanical data collection

An ethnobotanical study formed the second part of the vegetation studies in the Naran Valley exploring how the local people interact with local plants. Interviews using questionnaires were organized during summer (May-September) 2010. Ethical approval was obtained from the University of Leicester before starting the second field campaign (Appendix 5.1).

Data collection was conducted in two phases i.e., questionnaire preparation and field survey.

1) Observations of local people during the first fieldwork about the utilization of plant biodiversity for various purposes were used for the questionnaire preparation. A mixture of qualitative and quantitative methods of data collection was adopted in preparing a

questionnaire for collecting local knowledge about plant species. Local names of the plants were listed along with the botanical names of the recorded 198 plant species (Chapter 4). Plant species were also photographed during the first field campaign in 2009. Pictures were shown to the interviewee where and when it was felt necessary.

2) Each of the main 12 localities (villages) in the project area, where vegetation transects had been taken, were visited again (Fig. 3.1). Meetings were arranged with village heads or councillors and guidance and permissions were obtained. A local community member was taken as a guide who knew the norms and traditions of the indigenous society (Martin, 2004, Da Cunha & De Albuquerque, 2006). Ten houses at each of the 12 main localities of the Valley (a total of 120) were selected randomly for the interviews, using a random number table. Each village was visited from one side; a coin was tossed in front of each 5th house and if it fell head side up, then an interview was requested from that family (Martin, 2004, Cunningham, 2001). If willing, one member in the household was interviewed about their uses of plants, their preferences, accessibility of plants, therapeutic uses and plant part that was used. Ten households were interviewed in each locality.

Informants were asked about their general uses of plant species, e.g. as food (F), fodder (Fd), grazing (Gr), timber (Ti), fuel (Fu), aesthetic (Ae), medicinal (M) and others (Ot). Uses mentioned by the respondents were grouped in the above eight categories which is in line with methodologies available in the published literature (Phillips *et al.*, 1994, Rossato *et al.*, 1999, Da Cunha & De Albuquerque, 2006, Ferraz *et al.*, 2006, De Albuquerque, 2009). Informants were also asked about their species preference in the case of multiple uses, accessibility to the species and their views on any trends of increase or decrease in the population of that species. Respondents were further asked about the plant part(s) that were used in the case of medicinal use of a particular species, the diseases it cured and the recipe of use. Preferences were requested if an individual utilised a species for several purposes – food, fodder, grazing, fuel, timber or medicinal purposes. Accessibility was simply estimated using a three category scale i.e., door step (DS), nearby (NB) and far away (FA). Trend was also estimated with a scale of three categories i.e., decreasing (D), increasing (I) and No Visible Change (NC) (Appendix 5.2).

5.3 Data Analyses Methods

5.3.1 Analyses of the questionnaire data in MS Excel

MS EXCEL was used to categorize the basic figures and graphs related to respondents i.e., their gender classification, age groups and literacy ratio and detailed analyses of the various provisioning services (use categories), use preferences, trends, accessibilities and market information. Average numbers of uses in each category of provisioning services were calculated at each locality (by adding the number of uses in each category divided by the number of informants). In the case of medicinal plants, parts used, recipes and treatment categorization was done with slight changes to the methodology adapted by Kassam *et al.*, (2011), Chowdhury & Koike, (2010) and Uprety *et al.*, (2010).

5.3.2 Principal Components Analysis (PCA) using CANOCO

Principal Components Analysis (PCA) was used on the use categories (provisioning services) data for the various localities along the valley to explore the cultural gradient alongside the environmental gradient (Dalle *et al.*, 2002, Law & Salick, 2007, Tarrasón *et al.*, 2010). Average numbers of uses in each category at each locality were calculated in MS EXCEL according to the requirement of CANOCO. Response curve as a utility under the data attribute plot was used to analyze the pattern of each of the use categories along the valley. The curves were calculated based on the Generalized Linear Model (GLM) (Toledo *et al.*, 2009).

5.3.3 Regression analyses of the families for residual values using SPSS

Moerman’s methods of comparative analyses were used for comparing the medicinal plants with the inventory of vascular plants (obtained from quadrat data (Khan *et al.*, 2011b) of the study area using SPSS 18 (Moerman, 1991, Bryman & Cramer, 1997, Colman, 2008, Peter & Kellie, 2010). It was hypothesized that plant families with a higher number of medicinal plants will not necessarily be those with the higher species richness values. The general species richness of families and richness in terms of medicinal plants were analyzed through residual analysis of all the species and the number of medicinal species per family that were reported in the questionnaire survey. After the analyses, the families were arranged in descending order according to their residual values. These statistics indicate the difference between the real number of species and the predicted number of medicinal species and hence, the families with higher residual values are more valued for their medicinal plants. At the same time the families with negative residual values are less frequently used for medicinal purposes. The Moerman's method was used to correlate the traditional ethnobotanical data with the species data (Moerman, 1991, Lira *et al.*, 2009), providing an indication of how the medicinal species compare to the available species. It was also hypothesized that the people of the region use the plant species according to their indigenous knowledge and not according to plant abundance in the region. Residual values analyses helped to answer such questions by giving predicted and residual values for each group (Amiguet *et al.*, 2006, Bennett & Husby, 2008).

Table 5.2 Variables processing summary in SPSS

		Variables	
		Dependent	Independent
		Med. Spp.	Rep. Spp.
Number of Positive Values		52	68
Number of Zeros		16	0
Number of Negative Values		0	0
Number of Missing Values	User-Missing	0	0
	System-Missing	0	0

Med. = Medicinal; Rep. = Representative; Spp. = Species

Regression analyses illustrate relationships between the representative species in 68 families (independent variable) and the medicinal species (dependent variable). The only species data available for the study area for this comparison was the first year phytosociological data of 198 plant species in 68 families and hence these data were compared with the data set of medicinal plants (102 species in 52 families) (Table 5.2 & 5.3).

Table 5.3 Regression model summary

Model	R	R Square	Adjusted R Square	Change Statistics				
				R Square Change	F Change	df1	df2	Sig. F Change
1	0.790[a]	0.624	0.618	0.624	109.476	1	66	0.000

5.4 Results

5.4.1 Preliminary information about the respondents

The questionnaire respondents represented a diverse array of people including farmers, women, literate, illiterate, young and elders. Among the 120 informants, 87 were male and 33 were female. The largest proportions of the respondents were elderly, above 40 years of age (81.6%) (Fig. 5.1). These very basic results also reflect the reality that indigenous knowledge is well established in the elder generation. More than half of the respondents were illiterate (51.7%), whilst, most of those with an education had merely been educated at primary level (30%) (Fig. 5.2).

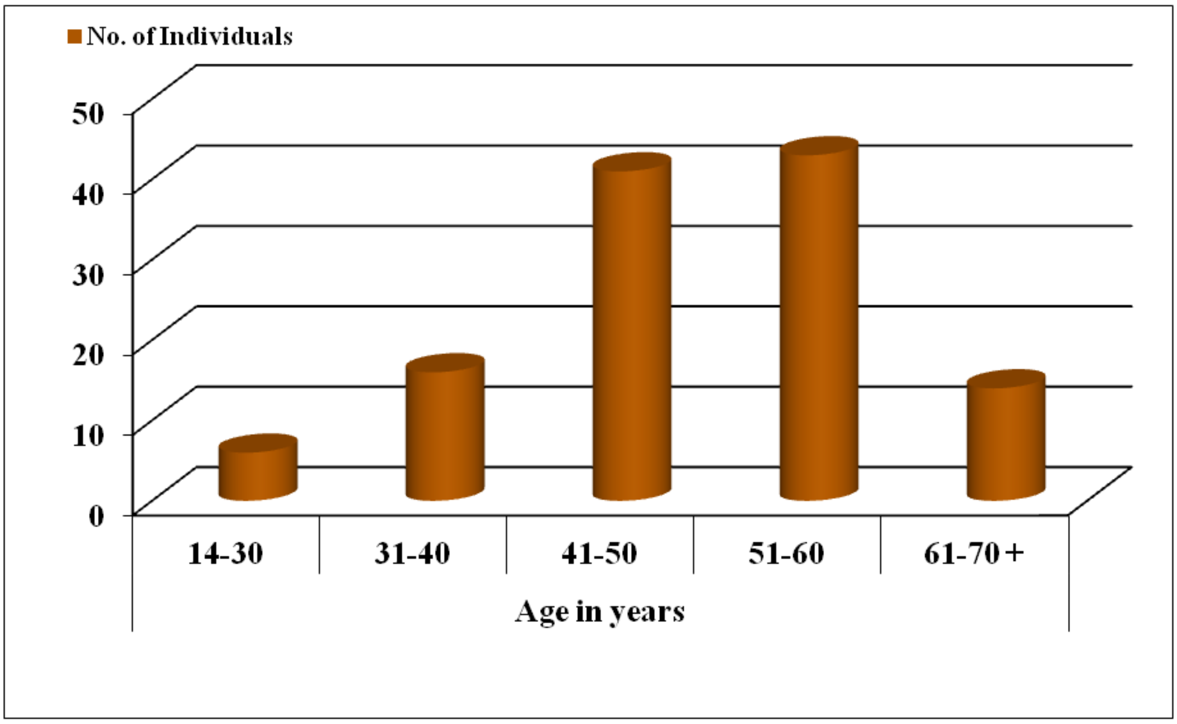


Fig. 5.1 Age group frequency of the interviewed people in the region

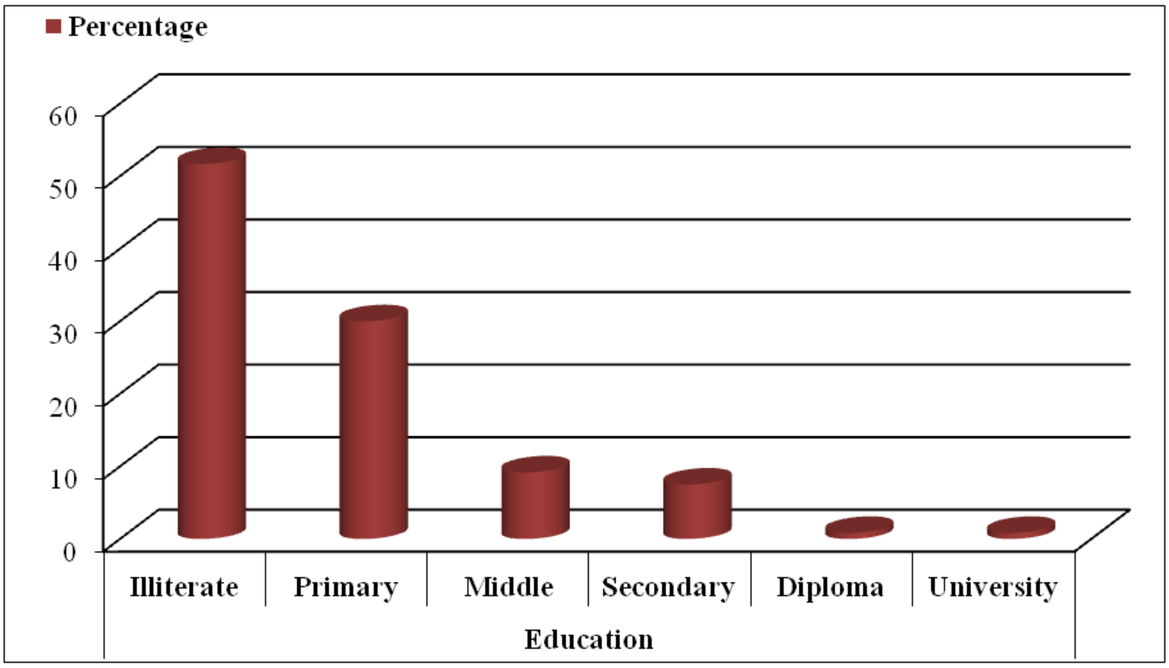


Fig. 5.2 Percentage of the interviewed people's education level in the study area

5.4.2 Overview of the provisioning ecosystem services provided by natural vegetation

Due to the high elevation of the study area, the vegetation is mainly herbaceous and shrubby and hence uses are in the form of non-timber forest products (NTFPs). The questionnaire analyses show that 183 plant species (92.4% of the surveyed species) provide services to the dwellers of the area in the form of fuel, food, fodder, medicinal, grazing, timber, aesthetics and other services. Many of the species offer more than one service. There is a significant diversity among the plant uses in the area but the highest recorded use was for grazing (31.5%), followed by medicinal plants collection (23.1%) and fodder (22.7%). Fuel, food and timber were mentioned by 8.2%, 7.6% and 3.4% of respondents, respectively (Fig. 5.3 and 5.4). The high percentage of grazing and fodder indicate the importance of grazing for local livelihoods and the likely main pressure on the plant biodiversity of the region. The number of plant species used for medicinal purposes indicates the long and well established traditional ethnobotanical knowledge of this region and the lack of conventional health facilities.

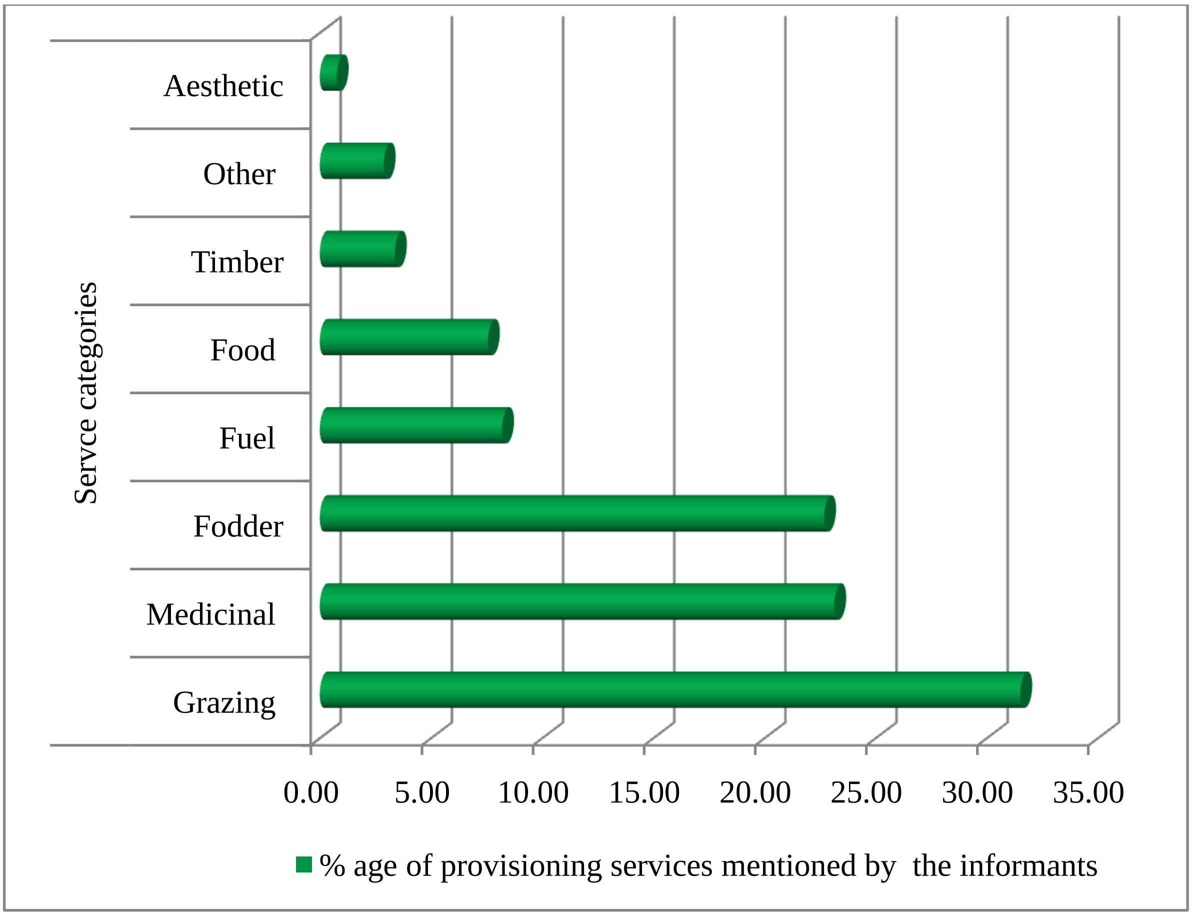


Fig. 5.3 Average number of provisioning services (number of uses) mentioned by informants, for 183 plant species based on questionnaire data

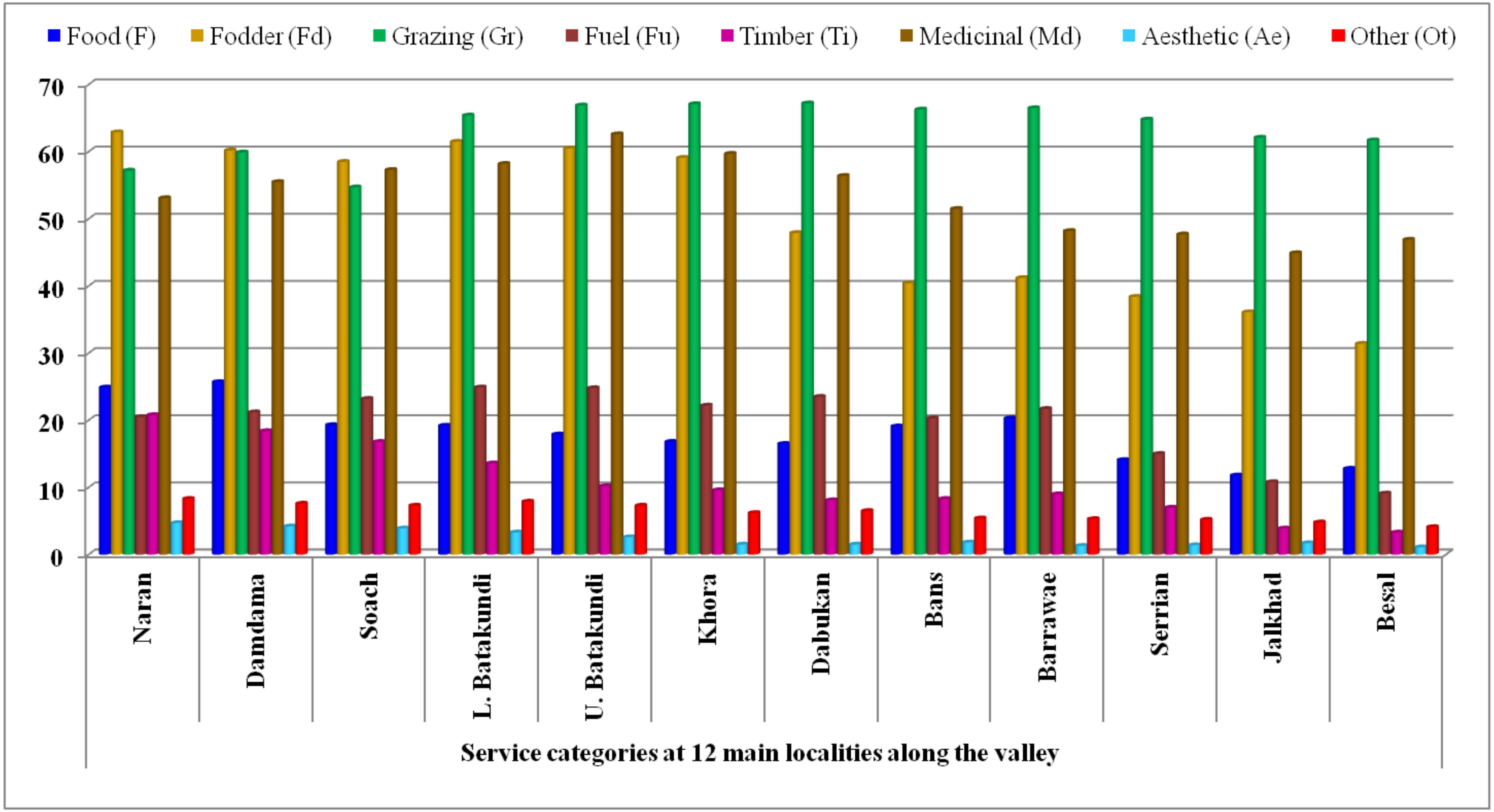


Fig. 5.4 Average number of provisioning service categories provided by183 plant species based on responses from 10 respondents at each of 12 localities in the study area

Each of the categories of provisioning services provided by natural vegetation is discussed below.

5.4.3 *Description of provisioning ecosystem services along the valley*

5.4.3.1 Principal Components Analysis

The first axis of the PCA scatter plot showed that there was a traditional gradient in plant utilization along the valley (along altitudinal & latitudinal gradient) from multiple uses at the mouth of the valley which gradually turned to simply grazing use in the upper reaches. The PCA results further clarified that people in the lower valley had the tendency to use vegetation for timber, aesthetics and fodder. In the middle of the valley the trend was more likely towards fuel wood and medicinal plant collection, whilst grazing dominated in the upper parts of the valley, where the main plant community was alpine meadow (Fig. 5.5, 5.6, 5.7, 5.8, 5.9, 5.10, 5.11, 5.12, 5.13 & 5.20). Traditional use of plants for medicinal purposes was highest in the middle of the valley.

Table 5.4. Description of the first four axes of the PCA for the various categories of provisioning services of vegetation (using informants' data at various localities along the valley)

Axes	**1**	**2**	**3**	**4**	**Total variance**
Eigen values	0.802	0.128	0.045	0.015	1.000
Cumulative percentage variance of species data	80.2	93.1	97.6	99.2	

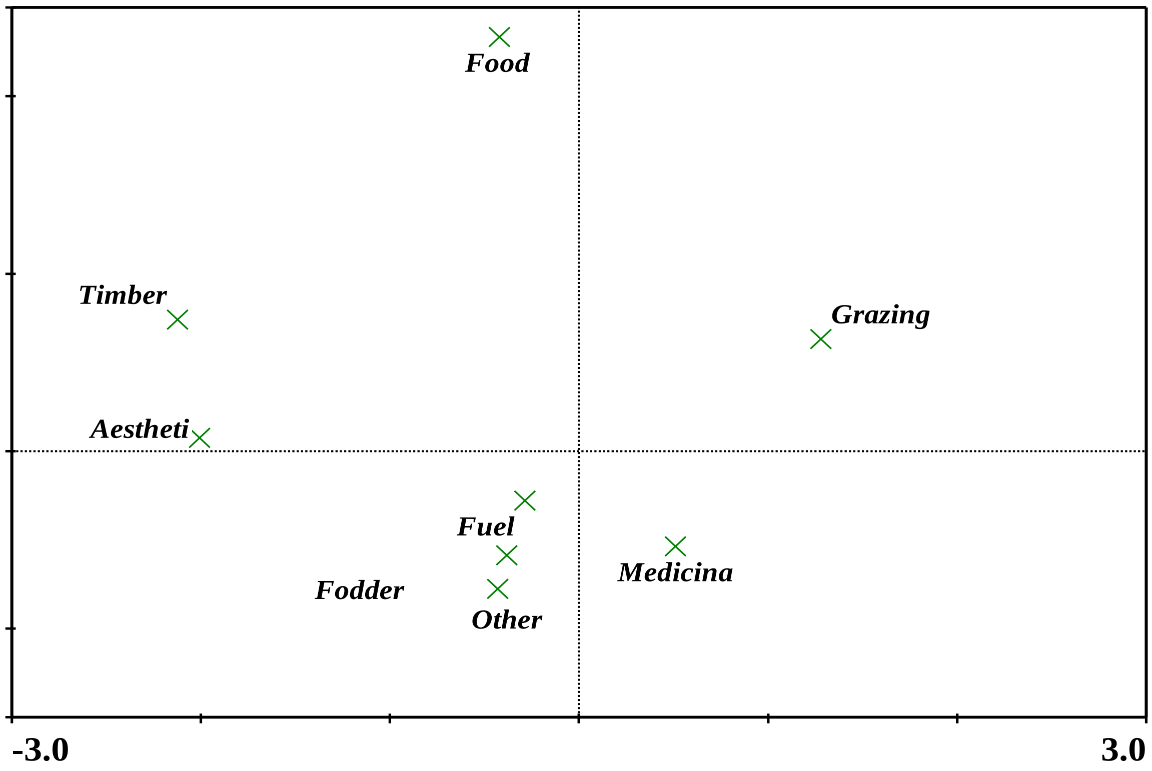


Fig. 5.5 PCA plot showing the distribution of various categories of provisioning services of vegetation along the valley as mentioned by informants

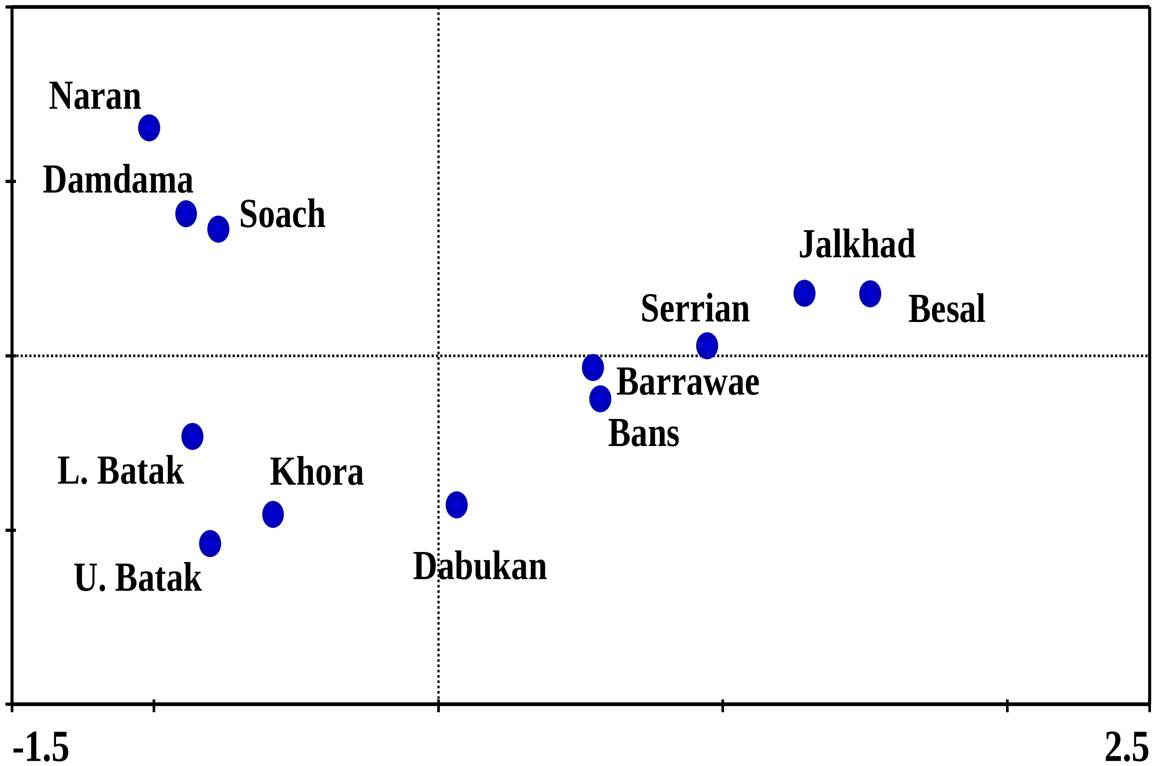


Fig. 5.6 PCA sample plot showing the categorization of localities according to the provisioning services of the vegetation

5.4.3.2 Provisioning services in the form of grazing and fodder

Collectively, 51.21% of the species used were reported to be important for grazing animals either as plants in grassland or in fodder form (with a 31.51% and 22.70% share in each category). The plant species which the local community prioritizes for grazing by their livestock are *Poa alpina, Poa annua, Bistorta affinis, Alopecurus arundinaceus, Anaphalis triplinervis, Anemone falconeri, Phleum alpinum, Anemone tetrasepala, Malva neglecta, Trifolium repens, Taraxacum officinale, Plantago himalaica, Plantago lanceolata, Plantago major, Polygonum aviculare, Leucas cephalotes, Androsace rotundifolia* and *Hackelia uncinata*. In addition, some people noted that they cut some of the herb species and used them either fresh or in dry form for livestock fodder during the off-season, during bad weather and at night. Plant species which the people prefer for fodder are *Bistorta amplexicaulis, Bromus hordeaceus, Eragrostis cilianensis, Pennisetum lanatum, Lathyrus pratensis, Pimpinella acuminata, Pimpinella diversifolia, Silene vulgaris* and *Chenopodium album.*

Data attribute plots and graph of response curves using CANOCO, show an increasing trend of grazing along the valley. In contrast the use of plants as fodder decreases along the valley. There is, therefore, a coincidence between climatic and cultural gradients. Climatic conditions favour the vigorous growth of herbaceous vegetation in the lower valley and people here also have other occupations than rearing animals; hence people use plants as fodder. In the upper valley the grazers can utilize the meadow vegetation only during the short summer. The size of the circles in the PCA plots shows the strength of the service category at each locality along the valley (along both an increasing altitudinal as well as a latitudinal gradient) (Fig. 5.7, 5.8 & 5.20).

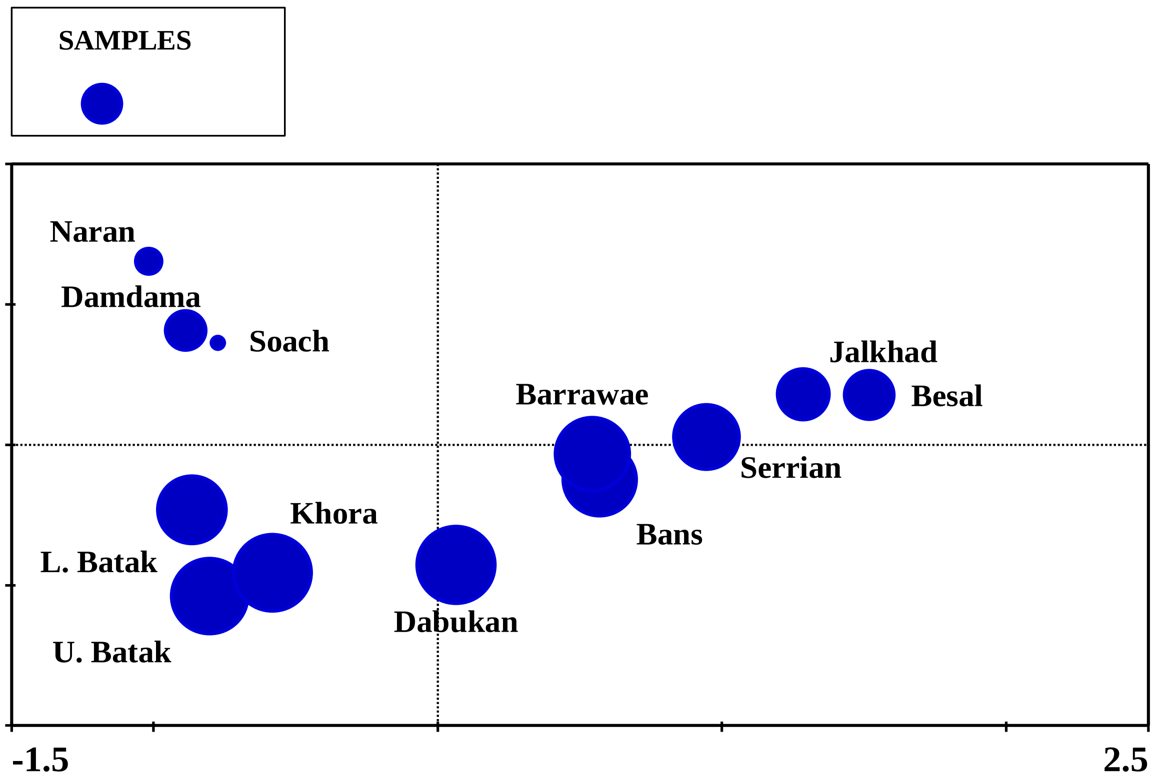


Fig. 5.7 PCA data attribute plot showing the grazing intensity at various localities along the valley.

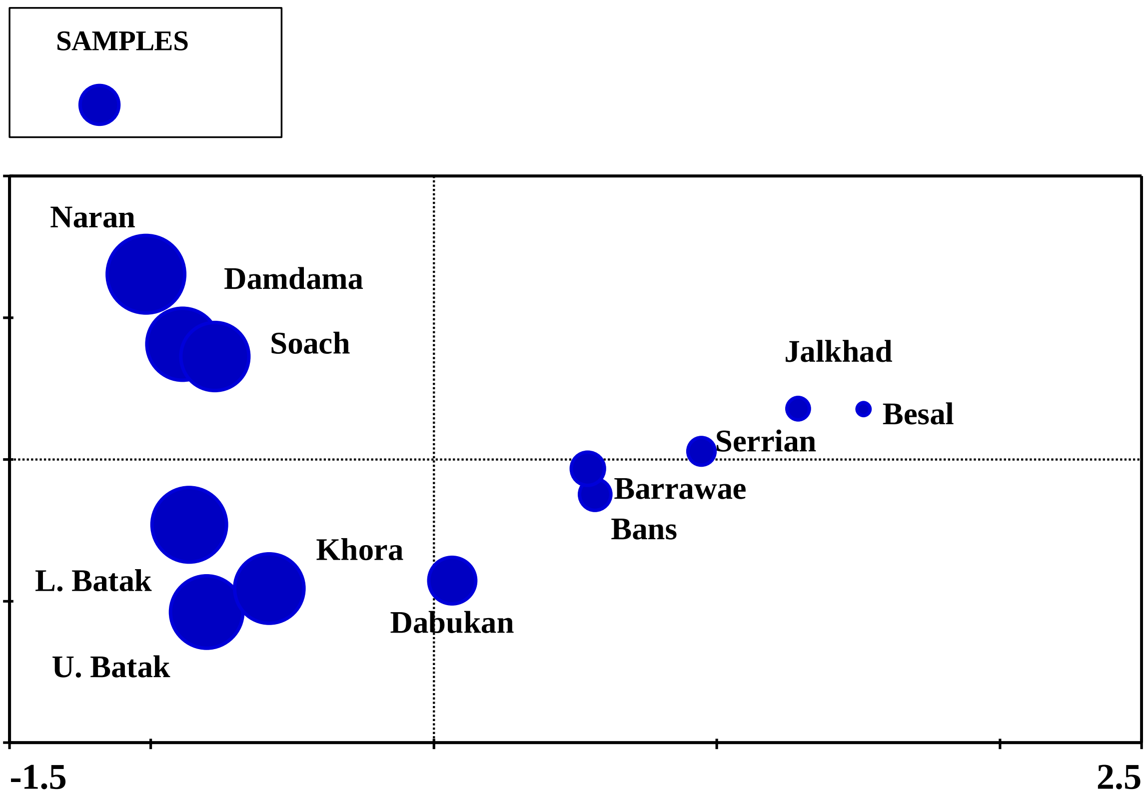


Fig. 5.8 PCA data attribute plot showing the fodder use of plant species at various localities along the valley.

5.4.3.3 Provisioning services as food

A number of plant species provide food supplements for the local people. People use *Caltha alba, Dryopteris juxtapostia, Eremurus himalaicus, Salvia lanata* and *Urtica dioica* as pot herbs (wild vegetables). Fresh aerial parts of *Rheum australe* are used as salad. The rhizome of *Polygonatum verticillatum* is considered a tonic and eaten mixed with dairy products. *Fragaria nubicola, Viburnum grandiflorum* and *Crataegus oxyacantha* provide wild fruits and *Juglans regia* dry fruits (nuts). These species were given highest preference by the local people although other plants were also used as food, including *Chenopodium album, Dryopteris stewartii, Leucas cephalotes, Malva neglecta, Mentha longifolia, Polygonum aviculare, Rumex dentatus, Viburnum grandiflorum* and *Viola canescens.*

The data attribute plot and the graph of the response curves after the PCA analyses show that food plants are utilized more frequently in the lower valley and the use is gradually decreasing. This can be correlated to the greater availability of food species in the lower valley. Furthermore, some of the pot herbs like *Caltha alba, Dryopteris juxtapostia, Eremurus himalaicus, Malva neglecta, Mentha longifolia* and *Viburnum grandiflorum* are collected for sale especially in the lower valley where the main population reside and local market is also available for selling food plants (Fig. 5.9 & 5.20).

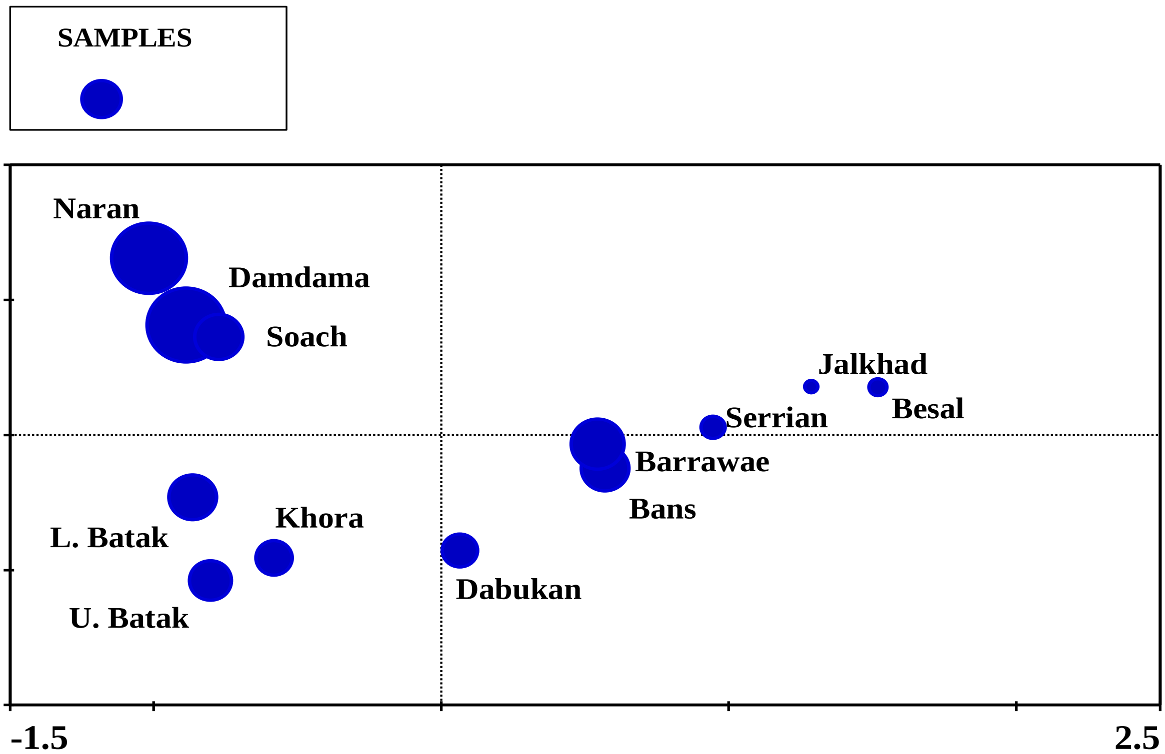


Fig. 5.9 PCA data attribute plot showing the services plant species in food category at various localities along the valley.

5.4.3.4 Provisioning services as fuel

In the lower valley, tree species provide fuel to the villages inhabitants; whilst in the upper valley people extensively use the woody shrubs for fuel. The important fuel species are *Juniperus excelsa, Juniperus communis, Juniperus squamata, Betula utilis, Indigofera heterantha, Prunus cerasoides, Aesculus indica, Acer caesium* and *Viburnum cotinifolium.* Twigs of Gymnosperm trees i.e., *Abies pindrow, Cedrus deodara, Pinus wallichiana* and *Picea smithiana,* are also considered a good fuel source, while trunks are used as timber.

PCA analyses and data attribute plots show that tree and shrub species are more or less homogeneously used for fuel. Collection and use of fuel wood is at a maximum in the middle of the valley. In the upper valley where access to woody species is more difficult, people use cow dung for fuel (Fig. 5.10 & 5.20).

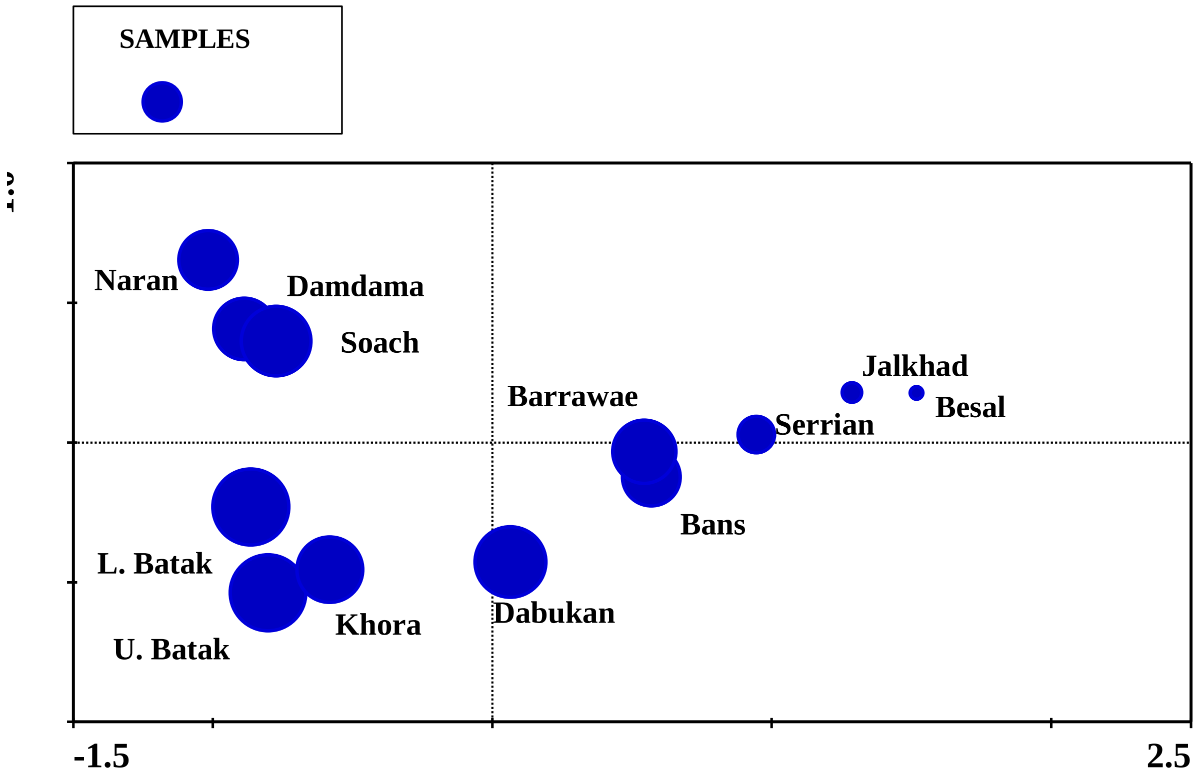


Fig. 5.10 PCA data attribute plot showing the fuel use of plant species at various localities along the valley

5.4.3.5 Vegetation services as timber

Cedrus deodara and *Pinus wallichiana* provide the best timber in the region as in other parts of the Himalayas and Hindu Kush. Species of *Abies pindrow, Picea smithiana* and *Populus glauca* also provide good quality timber. These timbers are used in ceilings of buildings, for making doors, windows and utensils etc. Timber obtained from species of *Aesculus indica, Acer caesium, Juglans regia* and *Prunus cerasoides* is considered the best for making agricultural tools.

The data attribute plot and graph of response curves using Principal Component Analysis (PCA) shows the extensive use of timber at the lower localities (opening of the valley). In the upper valley people are seasonal grazers and live in tents and hence have less use of timber (Fig. 5.11 & 5.20)

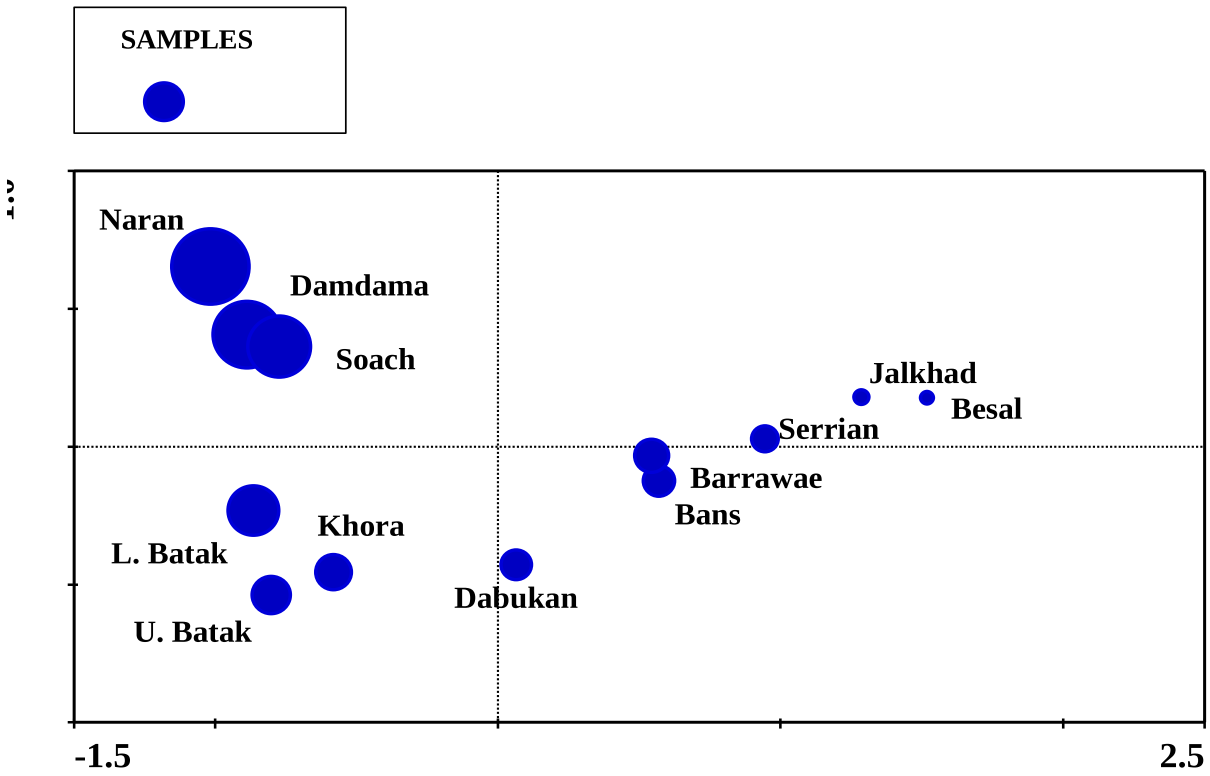


Fig. 5.11 PCA data attribute plot showing the services in the form of timber wood at various localities along the valley

5.4.3.6 Aesthetic services of vegetation

Forests of coniferous trees, mainly *Cedrus deodara*, *Pinus wallichiana*, *Abies pindrow* and *Picea smithiana*, have high aesthetic values for tourists as well as inhabitants. Other species like *Aesculus indica*, orchards and alpine flowering plants are also valued. People in the lower valley are linked to the ecotourism industry by working in hotels, fishing in the river Kunhar and may keep horses for tourist transportation. They also have a more developed aesthetic sense and value the vegetation for its natural beauty. The data attribute plot and the graph of response curves using PCA, confirm this cultural gradient from south to north in the valley (Fig. 5.12 & 5.20).

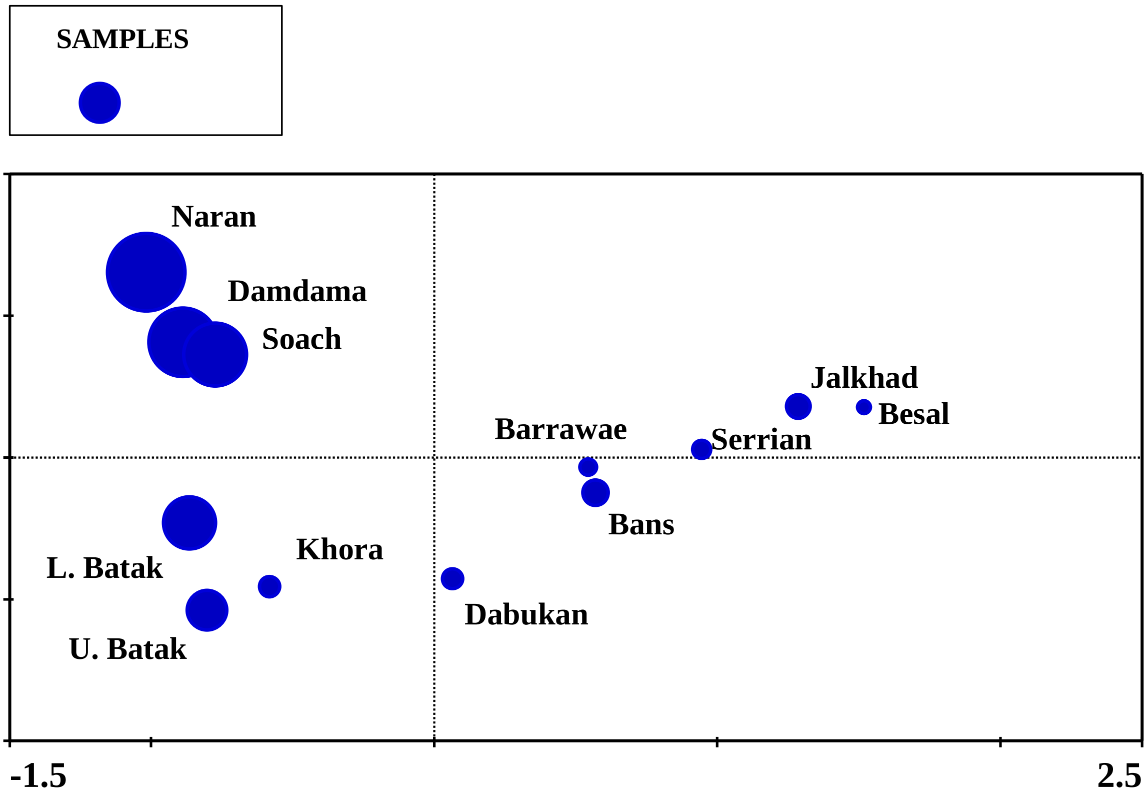


Fig. 5.12 PCA data attribute plot showing the aesthetic importance of plant species at various localities along the valley

5.4.3.7 Other provisioning services of vegetation

Plants play an important role in providing other services to the indigenous population. They use whole plants or plant parts to make hedges around their fields for protection and demarcating boundaries. *Populus glauca*, *Rubus sanctus* and *Ribes alpestre* are grown around fields for this purpose. Twigs of tree species are also used for hedging. Plant species like *Salix flabellaris*, *Dryopteris stewartii* and *Viburnum grandiflorum* and twigs of most of the tree species are used for roofing and thatching purposes. Bark of *Betula utilis* is used as paper especially by religious scholars to write spiritual verses to treat psychological ailments. Species like *Rumex dentatus* is used as a dye to colour livestock with identifiable signs for distinguishing from others' grazing live stock (Fig. 5.13).

Ecologically, the lower valley has more agricultural land and woody vegetation. My findings show that most of the services in the category of 'other services' are associated with woody species and hence are more common in the lower valley.

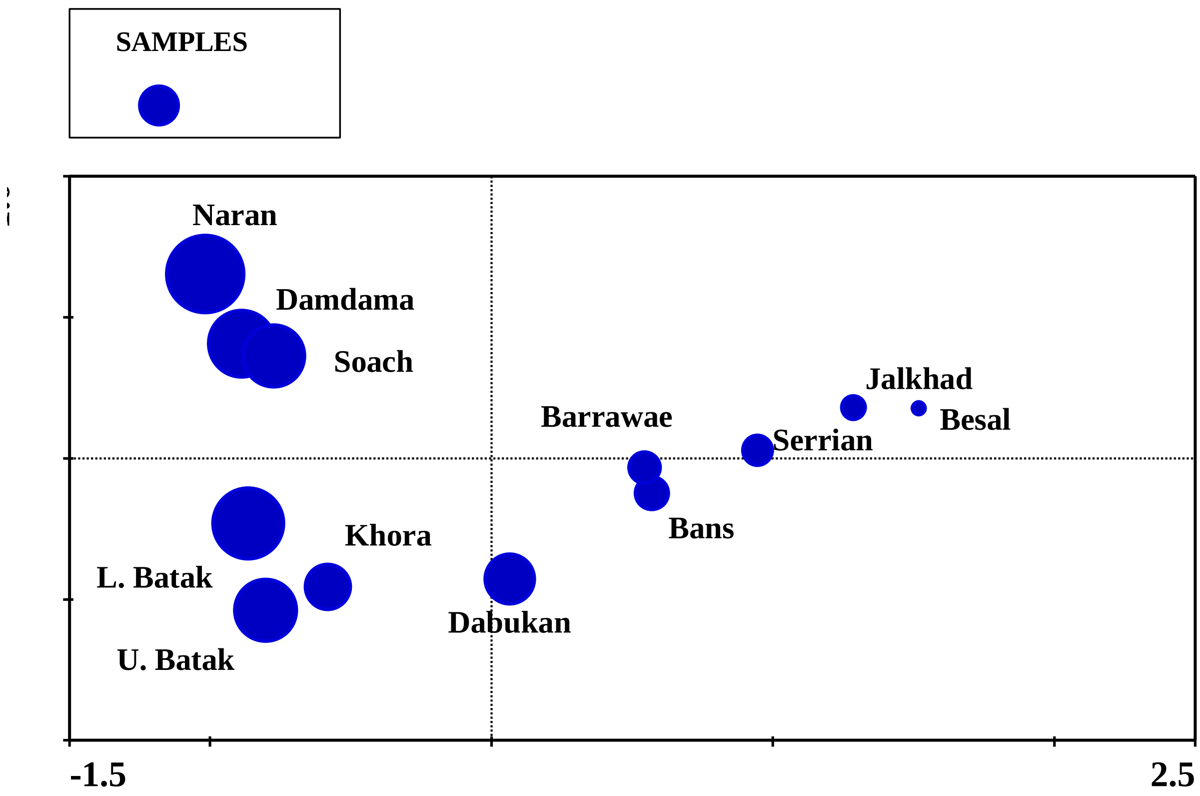


Fig. 5.13 PCA data attribute plot showing the other services of plant species at various localities along the valley.

5.4.4 *Ethnomedicinal plant resources*

People in the valley use 102 species belonging to 52 families (51.5% of the total plants) for medicinal purposes (55.7% of the used species). Lamiaceae, with 9 species, was the most represented family followed by Polygonaceae and Rosaceae with 8 species each. Details of the individual plant species and their medicinal uses are given in Appendix 5.3. Many of these species provide a number of provisioning services and hence the respondents were asked what preference they gave for a specific service category. The results of the preference analysis showed the highest priority was for medicinal use (56.9% responses) followed by grazing and food (13.1% and 10.8% respectively) (Fig. 5.14). The high priority given to medicinal use illustrates the high level of traditional knowledge about plants in the community and the lack of basic health facilities. It can also be attributed to the high market value of medicinal species.

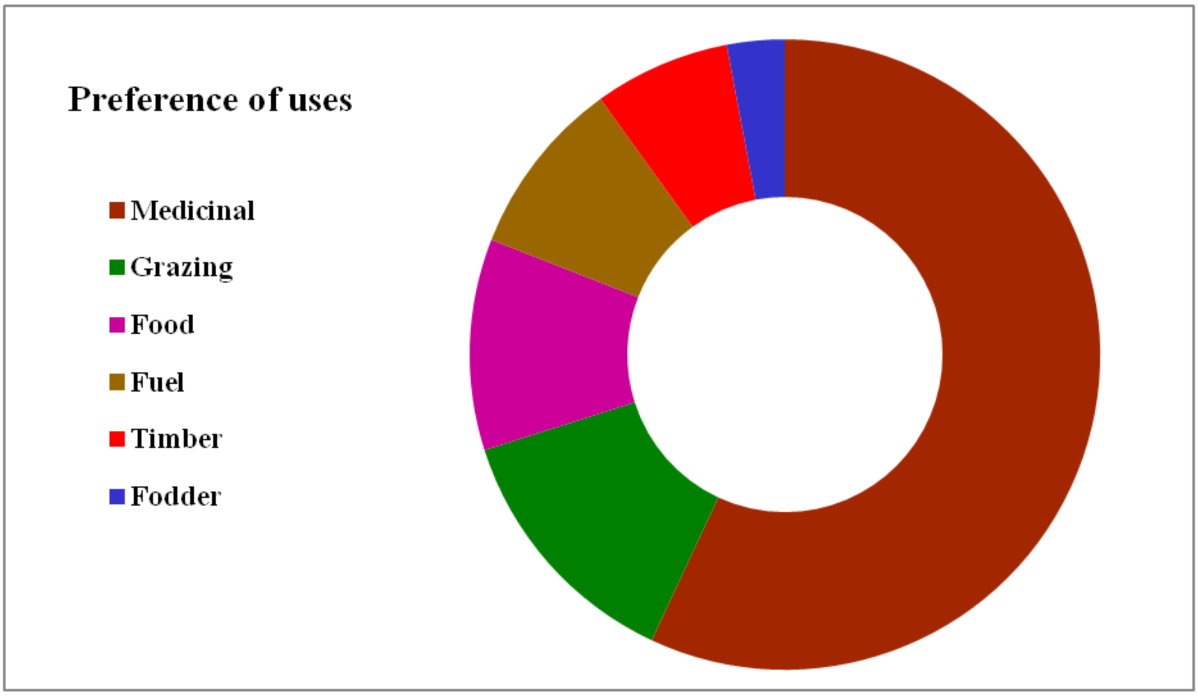


Fig. 5.14 Preferences mentioned by the informants for the species having more than one local use

5.4.4.1 *Important medicinal plant species*

Each medicinal species found in the region is noteworthy but a few of them have a particular importance in the local health care system, for example, *Dioscorea deltoidea* is locally used as a diuretic, tonic and anthelmintic. Local hakeems (experts in traditional medicine) use *Podophyllum hexandrum* as a purgative, laxative and anti-cancer treatment. Powdered bark of *Berberis pseudumbellata* is locally utilized for the treatment of fever, backache, jaundice and urinary tract infection whilst its fruit is valued as a tonic. Orchid species i.e., *Cypripedium cordigerum* and *Dactylorhiza hatagirea* are considered as aphrodisiacs and as nerve tonics. Other noteworthy medicinal species are *Cedrus deodara* and *Aesculus indica*. Oils extracted from *Cedrus deodara* are used in skin diseases while powder of the dried fruit nuts of *Aesculus indica* are used in colic and also as an anthelmintic. Among other species, *Aconitum heterophyllum, Aconitum violaceum, Ephedra gerardiana, Eremurus himalaicus, Hypericum perforatum, Indigofera heterantha, Geranium wallichianum, Iris hookeriana, Nepeta laevigata, Origanum vulgare*, *Paeonia emodi, Rheum australe*, *Thymus linearis* and *Ulmus wallichiana* are also of great importance in the traditional health care. For detailed use of each species see appendix 5.3.

5.4.4.2 *Plant parts used and their preparation*

The interview results indicate that whole plants are used in 54% of treatments followed by rhizomes (21%), fruits (9.5%) and roots (5.5%). Bark, flowers and seeds are used less frequently. Most of the plants used are hemi-cryptophytes and geophytes and fewer are woody (Phanerophytes and Chamaephytes) or therophytes (Fig. 5.15). Whole plants or plant parts are utilized in various forms in traditional herbal recipes. In the majority of recipes, they are in the form of powder (19%) followed by decoction (10.5%) (Fig. 5.16).

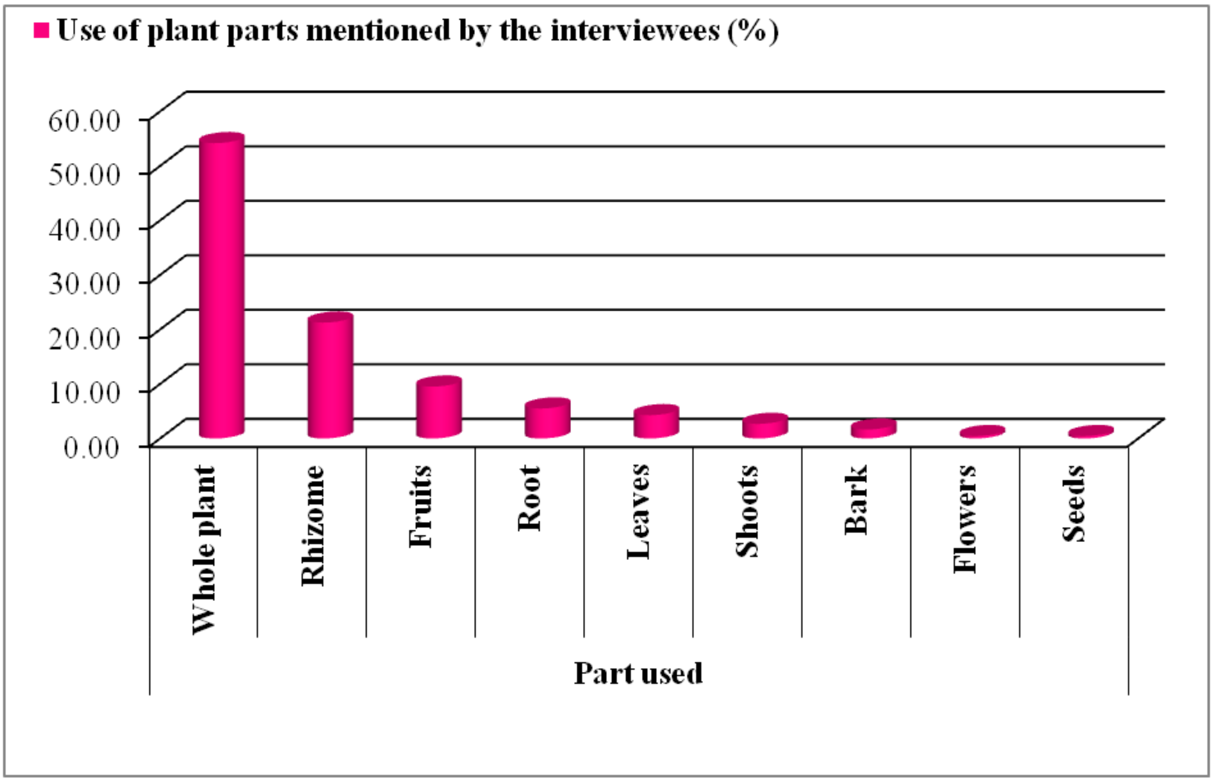


Fig. 5.15 Parts of plant used for medicinal purposes.

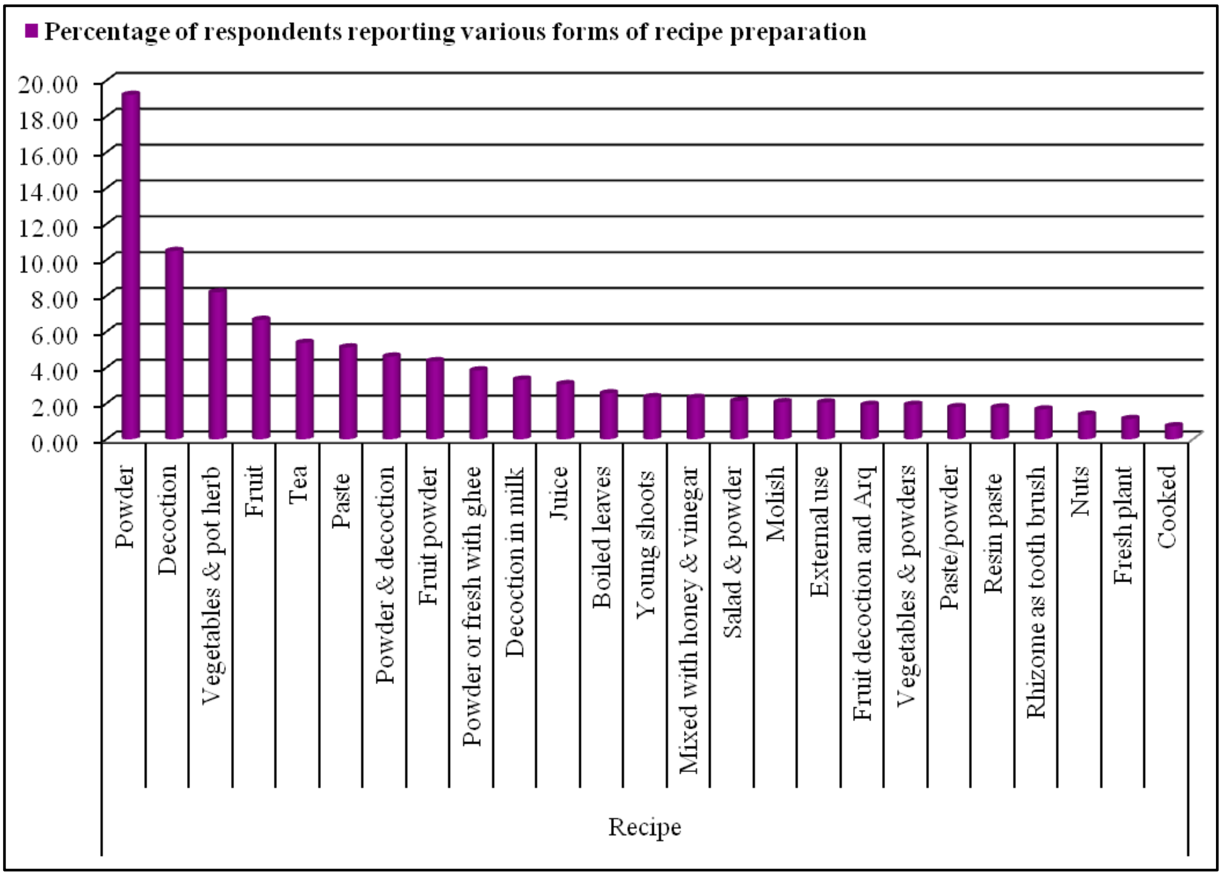


Fig. 5.16 Recipes for medicinal plants reported by interviewees (%)

5.4.4.3 Therapeutic uses

The results of the questionnaire analysis reveal 97 prominent therapeutic uses of medicinal plants, divided into 15 major categories based on the specific ailments being treated. The largest number of ailments cured with medicinal plants are associated with the digestive system (32.76% responses) followed by those associated with the respiratory and urinary systems (13.72% and 9.13% respectively). The percentage of ailments associated with the blood circulatory and reproductive systems and the skin are 7.37%, 7.04% and 7.03%, respectively. In terms of a single problem of a specific system the urinary tract infection (UTI) was mentioned on top, followed by asthma and gastric problems. The other diseases related with general body, endocrine system, nervous system, mouth and eyes etc were considered each by 5% or less than 5% of respondents. Figures 5.18 and 5.19, show the details of the specific diseases of the human system cured with medicinal plants mentioned by interviewees, whilst a detailed summary of the species along with a list of the specific diseases is presented in Appendix 5.3.

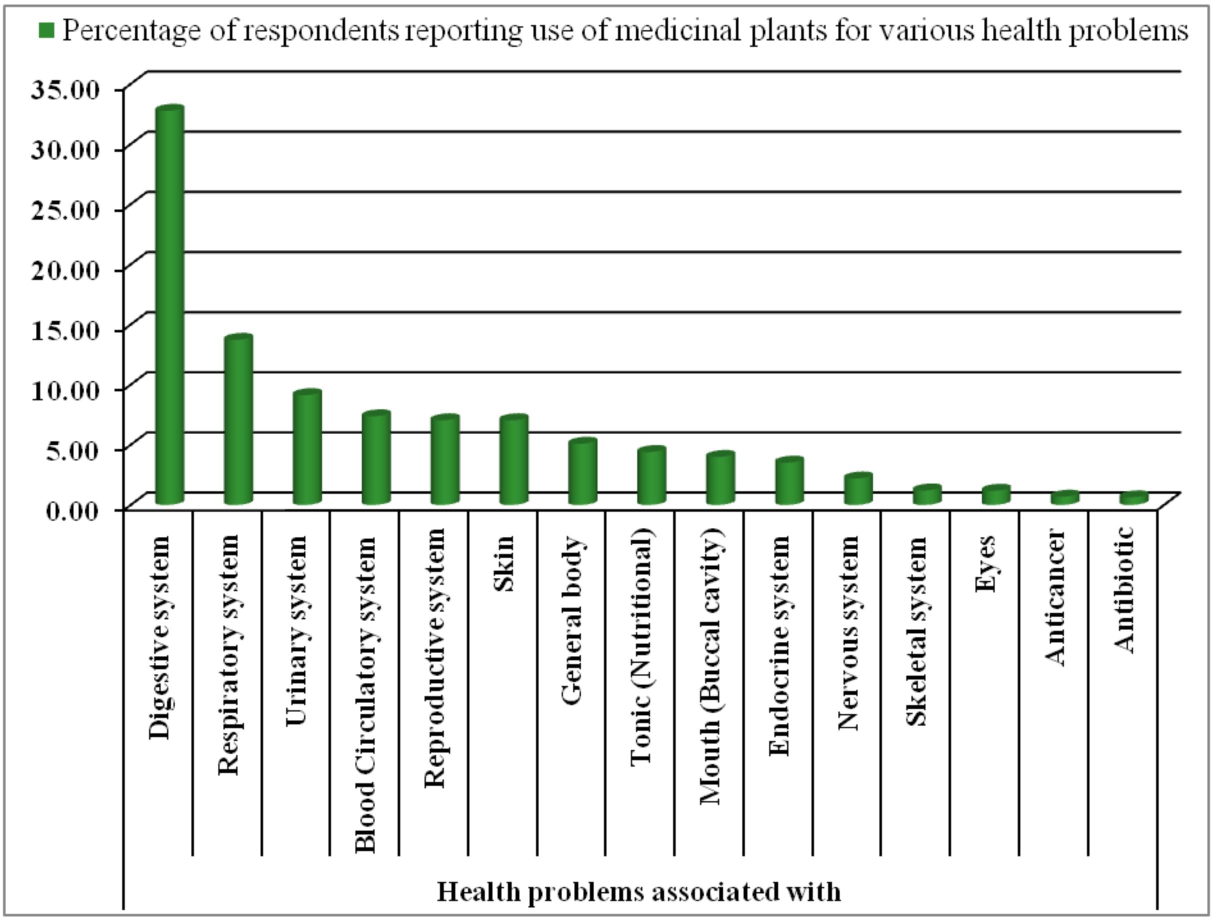


Fig. 5.17 Medicinal use categories mentioned by respondents for the treatment of different categories of disease or other ailments.

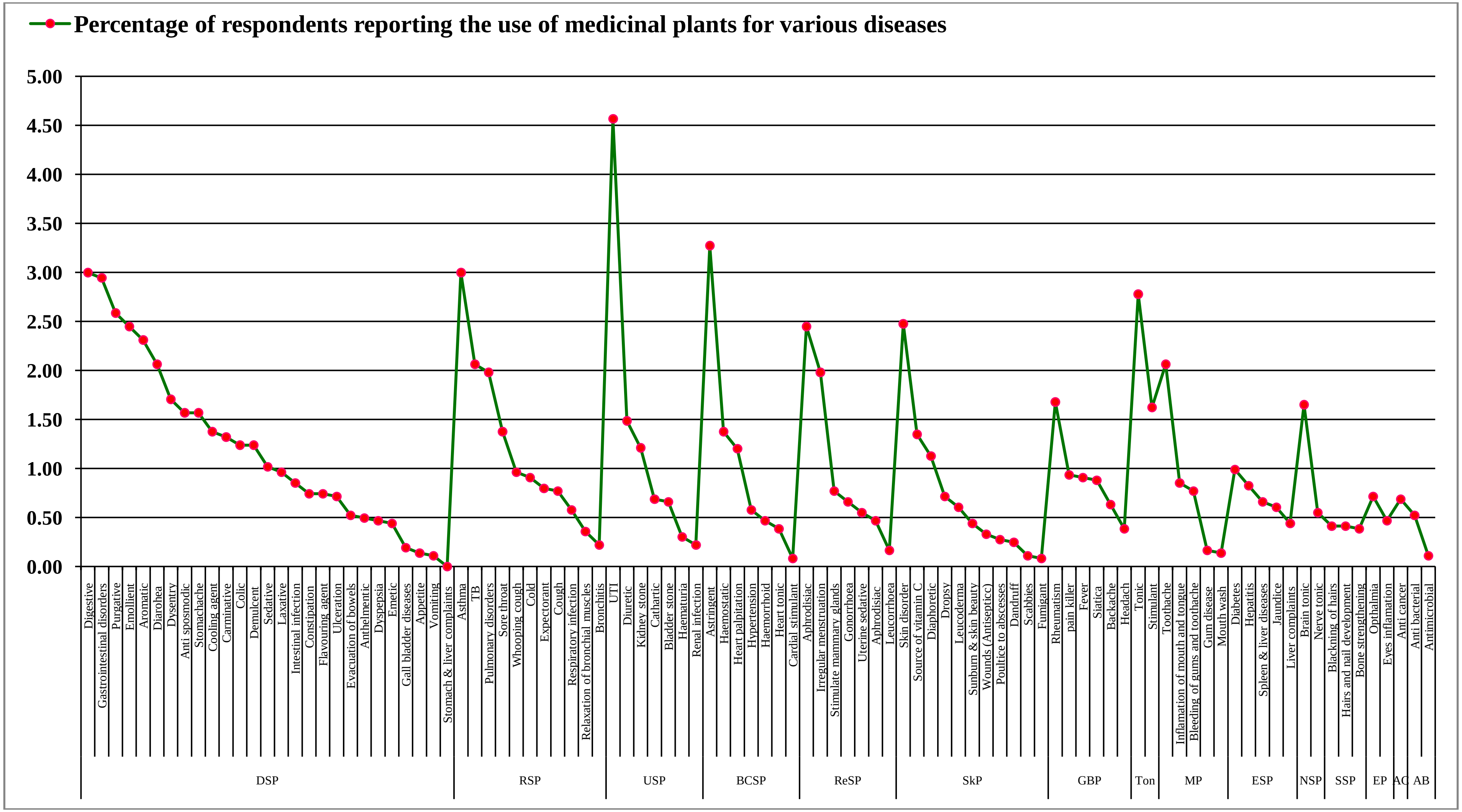


Fig. 5.18 Medicinal plant uses for treating different diseases & ailments.

DSP= Digestive System's Problems; RSP= Respiratory System's Problems; USP= Urinary System's Problems; BCSP= Blood Circulatory System's Problems; ReSP= Reproductive System's Problems; SkP= Skin Problems; GBP= General Body Problems; Ton= Tonic; MP= Mouth Problems; ESP=Endocrine System Problems; NSP= Nervous System's Problem; SSP= Skeleton System's problems; EP= Eyes problems; AC= Anti Cancer AB= Antibacterial

5.4.4.4 Marketing of medicinal plants

Respondents reported that 38 of the medicinal plant species were sold in the local markets. The plants were collected in the summer and sold in the local shops or through middle men. Some of the plant parts are sold in a dry form, some in a fresh form while some are sold in both forms. Table 5.5 shows the marketable medicinal species with their price per Kg and also the availability trend mentioned by local people i.e., whether those species' populations were increasing or decreasing.

5.4.4.5 Residual value analysis of the medicinal plant families of the region

Residual value analysis was used to measure the significance of medicinal families as a taxonomic group. Plant families were compared quantitatively for the forecast of medicinal plants. For this purpose the number of medicinal species in each family was regressed in SPSS against the representative species of the same family. This provided the residual and predicted values for each family. The standard deviation for residual values of all the 68 families was 0.993. The results of the residual analysis indicated that 7 of the families were overused by the local people i.e. they had residual values greater than the standard deviation. The top 5 families with the highest residual values were Polygonaceae, Gentianaceae, Lamiaceae, Rosaceae and Plantaginaceae. The lowest residual values were recorded for families Salicaceae, Ranunculaceae, Primulaceae, Boraginaceae and Poaceae. Only a few of the most abundant plant families contain a high number of medicinal plants and hence the high residual values, nevertheless few other have none or very less for example the third largest family Poaceae is the lowest in terms of residual values while the largest Asteraceae is on number 48 (Appendix 5.4). On the contrary, many of the species in the less abundant families have a medicinal use. This supports the hypothesis that people do not utilize plants according to their abundance but according to their local knowledge. For example, 31 small families with only 1 or 2 species are all used medicinally. Only 16 plant families in the region (from a total of 68) have no reported medicinal use (Table 5.2).

Table 5.5 List of the medicinal plants collected for selling purposes in the region

S. N	Botanical Name	Preference	Part used	No of respondents	Price per Kg in Pak Rs	Form	Trend
1	*Juglans regia*	Food	Fruits	41	400	Dry	D
2	*Berberis pseudumbellata*	Medicinal	Root & bark	48	270	Both	NC
3	*Ephedra gerardiana*	Medicinal	Whole plant	16	180	Dry	D
4	*Juniperus communis*	Fuel	Berries	59	900	Fresh	D
5	*Juniperus excelsa*	Fuel	Fruits	54	800	Fresh	D
6	*Viburnum grandiflorum*	Fuel	Fruits	08	300	Fresh	D
7	*Achillea millefolium*	Medicinal	Whole plant	33	320	Both	NC
8	*Allium humile*	Medicinal	Whole plant	21	200	Both	D
9	*Asparagus racemosus*	Medicinal	Root & stem	14	1200	Both	D
10	*Bergenia ciliata*	Medicinal	Latex & Rhizome	11	200	Both	D
11	*Bergenia stracheyi*	Medicinal	Rhizome	23	200	Both	I
12	*Bistorta amplexicaulis*	Fodder	Rhizome	13	200	Dry	NC
13	*Caltha alba*	Food	Roots & aerial parts	16	100	Fresh	D
14	*Capsella bursa-pastoris*	Grazing	Aerial parts, seeds	06	100	Fresh	NC
15	*Colchicum luteum*	Medicinal	Dried corms	16	200	Both	NC
16	*Cypripedium cordigerum*	Medicinal	Rhizome	21	250	Both	D
17	*Dactylorhiza hatagirea*	Medicinal	Tubers	23	300	Both	D
18	*Dioscorea deltoidea*	Medicinal	Tubers	08	280	Dry	D
19	*Dryopteris juxtapostia*	Food	Young shoots	37	60	Fresh	D
20	*Euphorbia wallichii*	Medicinal	Latex/whole	27	250	Dry	D
21	*Fragaria nubicola*	Food	Fruits	50	150	Fresh	I
22	*Fritillaria roylei*	Medicinal	Bulb	19	800	Dry	D
23	*Gentiana kurroo*	Medicinal	Root	11	350	Dry	D
24	*Geranium wallichianum*	Medicinal	Rhizome	25	200	Dry	D
25	*Hyoscyamus niger*	Medicinal	Leaves/seeds	22	400	Dry	D
26	*Hypericum perforatum*	Medicinal	Whole plnt	07	200	Both	D
27	*Malva neglecta*	Grazing	Whole plant	13	80	Fresh	NC
28	*Mentha longifolia*	Medicinal	Whole plant	71	50	Fresh	I
29	*Paeonia emodi*	Medicinal	Seeds & tubers	54	400	Both	D
30	*Plantago lanceolata*	Grazing	Leave, seeds	13	600	Fresh	NC
31	*Plantago major*	Grazing	Root, seeds, leaves	15	600	Fresh	D
32	*Podophyllum hexandrum*	Medicinal	Rhizome & Fruits	38	1600	Dry	D
33	*Polygonatum verticillatum*	Food	Root	42	900	Both	D
34	*Primula denticulata*	Medicinal	Rhizome	18	450	Both	D
35	*Rheum australe*	Food	Rhizome & shoots	33	250	Fresh	NC
36	*Salvia lanata*	Food	Whole plant	20	70	Fresh	NC
37	*Thymus linearis*	Medicinal	Whole plant	31	60	Both	NC
38	*Viola canescens*	Medicinal	Whole plant	84	450	Both	NC

D; Decreasing, I; Increasing, NC; No visible change

Table 5.6 Summary of the residuals statistics in regression analyses

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	0.68	7.65	1.51	1.559	68
Residual	-5.035	3.400	0.000	1.210	68
Std. Predicted Value	-.534	3.933	0.000	1.000	68
Std. Residual	-4.129	2.788	0.000	0.993	68

Table 5.7 Model summary for regression plot and parameter estimates

	Dependent Variable: Med Spp. Model Summary					Parameter Estimates	
Equation	R Square	F	df1	df2	Sig.	Constant	b1
Linear	0.624	109.476	1	66	0.000	0.247	0.435

The independent variable is Rep Spp.

The residual analyses and regression plot show that the family Polygonaceae is the top- ranking family followed by Gentianaceae and Lamiaceae. All of these three families include typical alpine species of high medicinal value. *Rheum australe, Rumex nepalensis, Bistorta amplexicaulis* and *Oxyria digyn*a (Polygonaceae), *Gentiana kurroo, Gentiana moorcroftiana* and *Swertia ciliate* (Gentianaceae), *Thymus linearis, Mentha longifolia, Origanum vulgare* and *Salvia moorcroftiana* (Lamiaceae) are the most important medicinal plants. The 4^{th} and 5^{th} top residual scoring families are Rosaceae (*Fragaria nubicola, Crataegus oxyacantha* and *Rosa webbiana*) and Plantaginaceae (*Plantago lanceolata* and *Plantago major*).

The five lowest ranking families are Poaceae, Boraginaceae, Primulaceae, Ranunculaceae and Salicaceae. The grass family Poaceae, though a highly abundant and important family for grazing animals, has the lowest medicinal value and hence is at the bottom of the residual values list.

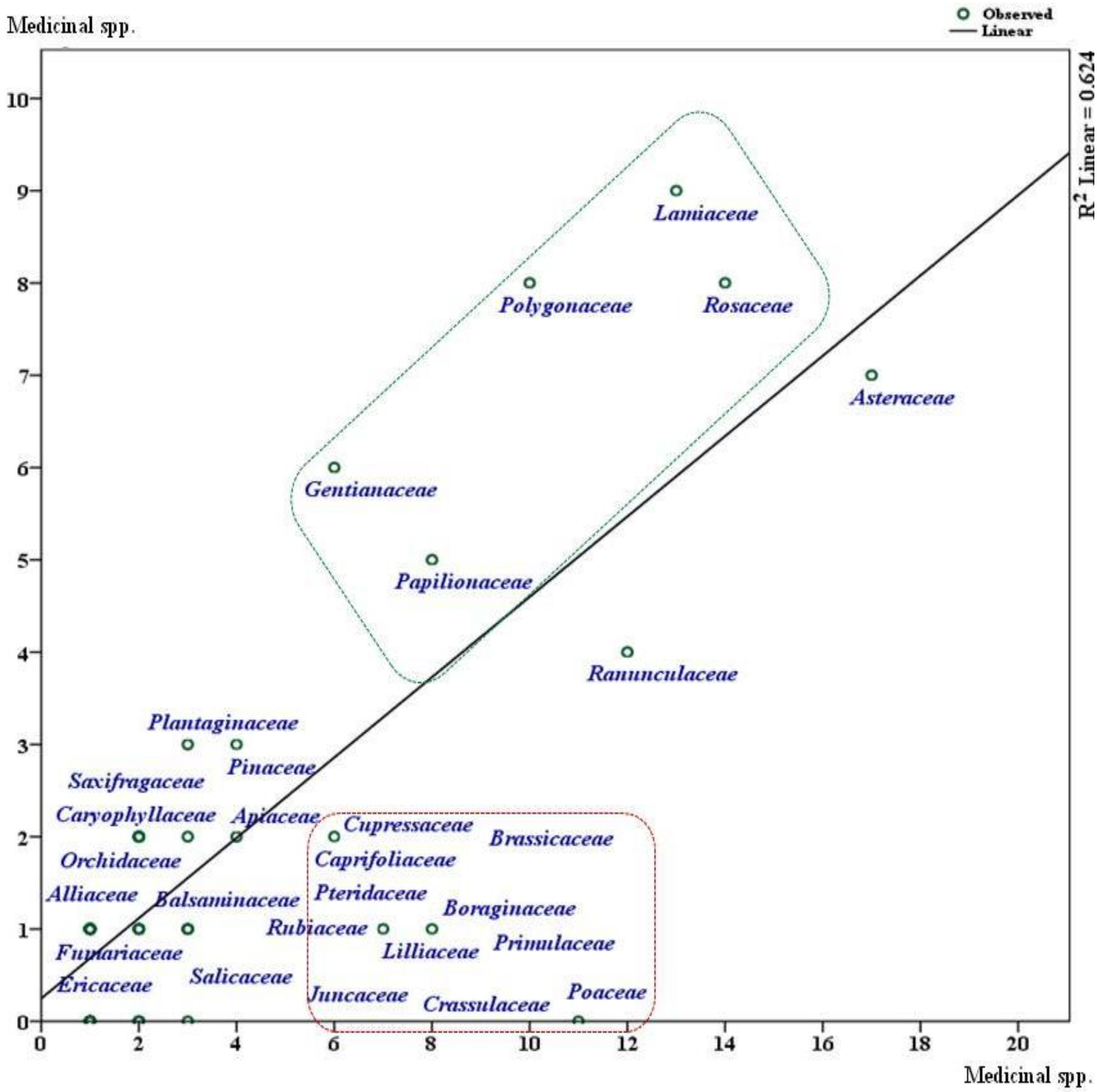


Fig. 5.19 (a) Regression plot showing number of medicinal plant species in each family, versus the total number of species recorded in each family in the quadrat survey (N = 68; p = 0.000; $r^2 = 0.624$)

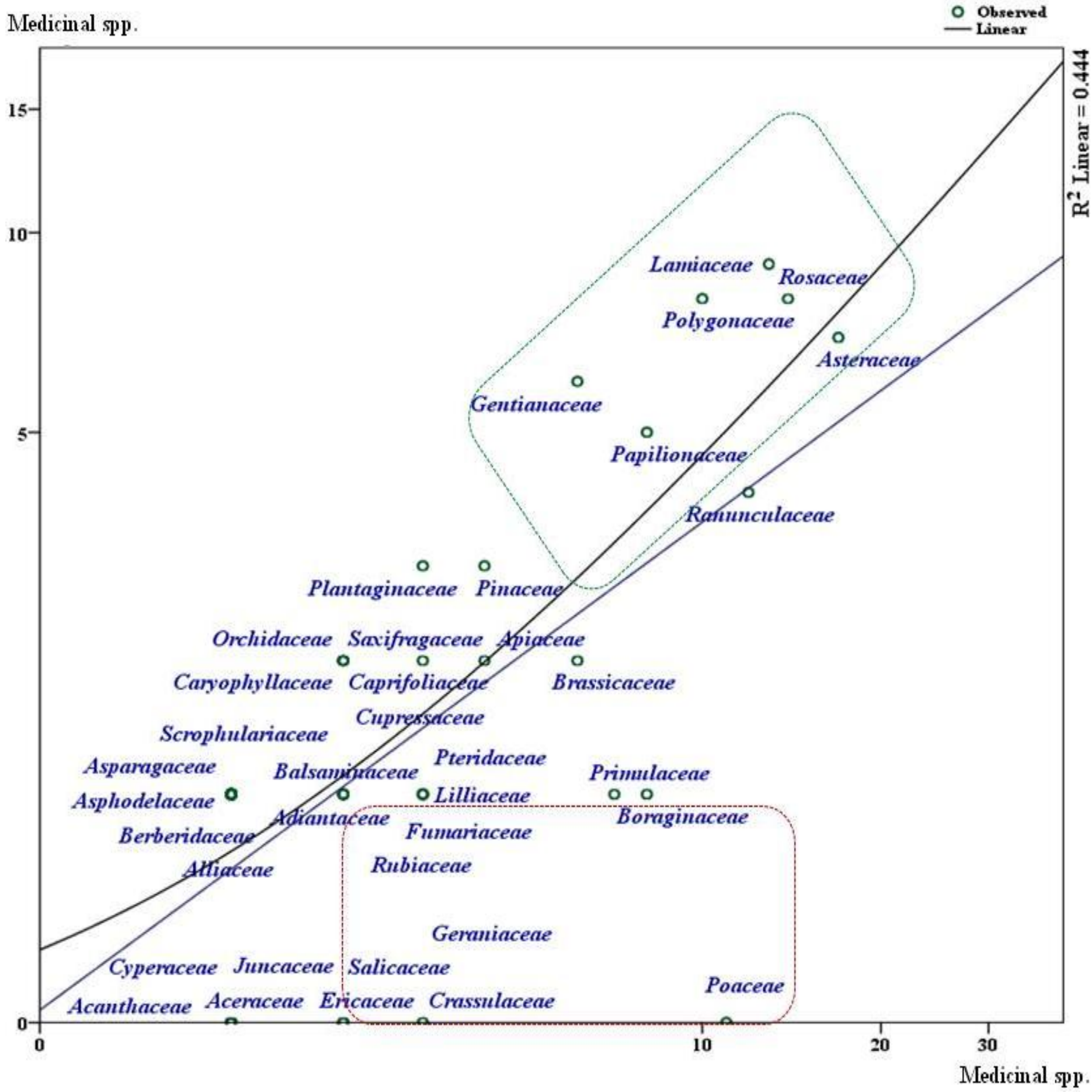


Fig. 5.20 (b) log regression plots showing number of medicinal plant species in each family, versus the total number of species recorded in each family in the quadrat survey (N = 68; p = 0.000; 0.444)

5.4.5 Use pattern of natural vegetation along the valley

Distribution of the miscellaneous services of plants also exhibits a cultural gradient along the valley. People have diverse professions in the lower part of the valley and utilize plants for a number of purposes. As one goes along the valley, the provisioning services provided by natural vegetation vary i.e., grazing and fuel wood collection increase and reach an optimum in the middle of the valley. On the other hand use of vegetation as fodder and timber wood is valued more in the lower valley as compared to the upper reaches. There seems a continuity of services in the form of food, medicinal, and aesthetic plants (Fig. 5.20) throughout the valley.

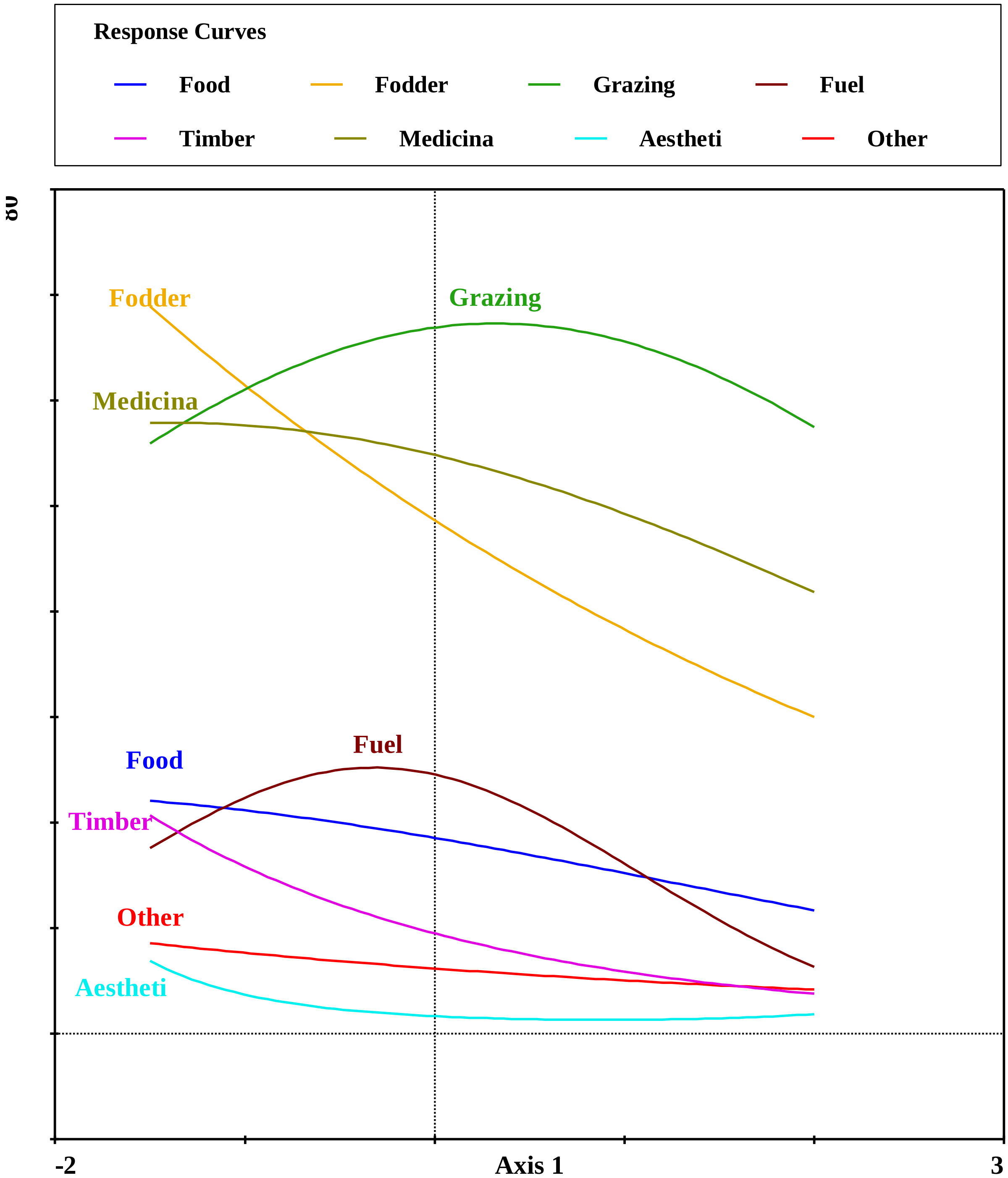


Fig. 5.21 Response curves for each category of provisioning services provided by plants along the valley

5.5 Discussion

5.5.1 Role of native plants in supporting human livelihoods and well being

The results show good evidence of the relationship between the provisioning ecosystem services of vegetation and human well-being in the study area. They also show that people utilize the vegetation according to their indigenous knowledge. The questionnaire analyses indicate that the people of the Naran Valley possess valuable knowledge of local plant biodiversity and the services it can provide are immensely important to them. There will be a variation in knowledge at the level of the individual depending upon the relation between the person and the specific plant species or group which he/she prioritizes for certain uses (Costanza, 2008, Quijas *et al.*, 2010). Nevertheless, this study has been able to demonstrate that in the study area plants are used to support a wide range of livelihood activities, and particularly as a source of traditional medicines. Furthermore, plant biodiversity of the region provides timber, fuel, medicines, food, fodder, grazing and other services to the indigenous communities. However, extensive use of natural vegetation in the past has decreased the provisioning services. Local residents, especially of the older generation, prefer to live in the valley because of the existing provisioning ecosystem services. However, the new generation tend to leave those rural spaces in search of education, facilities and an easy modern life (Giam *et al.*, 2010).

5.5.2 Indigenous knowledge as a cultural asset

Rapid technological and economic development has brought ecological and social changes all over the world. Cultural changes are even take place in rural societies due to increasing interactions with modern urban cities. Consequently, knowledge about the use of plant resources, as well as the plant wealth itself, is declining in a number of regions (Zavaleta & Hulvey, 2004, Bussmann & Sharon, 2006). The present study reveals that indigenous knowledge is well established in the people of these mountainous valleys. This phenomenon is confirmed from the study of Pieroni *et al.*, (2007) on the South-Asian migrants in Bradford UK. They carried out research on 150 South-Asian women about the traditional uses of vegetables and other plant and confirmed an important generational deviation of traditional knowledge, which is considered a sign of cultural heritage. These studies further communicate the extinction of traditional knowledge in modern societies. Indigenous people, although they possess traditional knowledge, have no proper training in sustainable ways of plant collection, post collection care and processing and usually waste a considerable quantity of medicinal plants. Such unwise practices over a long time will cause a reduction in plant biodiversity in general and of plant species providing provisioning services in particular (Hynes *et al.*, 1997, Pilgrim *et al.*, 2008). It is therefore suggested to recruit ethnobotanists and experts to train the local people for the long term utilization of medicinal plant resources. Some of the problems associated with the overuse of plant resources can be overcome through research on domestic growth of medicinal plants and development of processing techniques among the people. This present study in common with a number of other recent research studies makes an urgent call for the preservation of both long-established remedial knowledge and medicinal plant resources in the developing, world particularly in the Himalayas (Khan *et al.*, 2009). A number of issues were identified during the present project. These include poor documentation of the traditional knowledge; weak acknowledgement of the intellectual property rights of the local people; and lack of training about the sustainable use of the available resources. Furthermore, long-established knowledge about the medicinal values of plants has contributed a lot in the recent past to the production and synthesis of synthetic drugs and market values. It has played and still plays a remarkable role in solving health related problems, especially in less developed and remote parts of the world.

5.5.3 Medicinal plant resources

The use of plants to cure diseases is as old as human history. Around 20% of the plant species of the world are estimated to be used in health care systems (Baillie, 2004). Medicinal plants play an important role in the traditional health care systems of the study region also. A few of the species found in the Naran Valley, i.e. *Dioscorea deltoidea, Podophyllum hexandrum, Berberis pseudumbellata, Cypripedium cordigerum* and *Dactylorhiza hatagirea,* are listed on the CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) list of endangered species (CITES appendix II). One or more of these species were also reported in a few other studies from the Himalaya and Hindu Kush (Khan *et al.*, 2007b, Ahmad *et al.*, 2009). Several medicinal species are endemic to the Himalayas and hence should also be given attention in order to ensure sustainable use e.g., *Cedrus deodara* and *Aesculus indica,* whilst some are rare in the region e.g., *Aconitum heterophyllum, Aconitum violaceum, Ephedra gerardiana, Hypericum perforatum, Indigofera heterantha, Paeonia emodi,* and *Ulmus wallichiana*. In addition to medicinal uses these species provide other services like timber, fuel and grazing etc. Most valleys in the Himalayas have not been studied specifically for ecosystem services and plant medicinal uses. Yet all indigenous people in this region have a long established system of health care and cure health problems with available plant resources. Knowledge of which plant part to use and the recipes are based on the long experiences of the experts who know how to improve effectiveness of medicinal plants. The elder people have more accurate knowledge about the parts and recipes. A similar trend was also reported by Balemie & Kebebew, (2006) and Khan *et al.*, (2011). In the present study, people reported a decreasing trend for 55.3% and no visible change for 34.2% of the species with medicinal value. It is important to recognise, however, that plant collections for medicinal use is only one of the causes of plant population decline. Increasing human population, extensive grazing, habitat losses, multipurpose collection and carelessness are also important. All such ecological as well as cultural matters need to be documented for the best possible vegetation management, preservation and conservation strategies. The results of this study also demonstrate that most of the plants are either used whole or it is roots and rhizomes that are gathered. This type of use is an alarming signal that the use of these highly valued plants may not be sustainable.

5.5.3.1 Economics of the medicinal plants

Thirty eight of the medicinal species have an economic value and are sold by local people for marginal earnings. Price values of the sold species vary from 60-1600 Pakistani rupees per Kg in the market. Analyses show that *Podophyllum hexandrum, Asparagus racemosus, Polygonatum verticillatum, Juniperus communis, Juniperus excelsa, Fritillaria roylei, Cypripedium cordigerum* and *Dactylorhiza hatagirea* have high prices in the market. Furthermore, three of these high priced species i.e., *Podophyllum hexandrum, Cypripedium cordigerum* and *Dactylorhiza hatagirea* are also mentioned on the CITES list. Respondents also reported a decrease in the populations of 24 species (63.2%) including the 4 CITES species, with no visible change in 11 species (28.9%) and an increase only in 3 (7.9%) species. The high local utilization rate and marketing of certain species provide an indication of a likely high conservation threat. The study results also suggest that a number of these economically important species could be domesticated and propagated in protected places for marketing purposes.

5.5.3.2 Medicinal plant families of the region

The top five families identified as overused by the residual analyses i.e., Polygonaceae, Gentianaceae, Lamiaceae, Rosaceae and Plantaginaceae, showed the medicinal importance of these families in other floras also whilst the lowest ranking family in terms of medicinal use was Poaceae. A number of other studies have also confirmed its low medicinal use, although it is important for food and fodder purposes (Amiguet *et al.*, 2006, Bennett & Husby, 2008). In contrast to a few other studies our findings show that Orchidaceae has a high and Asteraceae a low medicinal value (Amiguet *et al.*, 2005). Asteraceae is the most abundant family moved from 1st position to number 48 while the 5th richest family Poaceae moved to 68th the last position. In contrast family Plantaginaceae moved up from position 17th to position 5 and Caryophyllaceae from 23rd to 9th. Results of the residual analysis showed that the people of the Naran Valley used the plants based on their availability and not on their abundance. Interestingly, most of the less abundant families are utilized frequently by the locals and hence prove the hypothesis that people utilize the plants according to their traditional knowledge and not their abundance. For example, 31 small families with only 1 or 2 species are all used medicinally in the area. 16 plant families in the region have no reported medicinal plants of which 7 have only one representative species. The results also show that low ranking families are not so important medicinally but may be utilized by locals for other purposes e.g., Poaceae the grass family, is highly abundant and important for grazing animals.

5.5.4 Novelty of the ecosystem services studies

Plant biodiversity directly or indirectly provides a range of services to mankind and it is, therefore, imperative that it is fully evaluated, managed and safeguarded (CBD 1992). People in the developing world depend heavily on natural resources for livelihood support (Uprety *et al.*, 2010). A number of studies in the Himalayas and the Hindu Kush region have previously only provided plant inventories and an account of the local knowledge of people on how they utilize the species (Ahmad *et al.*, 2009, Ali & Qaiser, 2009a, Negi *et al.*, 2010). Few of our study's features, like medicinal use categories, can be compared with them. Moreover, very limited attention has been given to quantitative ethnobotany in these mountain ranges. In this study this new and novel approach (i.e., quantitative ethnobotany) was used, which has previously only been used in published work from South American countries (Rossato *et al.*, 1999, Bermudez *et al.*, 2005, Da Cunha & De Albuquerque, 2006, Ferraz *et al.*, 2006, Goleniowski *et al.*, 2006). In the present project the provisioning services of the inventoried flora have been linked both to the traditional knowledge and the plant species abundance. Furthermore, the perception (ecological knowledge) of locals was also documented in order to assess whether local people thought populations of particular species were increasing or decreasing. Principal Components Analysis (PCA) and Response Curves were used to understand and link the cultural gradient with the ecological gradient. The use of these techniques has helped to identify the pattern of services provided by plant biodiversity (Garibay-Orijel *et al.*, 2007, Abraão *et al.*, 2008). Such ecological understanding can be used in conservation management and planning policies, and will be discussed more fully in Chapter 6.

A recent study has indicated that the majority of ecosystem service studies have been carried out in the developed world with only 13% of studies from Asia and the Pacific (Vihervaara *et al.*, 2010). Similarly few authors have pointed out the importance of mountain plant biodiversity as a basic driver of ecosystem services (Nakashizuka, 2004, Hermy *et al.*, 2008, Christensen & Heilmann-Clausen, 2009, Rey Benayas *et al.*, 2009). In this scenario it was felt necessary to integrate the ecological gradients exhibited by the plant biodiversity with the cultural gradients of plant use in order to assess present anthropogenic trends and pressures to develop immediate and long term management plans.

Chapter 6 LINKING ABUNDANCE OF PLANT SPECIES WITH HUMAN USE TO ASSESS THE ANTHROPOGENIC PRESSURES

6.1 Introduction

The classification and ordination of vegetation (discussed in chapter 4) provides an insight into the vegetation communities and plant species diversity of the Naran Valley whilst analyses of the questionnaire data provides information about the range of vegetation provisioning services (chapter 5). Both types of studies provide separate baselines for the management and conservation of vegetation at ecosystem and species levels. In the current chapter, plant species abundance data are linked with data on human use of plants to assess anthropogenic pressures and identify the risks to critical species.

A consideration of environmental gradients clarifies the species requirements and ecosystem processes which determine the indicator vegetation that can be used in proposing conservation strategies. A review of available literature shows that there are huge deficiencies in knowledge about the significant indicator, endemic and threatened species in the Himalayas especially in the Pakistani part, and proper quantification is needed for each of the taxa along with their environmental requirements (Miller *et al.*, 2007, Ali, 2008). People from the natural and social sciences have studied the natural and traditional systems separately and very limited consideration has been made to link these disciplines together for the better assessment of anthropogenic pressure on plant resources and their management. Recently interest in such issues has developed in different parts of the world as an attempt to integrate traditional knowledge with ecosystem management and can be studied in the publications cited here (Zou *et al.*, 2007, Chowdhury *et al.*, 2009, Fazlur-Rahman, 2009, Dong *et al.*, 2010, Sharma *et al.*, 2010, Mutenje *et al.*, 2011, Vačkář *et al.*, 2012). In this regard assessment of vegetation quality and quantity is as important as its floristic and economic evaluation. One of the ways to assess vegetation quality is valuation of its use value. Recently this term ‘Use Value’ has been introduced in plant sciences based on the services of plants to human communities (Phillips *et al.*, 1994, Rossato *et al.*, 1999). Through the Convention on Biodiversity (CBD), countries are making efforts to elaborate not only on the quantity of plant biodiversity but also on the quality by identifying indicator species and measuring their abundance (Normander *et al.*, 2012). This is not only imperative for the conservation of biodiversity itself but also for environmental sustainability against the scenario of changing climate, global warming and economic crises (Müller & Lenz, 2006, Moldan *et al.*, 2011).

People's observations about the trends in plant populations can also be taken into consideration in conservation as they have long established associations with those plants and natural surroundings (Tarrasón *et al.*, 2010).

6.2 Methodology

6.2.1 Calculation of Importance Value (IV)

Based upon the data from the first field work in 2009, the relative values of density, cover and frequency of each plant species were added and the product was divided by 3 to obtain the Importance Value (IV) of species in the area (Mueller-Dombois & Ellenberg, 1974, Zhang *et al.*, 2008, Chettri *et al.*, 2010) (Table 4.4).

IV = RD+RC+RF/3

Where

RD = Relative density
RC = Relative cover
RF = Relative frequency

6.2.2 Calculation of Use Value (UV)

During the second field work in 2010, informants were asked their opinions on the provisioning services of plant species e.g., food (F), fodder (Fd), grazing (Gr), timber (Ti), fuel (Fu), aesthetic (Ae), medicinal (M) and others (Ot) (Appendix 5.2). A Use Value (UV) for each of the plant species was calculated using data from the 120 questionnaires and the formula UV = $\sum$ U/n proposed by Phillips *et al.*, (1994) and modified by Rossato *et al.* (1999)
Where

UV = Use Value of a species
U = No. of uses mentioned by the informants
n = number of informants

Furthermore individuals were also asked their opinion about the trend of the species that they observed their lifetimes. Trend was recorded using a scale with three categories i.e., decreasing (D), increasing (I) and no visible change (NC) (Appendix 5.2). Such social perceptions were then used together with our findings on plant abundance (Chapter 4) for comparison, confirmation and assessment of anthropogenic pressures (Camou-Guerrero *et al.*, 2008, Tarrasón *et al.*, 2010, Khan *et al.*, 2011a).

6.3 Data analysis

SPSS version 18 was used for regression analyses, residual value analyses and regression curve fit to compare the importance value (IV) of the vascular plants (from the quadrat data) with the use values (UV) (from the questionnaire data) (Moerman, 1991, Bryman & Cramer, 1997, Colman, 2008, Peter & Kellie, 2010). Residual value analysis is a better approach to compare the abundance of plant species with their local uses. It not only gives the pattern of traditional use but also explains to the hypothesis put at the start of the study. It was assumed at the beginning of the study that people of the region use the plant species according to their indigenous knowledge and not based on plant abundance in the region. These analyses help to answer such questions by giving predicted and residual values for each species (Amiguet *et al.*, 2006, Bennett & Husby, 2008).

Table 6.1 Descriptive statistics of variables

	Mean	Std. Deviation	N
Use Values (UV)	15.44	11.361	198
Importance values (IV)	388.36	750.105	198

Curve fit using regression analyses demonstrates relationships between the IV and the UV of the available species. The only species data available for the study area for this comparison was the first year phytosociological data for 198 plant species (Khan *et al.*, 2011b) and hence these data were compared with the questionnaire data obtained from the second field work in 2010 (Table 6.1, Table 6.2 & Chapter 5).

Table 6.2 Regression model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.351	0.123	0.119	10.665	0.123	27.558	1	196	0.000

a. Predictors: Importance values (IV)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.351	0.123	0.119	10.665	0.123	27.558	1	196	0.000

a. Predictors: Importance values (IV)
b. Dependent Variable: Use Values (UV)

6.4 Results

6.4.1 Integration of species abundance with use value data to assess anthropogenic pressure

Integration of species abundance with use value data gave the predicted values of use. Regression analyses for importance values (abundance) in relation to use values of species were statistically significant (p = 000). The standard deviation for residual values of all the 198 species was 0.997. Detailed Importance Values for each species are given in Appendix 4.5. The results of the residual value analyses using linear regression statistics revealed that 93 species (50.8% of the used and 46.9% of all the species) had residual values greater than the standard deviation, signifying they are overused by the inhabitants in the project area. The top 10 species with highest residuals are *Juglans regia*, *Polygonatum verticillatum, Origanum vulgare, Cedrus deodara, Malva neglecta, Rumex nepalensis, Rheum australe, Geranium wallichianum, Polygonum aviculare* and *Paeonia emodi*. Other important overused tree species are *Abies pindrow, Betula utilis, Aesculus indica, Ulmus wallichiana, Pinus wallichiana, Prunus cerasoides,* and *Picea smithiana. Hypericum perforatum, Berberis pseudumbellata, Valeriana pyrolifolia, Viola canescens, Indigofera heterantha, Juniperus excelsa* and *Thymus linearis* are also over used among the shrub and herb species. From an ecosystem services perspective, these species have multiple uses. The ten species with lowest residual values' are *Sambucus wightiana, Artemisia brevifolia, Onopordum acanthium, Polygonum alpinum, Sedum album, Sedum ewersii, Gnaphalium affine, Iris hookeriana, Cyperus niveus* and *Acantholimon lycopodioides*. Other species with lower residual values are *Astragalus scorpiurus, Senecio chrysanthemoides, Ranunculus hirtellus, Ranunculus laetus, Sorbaria tomentosa, Geum elatum, Stipa himalaica, Cassiope fastigiata, Bergenia stracheyi, Erysimum melicentae* and *Minuartia kashmirica*. When these species are considered from a provisioning services perspective, most are unwanted and unpalatable species of an invasive or alien nature; for example the first and second most abundant species *Sambucus wightiana* and *Artemisia brevifolia* with highest importance values have the lowest residual values also. These species are unpalatable and spreading widely into the area. On the other hand a number of abundant species with high IVs also have high use values and hence high residual values e.g., *Abies pindrow, Betula utilis, Pinus wallichiana, Viola canescens, Thymus linearis, Rheum australe* and *Malva neglecta.* Similarly other species have relatively lower IVs but high use and residual values e.g., *Juglans regia, Aesculus indica, Ulmus wallichiana, Prunus cerasoides, Indigofera heterantha* and *Paeonia emodi* (Appendix 6.1). As a whole most of the less abundant species have a higher number of uses and high residual values and hence support the hypothesis that people do not utilize the plants according to their abundance but according to their indigenous knowledge.

Summarizing the results using the curve fit option in SPSS, resulted in the graphs shown in fig. 6.1 & 6.2. The first graph shows the linear regression line. As most of the species have lower values both for IVs and UVs the points accumulate together to the left corner of the plot. Log regression plots were constructed to show the clear distribution of the species all over the plot. These plots show the relationship between importance values (IV) and use values (UV) of the species. Species above the regression line have higher use values in relation to their abundance and can be considered as vulnerable in a regional context. A few of the species are of national and global importance and can be categorized more critically. Some of the endemic species of the Himalayas like *Androsace hazarica, Arnebia benthamii, Aster falconeri, Cedrus deodara, Dactylorhiza hatagirea, Fritillaria roylei, Pedicularis pectinata, Salvia moorcroftiana, Vicia bakeri* and *Ulmus wallichiana* are under strong continuous anthropogenic pressure and hence lie above the regression line (Fig. 6.1 & 6.2).

Table 6.3 Summary of residuals statistics showing predicted and residual values with standard deviations

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	13.20	43.76	15.44	3.989	198
Residual	-22.759	28.513	0.000	10.638	198
Std. Predicted Value	-.562	7.098	0.000	1.000	198
Std. Residual	-2.134	2.674	0.000	0.997	198

Table 6.4 ANOVA table showing a significant relationship between the importance values/abundance and use values data

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3134.406	1	3134.406	27.558	0.000
	Residual	22292.482	196	113.737		
	Total	25426.889	197			

a. Predictors: Importance values (IV)
b. Variable: Use Values (UV)

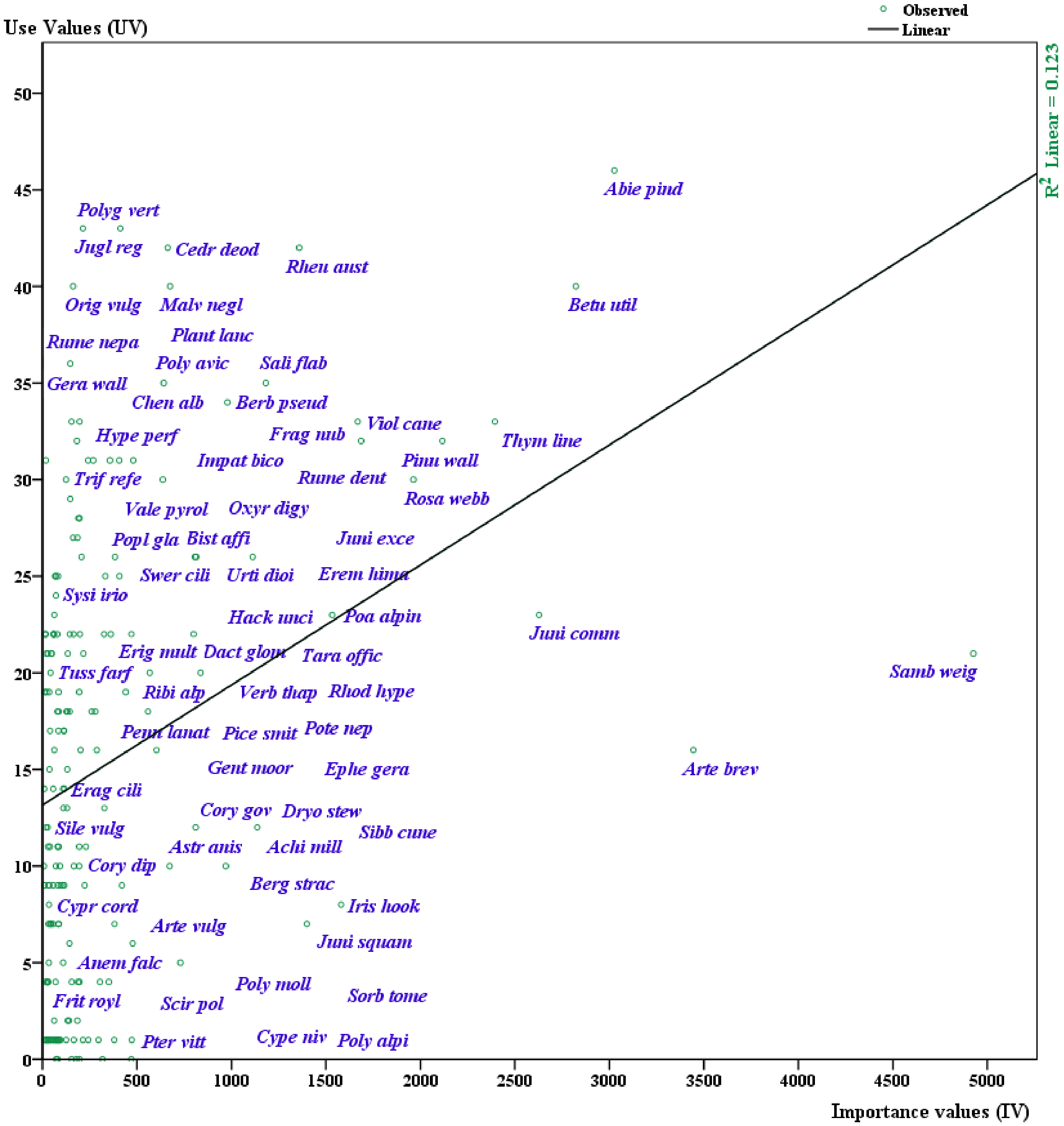


Fig. 6.1 Linear regression graph showing association between importance values (abundance) and use values of the species (N = 198; p = 0.000; r^2 = 0.123)

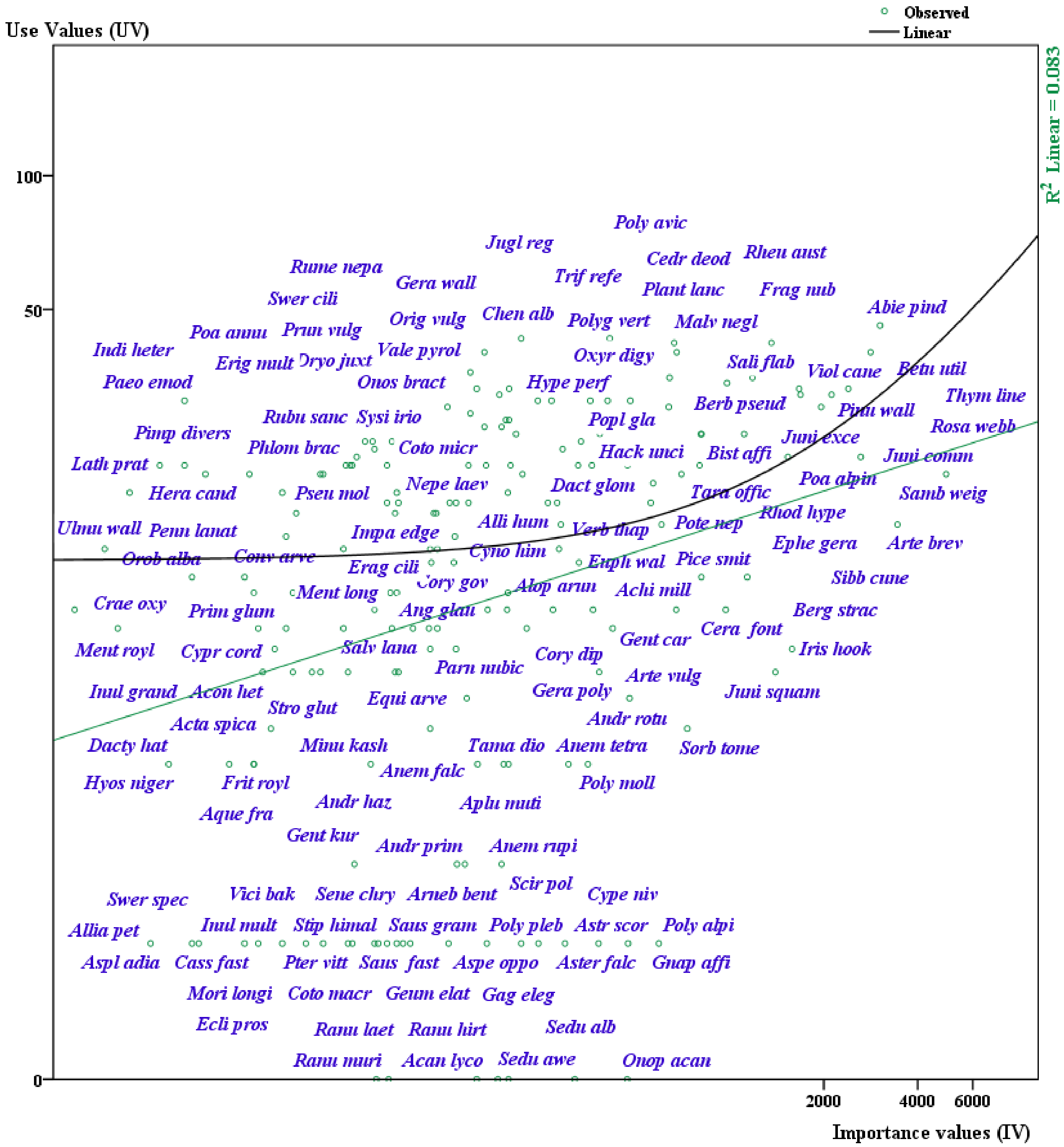


Fig. 6.2 (a) Log regression curve (X=1.8, Y = 3.5 with reference line) showing use values (UV) of the species versus the importance values (IV) (abundance); (N = 198; p = 0.000; r^2 = 0.083)

6.4.2 *Trend mentioned by respondents*

The results of an analysis of local people's views on vegetation abundance at a species level shows that there is a continuous decrease in more than 50% of the species. Only 34 % of the species were reported to maintain their population with no visible change whilst an increase was reported only in 10% of the species. Furthermore, the decreasing trend mentioned by local inhabitants when examined from species abundance, fidelity and endemism perspectives showed that most of the less abundant, indicator and endemic species with higher fidelity values are depleting rapidly in the region (Appendix 7.1).

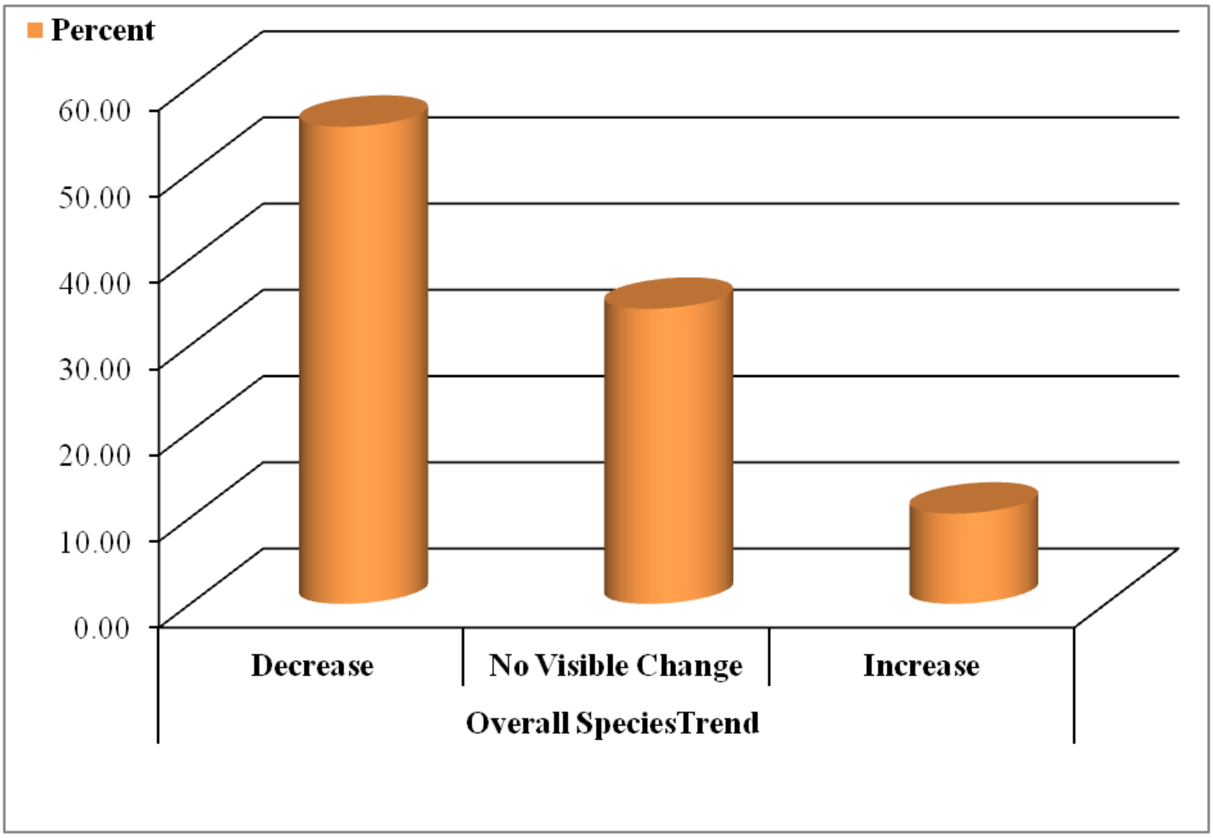


Fig. 6.3 Respondents perceptions about the trend of species abundance and population size in the recent past

6.4.3 Evaluation of residual values in relation to species fidelity, abundance, usage and trend mentioned by local people

Indicator species with higher fidelity to particular habitat types were assessed and compared from both data sets for recommendation of their conservation importance. Based upon the residual values species of the region were categorized in six different categories. Ninety three species are identified as overused as their residual values are greater than the standard deviation (Appendix 6.1). These species were checked for the faithfulness (Fidelity) to a specific community/habitat and constancy in the area. It is evident that most of the overused species (with high residual values) fall in the more faithful classes with relatively lower constancy. Twenty of these species are related to fidelity (faithfulness) class 5 (Exclusive species) or class 4 (Selective species) indicating high habitat selectivity. Nineteen species are in fidelity class 3 (Preferential species) which prefer a specific sort of habitats. This means that those 39 species grow in highly selective environments. Thirty four of these species have a constancy value less than 20% in the area. Only five of these very faithful species have constancy more than 20% i.e., *Bistorta affinis* (25.2%), *Eremurus himalaicus* (20.4%), *Juniperus excelsa* (21.4%), *Impatiens bicolour* (28.8%), and *Verbascum thapsus* (33.2%) but their higher use values indicate continuous utilization of these species in the region. This result again articulates the relatively low availability and abundance of most of the overused species. The high use and residual values indicate high anthropogenic pressure on these species whilst a high level of fidelity and lower constancy indicates the potential risk to such species by overuse because of their very narrow amplitude. The remaining 54 over used species are either in fidelity classes 2 or 1. Very similar results were found for the social perception about the same species. Respondents mentioned a decreasing trend for 21 and no apparent change for 14 of these species (Appendix 7.1). These species were also checked for endemism and other critical observations on their broader importance and this will be discussed in next chapter in details.

6.5 Discussion

6.5.1 Importance of linking available plant biodiversity with its usage

Assessment of plant biodiversity in terrestrial ecosystems is desirable not only for academic purposes but also because it establishes the basic trophic level in that system which provides a number of services. Mountain ecosystems all over the world usually have varied plant biodiversity due to their landscape, climate and history and are also the dwelling places for a vast human population (Herben *et al.*, 2003, Fosaa, 2004). The role of the vascular plants in an ecosystem is always representative of the function of that system because it signifies the nature of its biomass (Enquist, 2002, Myklestad & Sætersdal, 2004). The findings of this study show that people obtain goods and services mainly from vascular species. The loss of biodiversity is often attributed to anthropogenic effects such as deforestation, multipurpose collection and introduction of invasive species for various purposes (Hobbs & Huenneke, 1992). The Naran Valley not only supports a diverse plant biodiversity (198 species) (Khan *et al.*, 2011b) with varying levels of abundance but also with varying usages and use values (Khan *et al.*, 2011a). Due to the shortage of other resources and climatic constraints, the people of this region regularly utilize vegetation through activities such as wood cutting, grazing and medicinal plant collection. Consequently, a number of plant species are under tremendous human pressure and likely to become extinct from the region in the near future. A number of authors have addressed such issues in different regions using different approaches (Hamayun *et al.*, 2003a, Parolly, 2004, Lovett *et al.*, 2006, Niedrist *et al.*, 2009). Very little effort, however, has been made to tally the traditional knowledge with the abundance of plant species in order to better understand the anthropogenic pressures and conservation priorities for both plant species and habitats. The present approach is a novel one, especially the evaluation of use values versus importance values and to the best of our knowledge has not been adapted elsewhere in this way, although a few studies have made comparisons of social perception and usage of plants versus availability using other approaches (de Albuquerque *et al.*, 2010, Tarrasón *et al.*, 2010,). A major concern of this project was the assessment of species abundance and environmental variables, like a number of other studies in mountains (Brown *et al.*, 1993a, Brown *et al.*, 1993b, Kessler, 2000, Willig *et al.*, 2003, Carpenter, 2005, Kharkwal *et al.*, 2005a, Lovett *et al.*, 2006, Ren *et al.*, 2006, Khan *et al.*, 2011b). On the other hand exploration of plant species richness patterns with human variables was desirable in order to understand the association between cultural and natural systems (Evans *et al.*, 2006, Zafra-Calvo *et al.*, 2010). The findings also indicate that human usage of vegetation in the Naran Valley is exerting a high pressure and causing a reduction in plant biodiversity. The species providing multiple services and having more economic importance are generally chosen by indigenous people, which in turn increase rarity of these species and habitat fragmentation. Prediction through the use of regression models could be an appropriate way to assess such pressures and identify critical species (Lehmann *et al.*, 2002), providing a basis for plant conservation strategies.

6.5.2 Species assessment, ecosystem services and conservation strategies

Vegetation classification is increasingly being used for conservation planning in natural ecosystems. On the other hand major social problems are responsible for enormous anthropogenic pressure in this region; these include poverty, lack of awareness, education and seasonal utilization of vegetation which increases the negative competition and greed among individuals for overexploitation of available plant resources. Like the ecological indicators these social indicators and perception can be identified as we did in the present project. These indicators, when employed together with traditional and economic gauges, can play a vital role in designing conservation strategies (Zou *et al.*, 2007, Koc *et al.*, 2003, Tarrasón *et al.*, 2010). In a recent review, Vackar *et al.*, (2012) pointed out that each aspect of biodiversity cannot be examined with a single indicator. They suggest the use of multiple indices and indicators for a better understanding of biodiversity in relation to human activities (Dolan *et al.*, 2011, Feola *et al.*, 2011, Vačkář *et al.*, 2012). Indicator species based on fidelity distribution show the narrow range of their habitat specificity signifying the fact that species once destroyed in such habitats are extremely difficult to be re-grown due to a number of climatic, edaphic and anthropogenic constraints. For this purpose in the present project, from both data sets such indicators were assessed and compared for further evidences. Two different approaches to identify indicators species have been employed based on ecological as well as cultural analyses. Traditional indicators based on informant’s data are in close coincidence with our findings on ecological indicators (Chapter 4). It is evident that species with higher fidelity values also having high residual values should have conservation priority. The findings are closely allied to the conservation criteria of the endangered species i.e., species having restricted distribution, special or fragmented habitats, higher fidelity and a faster decrease in population (Zou *et al.*, 2007, Pinke & Pál, 2008, Haarmeyer *et al.*, 2010). This approach also opens new ways to study and manage ecosystem services and environmental sustainability (Moldan *et al.*, 2011, Layke *et al.*, 2011). The findings, based on ecological as well as cultural approaches, can be used as criteria for prioritization of protected areas, special habitats and species of conservation importance.

There is no thorough work on Red Data Book of endangered plant species in the Himalayan region, despite its important endemic flora. In part this is a result of the political conflict in this area over the last century (Hanson *et al.*, 2009). One can find very few comparators to evaluate the endangered and critical species at a national level (Ali, 2008) but new efforts are emerging and can be seen in a few publications over the last two or three years (Alam & Ali, 2010, Ali & Qaiser, 2010, Ali & Qaiser, 2011), although these provide description of a very few species. Nevertheless, our study can be compared to other regions of the Himalaya in terms of its potential for linking endemism and ecosystem services (Samant & Dhar, 1997, Aumeeruddy, 2003, Qureshi *et al.*, 2007, Kala, 2007). For the first time, this study develops a robust approach to critically evaluate the vegetation of the Naran Valley which could be extended to the wider Himalaya region. Such critical evaluation of plant biodiversity at both regional and national level should be a necessary part of the national laws like in developed world (Brown Jr. & Shogren, 1998). Our findings both from the natural and traditional perspectives indicate a high risk for a number of species and hence critical consideration must be taken for preservation and conservation both at species and habitat levels.

<u>Chapter 7</u> DISCUSSION AND SYNTHESIS

7.1. Vegetation dynamics in the Western Himalayas

As in all ecosystems plant biodiversity provides the first trophic level in mountain ecosystems and hence requires proper documentation and quantification in relation to abiotic environmental variables both at individual and aggregate levels (Jackson, 2006). The complex and dynamic Himalayas with their varying climate and topography exhibit diverse vegetation that provides a range of ecosystem services. The biodiversity of these mountains is also under the influence of diverse human cultures and land uses, thus ecosystem services provided by vegetation need extensive exploration at local as well as at regional levels (Zobel & Singh, 1997). In north-western Pakistan, three of the world's highest mountain ranges i.e., the Himalayan, Hindu Kush and Karakoram ranges, come together ensuring high floral diversity and phytogeographic interest. The Naran Valley is located at the far west of the Western Himalayas on the border with the Hindu Kush range, which lies to the west, and near to the Karakorum Range to the north. Geologically, the valley is located where the Eurasian and Indian tectonic plates meet and where the arid climate of the western Eurasian mountains gives way to the moister monsoon climate of the Sino-Japanese region (Takhtadzhian & Cronquist, 1986, Qaiser & Abid, 2005, Kuhle, 2007). The valley thus occupies an individual transitional position in the region. In remote mountainous valleys like the Naran, the complexity of ecosystems, their inaccessibility and the cost and time factors make it extremely difficult to observe each and every aspect of the vegetation features. Perhaps those were the reasons that in spite of its high phytogeographic importance, there have been no previous quantitative studies of the vegetation in this valley. The present study is not only the first in this location but is also quite exceptional because of the use of modern statistical techniques for the quantification of plant species and communities along geo-climatic environmental gradients that has limited comparator studies in this region (Dasti *et al.*, 2007, Saima *et al.*, 2009, Malik & Husain, 2008, Wazir *et al.*, 2008). The plant community pattern and species composition of the Naran Valley is largely influenced by variability in aspect and elevation followed by soil depth and grazing. Species patterns along environmental gradients can be compared with other studies of mountainous ecosystems around the globe where increasing altitudinal and latitudinal gradients cause variation in species richness and diversity (Johnson, 1996, Bergmeier, 2002, Valachovic *et al.*, 2002, Vanderpuye *et al.*, 2002, Wang *et* *al.*, 2003, Sánchez-González & López-Mata, 2005, Anderson *et al.*, 2006, Gould *et al.*, 2006, Chawla *et al.*, 2008, Nogués-Bravo *et al.*, 2008, Sanhueza *et al.*, 2009).

Unlike the eastern Himalayas, where monsoon driven vegetation predominates under higher rainfall and humidity (Dutta & Agrawal, 2005, Behera *et al.*, 2005, Roy & Behera, 2005, Chawla *et al.*, 2008, Anthwal *et al.*, 2010), the vegetation in the western Himalayas in general (Dickoré & Nüsser, 2000, Chawla *et al.*, 2008, Ahmad *et al.*, 2009, Kukshal *et al.*, 2009, Shaheen *et al.*, 2011,) and in the Naran Valley (Khan *et al.*, 2011b) in particular has closer affinities with that of the Hindukush mountains which have a drier and cooler climate (Noroozi *et al.*, 2008, Wazir *et al.*, 2008, Ali & Qaiser, 2009b,). Nevertheless, the vegetation in both these mountain systems as well as in the Karakorum (Miehe *et al.*, 1996, Eberhardt *et al.*, 2007) exhibit great similarity above the tree line (Miehe *et al.*, 2009), where climatic conditions are more comparable. The Naran Valley, which is floristically located in the Western Himalayan Province of the Irano-Turanian region, forms a botanical transitional zone between the moist temperate (from the South East) and dry temperate (from the North West) vegetation zones of the Himalayan and Hindu Kush mountain ranges, respectively. A phyto-climatic gradient of vegetation based on life forms further emphasises the nature of the area and makes apparent the transitional position of the region (Khan *et al.*, 2011b).

The quantitative approaches to vegetation description and analysis deployed in this study not only fills methodological deficiencies and gaps in the literature, i.e., classification of vegetation and evaluation of environmental gradients, but also provides a firm basis for extending this approach to the adjacent mountain systems that are in need of up to date vegetation mapping (Mucina, 1997, Fosaa, 2004). In addition, the present study documents and provides suggestions for the conservation of mountain plant biodiversity under a scenario of continuous human exploitation. In order to maintain some sort of equilibrium between natural, unmodified and cultural forms of land use systems, planning and conservation management are crucial. It is necessary to maintain ecosystem services in general and food security in particular, not only within mountain systems, but also for the people and ecosystems of the lowlands that depend on these mountains (Rasul, 2010, Manandhar & Rasul, 2009, Sharma *et al.*, 2010).

7.1.1. Plant Biodiversity; Indicator, Endangered and Rare species

This study of plant communities is distinctive as, unlike other vegetation studies along the environmental gradient which merely compare the diversity indices among communities and treat all the species equally without surveying their ecological position and their meaning in those particular ecosystems (e.g., Carpenter, 2005, Oommen & Shanker, 2005, Gould *et al.*, 2006, Ren *et al.*, 2006, Malik & Husain, 2007, Dasti *et al.*, 2007, Crimmins *et al.*, 2008, Wazir *et al.*, 2008, Siddiqui *et al.*, 2009), it has identified the indicator species based on their fidelity and abundance. Such ecological indicators can be used to understand the requirements and long term management of natural habitats (Tarrasón *et al.*, 2010, Kati *et al.*, 2009). The diversity of vegetation and diversity of gradients as well as other nature conservation criteria were considered. Species abundance data in PCORD were used to calculate the indicator values and thus at least one indicator species (statistically significant) was selected from each of the tree, shrub and herb layers in each of the plant communities using Indicator Species Analysis (ISA). At the same time the faithfulness of these indicators was tested by their categorization in the fidelity classes. Faithful and indicator species identified in this study can be used as a basis for extensive conservation studies on biodiversity at a regional and even country level in the fashion of most European and some Asian countries where the vegetation has been thoroughly mapped by ecologists (Brown *et al.*, 1993b, Rodwell *et al.*, 1995, Rodwell *et al.*, 1997, Roy *et al.*, 2000, Noroozi *et al.*, 2008, Sutherland *et al.*, 2008, Giam *et al.*, 2010).

In addition this study is the first ever community classification of the vegetation of a Himalayan region that is combined with an assessment of provisioning services associated with that plant biodiversity. This information is used to evaluate the conservation status of the recorded plant species. To date there has been very limited and fragmented published work on IUCN red list plant species (and only for a few species) (Ali, 2008, Alam & Ali, 2009, Alam & Ali, 2010, Ali & Qaiser, 2010, Haider *et al.*, 2010, Ali & Qaiser, 2011). Therefore, this thesis provides a basis for further evaluation.

Notably, several plant species were found that are endangered either globally or regionally, and listed by CITES i.e., *Dioscorea deltoidea, Podophyllum hexandrum, Cypripedium cordigerum* and *Dactylorhiza hatagirea* are all globally rare while *Acer caesium, Betula utilis, Ephedra gerardiana, Fritillaria roylei, Gentiana kurroo, Hyoscyamus niger, Inula grandiflora, Rheum australe* and *Rhododendron hypenanthum* are regionally endangered species. In addition, *Aconitum heterophyllum, Bistorta amplexicaulis, Cedrus deodara, Colchicum luteum, Geranium wallichianum, Iris hookeriana, Juglans regia, Paeonia emodi, Plantago major, Polygonatum verticillatum* and *Viola canescens,* are nearly threatened or vulnerable at a country level.

As suggested by some authors (Domínguez Lozano *et al.*, 2003, Crain *et al.*, 2011), this study also addressed rarity as a conservation criterion. After applying the IUCN criteria it is evident that species (beyond those mentioned in other publications which come under the next sub heading) are Critically Endangered (CR) in the study area i.e., *Aesculus indica, Alliaria petiolata, Asparagus racemosus, Crataegus oxycantha, Euphorbia wallichii, Indigofera heterantha, Orobanche alba, Prunus cerasoides* and *Ribes alpestre.* Species that come under the category of Endangered (EN) are *Gratiola officinalis, Erigeron multiradiatus, Hypericum perforatum, Mentha royleana, Primula denticulata, Sorbaria tomentosa* and *Tussilago farfara.* Among Vulnerable (VU) species are *Acantholimon lycopodioides, Cotoneaster microphyllus, Convolulus arvensis, Cotoneaster cashmiriensis, Eragrostis cilianensis, Geranium nepalense, Juniperus squamata, Leucas cephalotes, Primula calderana, Pseudomertensia parvifolia* and *Viburnum grandiflorum.* Nearly Threatened (NT) species are *Abies pindrow, Actaea spicata, Anaphalis triplinervis, Anemone rupicola, Asperula oppositifolia, Asplenium adiantum-nigrum, Caltha alba, Clematis Montana, Dracocephalum nutans, Gagea elegans, Inula multiradiata, Juniperus excelsa, Pimpinella diversifolia, Potentilla atrosanguinea, Pseudomertensia nemorosa, Rubus sanctus, Rumex nepalensis, Saussurea albescens, Saussurea graminifolia, Saussurea fastuosa, Silene vulgaris*, and *Swertia speciosa.* Only seventy eight (78) (39.4% of the total) species come under the IUCN criterion of Least Concern (LC) (Appendix 7.1).

Other important species having lower constancy, abundance and Importance Values (IVs) (other than those mentioned in the previous section on globally or regionally endangered species or in the following section on regionally endemic species) can be considered as rare in the study area e.g., *Aquilegia fragrans, Bergenia ciliata, Cynoglossum lanceolatum, Epilobium angustifolium, Heracleum candicans, Hyoscyamus niger, Inula grandiflora, Lathyrus pratensis, Morina longifolia, Pimpinella acuminata, Primula calderana, Prunella vulgaris Pseudomertensia parvifolia, Salvia lanata, Strobilanthes glutinosus, Trillidium govanianum, Ulmus wallichiana* and *Vicia bakeri.*

7.1.2. Plant Biodiversity; the Naran Valley as a hot spot for the Endemic flora

Endemic species have an exceptional individuality and significance as their distribution is limited to a particular region. Ecologists and taxonomists always emphasize the quantification, documentation and conservation of endemic flora. The Western Himalaya is an important hot spot for endemism as it hosts about 300 endemic species (Ali, 2008, Ali *et al.*, 1972-2009). The Convention on Biological Diversity in 2002 agreed to protect 50% of the significant regions for plant diversity and conservation based on species endemism, richness and ecosystem endangerment (Ma *et al.*, 2007). In this scenario by applying the IUCN criteria (IUCN, 2003) to the plant abundance data (Chapter 4) as well as plant use (Chapter 5 & 6) data and checking for coincidences it is estimated that plant species endemic to the Himalayas, the Hindu Kush and the Karakorum are highly threatened. Sixty four plant species (32.32% of the total recorded species) in the area are endemic to these mountains. According to published literature and the Flora of Pakistan, twenty (20) of these are endemic to the Himalayas alone and 29 are mutually shared by the Himalayas and Hindu Kush, while 19 are mutually shared by all three mountain ranges. When the IUCN red list criteria at regional levels are applied to these 64 endemic species, 20 can be classified as Critically Endangered (CR) in the study area. These species are *Androsace hazarica, Androsace primuloides, Aquilegia fragrans, Arnebia benthamii, Cedrus deodara, Cypripedium cordigerum, Dactylorhiza hatagirea, Fritillaria roylei, Gentiana kurroo, Heracleum candicans, Paeonia emodi, Pedicularis pectinata, Pimpinella acuminate, Plantago himalaica, Pseudomertensia moltkioides, Ranunculus hirtellus, Rheum austral, Ulmus wallichiana* and *Vicia bakeri.* Fourteen (14) species are Endangered/Threatened (EN) in the region i.e., *Aconitum heterophyllum, Angelica glauca, Anemone falconeri, Cassiope fastigiata, Corydalis govaniana, Gentianodes argentia, Geranium wallichianum, Picea smithiana, Rhododendron hypenanthum, Salix flabellaris, Salvia moorcroftiana, Trillidium govanianum* and *Viburnum cotinifolium*. Twelve (12) of them are Vulnerable (VU) in the study area i.e., *Aconitum violaceum, Berberis pseudumbellata, Bergenia ciliata, Gentiana moorcroftiana, Geum elatum, Erysimum melicentae, Pinus wallichiana, Primula glomerata, Primula rosea, Pteris vittata, Strobilanthes glutinosus* and *Viola canescens.* Eleven (11) species are Nearly Threatened (NT) while seven (7) endemic species come under the category of Least Concern (LC) i.e., *Bergenia stracheyi, Bistorta affinis, Dryopteris stewartii, Eremurus himalaicus, Galium asperuloides, Phlomis bracteosa* and *Stipa himalaica.* Species which are nearly threatened are *Allium humile, Anemone obtusiloba, Anemone tetrasepala, Aster falconeri,* *Bistorta amplexicaulis, Euphrasia himalayica, Iris hookeriana, Onosma bracteatum, Parnassia nubicola, Potentilla atrosanguinea* and *Swertia ciliata.* Species mentioned in each category in general and in the last three categories in particular, indicate that the Naran Valley is a hot spot for endemic flora and can be considered as an area that should be afforded protected area status for the long term conservation of plant biodiversity. Three (3) of the above mentioned species are endemic to Pakistan (at a country level), i.e., *Androsace hazarica*, *Dryopteris stewartii* and *Gentianodes argentia* (Appendix 7.1). The faithfulness values of these endemic species indicate they have a higher fidelity level (fidelity class 3-5), signifying their highly selective nature of specific environmental conditions. This knowledge can be helpful in habitat and landscape management planning. Optimum numbers of endemic subalpine species were recorded in Communities 2 and 4, mostly which is in close agreement with the assumptions provided in literature from other mountain studies (Vetaas & Grytnes, 2002, Noroozi *et al.*, 2008). As endemic flora restrict to a specific sort of environmental condition in a confined area and consideration of such region as a hot spot can safeguard valuable species (Behera *et al.*, 2002).

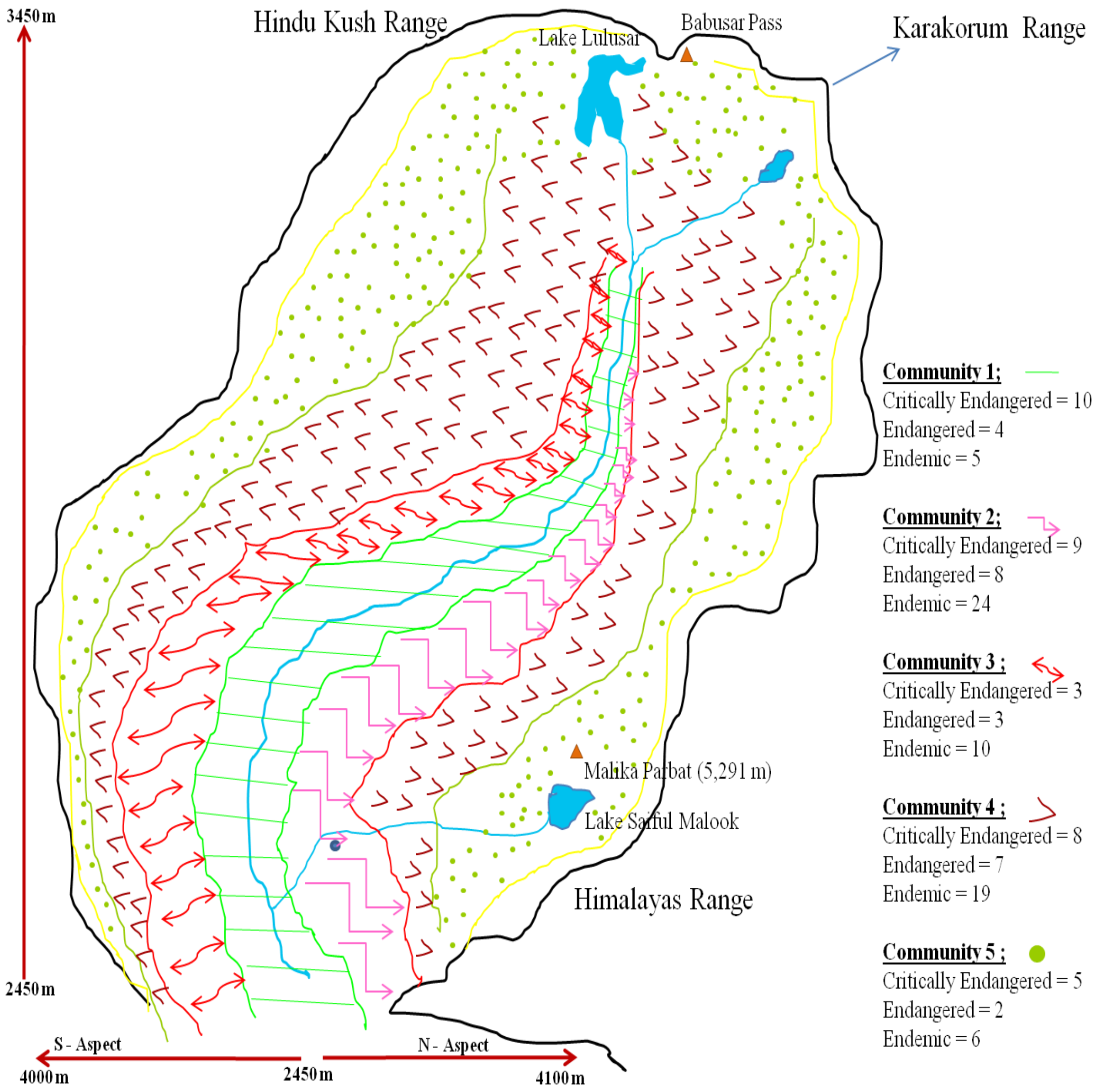


Fig. 7.1 Schematic map of the Naran Valley showing its various vegetation zones (Communities) and conservation status of endemic species

7.2. Reduction in the Ecosystem Services provided by natural vegetation

Landscape dynamics associated with anthropogenic activities and global climatic change will likely reduce the ecosystem services associated with natural biodiversity. Organizations and ecosystem managers should pay attention to these issues in order to minimize the present losses in natural ecosystems and to plan for their sustainable future (Zavaleta & Hulvey, 2004, Prato, 2007, Stewart & Pullin, 2008, Whaley *et al.*, 2010). Sustainable utilization and conservation of biodiversity are essential for the continuation of ecosystem functioning (Srivastava & Vellend, 2005). The indigenous people in the study area gave less attention to the long term ecosystem goods and services since they were focused on their marginal and short time benefits. They illicitly utilized plants for a number of uses including timber, fuel, medicines, food, grazing and fodder. Local residents, especially of the older generation, preferred to live in the valley because of the existing provisioning ecosystem services. However, members of the younger generation tended to leave these rural spaces in search of education, facilities and an easy modern life thus they were less aware of or dependent on ecosystem services. Extensive use of natural vegetation in the valley in the past has decreased the provisioning services (Dobson *et al.*, 2006, Stewart & Pullin, 2008, Giam *et al.*, 2010). This reduction is quite prominent in the categories of food, fodder, timber fuel and medicines. The consequence of the imbalance in supply of these services and the increasing human demands has been deterioration in the condition of the natural habitats and increasing rarity of plant biodiversity (Díaz *et al.*, 2006, Giam *et al.*, 2010). These effects are becoming worse as the indigenous people neither possess enough services locally nor can they compete in the urban societies. Due to the extinction of important species, the traditional indigenous knowledge of the people is decreasing day by day. These problems threaten the sustainability of the mountain ecosystem. Plant biodiversity can be restored and the risks of degradation may be combated, if measures like reforestation, establishment of protected areas, greater awareness by the people and *ex-situ* conservation of rare species are initiated (Brown Jr. & Shogren, 1998, Parody *et al.*, 2001, Niemi & McDonald, 2004, Pereira *et al.*, 2005, Muzaffar *et al.*, 2011). A continuous decrease in plant biodiversity causes not only a reduction in the net primary productivity and carbon storage but also influence soil, weather and climate (Rasul, 2010, Midgley, 2012). Long term management and conservation strategies might, therefore, have optimistic outcomes for the maintenance and increase in mountain biodiversity and ecosystem services which will also have a positive impact on the lowland ecosystems as they insure the flow of rivers for irrigation of agricultural land (Archer & Fowler, 2004).

7.2.1. *Assessment of traditional perception and conservation efforts*

Assessment of conservation status cannot be absolute and needs periodic revision but taking various criteria at a time validates the conclusion for a considerable period of time or for a specific geographic locality (Domínguez Lozano *et al.*, 2003, Broennimann *et al.*, 2005). In the remote valleys of the Himalayas people exploit natural resources and vegetation during their seasonal movements. Due to this extensive interaction with plant biodiversity these indigenous people have valuable knowledge of provisioning ecosystem services both in the recent past and at present. Such knowledge about the trends of abundance of various plant species in the recent past was evaluated and showed close coincidence with findings on plant abundance, constancy, fidelity and IUCN criteria. In the first part of the study the objective was quantification of plant species and communities with the crucial target of assessing the conservation value of the species using the criteria of diversity, rarity and faithfulness. In the second part the same vegetation was evaluated from the perspective of its traditional utilization.

Based upon Residual Value analyses (Chapter 6), 198 plant species were categorized into six categories (with high to low residual values), and then matched with findings about people's perceptions about the trend for each species population over the past few decades. I also compared the people's perception of species status with the IUCN criteria and again found considerable harmony between the data sets. Indigenous people reported a reducing trend in the availability and population of 112 plant species (56.56% of the total species), 32 of which fall in the IUCN categories of Critically Endangered, 22 in Endangered, 18 in Vulnerable, 24 in Nearly Threatened and only 16 in the category of Least Concern.

7.2.2. *Indigenous knowledge, ethnobotany and conservation*

In addition to the most accepted biodiversity conservation criteria, namely rarity, endangerment and endemism, there are other significant criteria relating to historical, traditional or educational values. Traditional knowledge in Asia in general and in the intact valleys of the Himalayas and Hindu Kush in particular can play a key role in formulating conservation strategies. Such knowledge is a life time's experience based on the relations among natural environments and cultures. Indigenous people get benefits from nature using their traditional knowledge but it may cause harm to the natural resources if carried out unwisely and unchecked. Increasing urbanization and industrialization also cause losses of traditional knowledge everywhere in the world. Ethnomedicinal knowledge is a cultural asset and is also an established base for modern phyto-chemicals. Traditional knowledge can be used for the recognition and preservation of valuable species as well as habitats in long term management (Pieroni *et al.*, 2007, Jules *et al.*, 2008, Gaikwad *et al.*, 2011). The prevailing poverty and expansion of agricultural land are the main causes of habitat and biodiversity loss in the Himalayan valleys and must be addressed when designing policy documents (Gorenflo & Brandon, 2005). Achieving such goals of checks and balances needs management and collaboration of various governmental and non governmental agencies involved in natural resources supervision and management.

Based on definite ecological criteria, prioritizing certain communities, habitat types and ecosystems is useful in long term management planning, nevertheless each species should keep its own individual importance (Vellak *et al.*, 2009). An awareness culture should be promoted among the locals so that they value and own the biodiversity and ecosystem services around them. It can be done by arranging workshops, lectures and seminars. The people can only own plant biodiversity and their associated ecosystem services if they are involved in the regeneration and conservation processes. Recent use of indigenous knowledge in conservation led to the new idea of 'ethno-conservation' in the late 1990s which is now a popular conservation approach around the globe (Rajeswar, 2001, Jules *et al.*, 2008, Negi, 2010).

7.3. Mountains vegetation and cultural heritage from its global perspective

Studies on mountain vegetation all over the world show that plants respond in a very sensitive way to environmental changes. Such studies further illustrate that the ecological amplitude of alpine species has increased over the recent past due to upward elevation shifts of habitat types and species from lower altitudes. This fragility increases the chances of species extinction in future due to their specific germination and reproduction requirements (Grabherr *et al.*, 1994, Holzinger *et al.*, 2008). Although sharp microclimatic variations in these mountainous habitats leads to vegetation heterogeneity and hence high species richness and diversity over their long succession history (Fahr & Kalko, 2011). On the other hand continuous climatic changes give chance to dominance of certain resistant and vigorous species and hence vegetation homogeneity has been observed in the recent past. This phenomenon is still continuing and further enhanced by selective utilization of species by humans (Del Moral *et al.*, 2010). These ecosystems are the hot spot for their characteristic biodiversity in terms of ecological indicators, ethnobotany and endemism and need proper management against negative climatic and anthropogenic influences for future sustainability (Kessler, 2000, Halloy & Mark, 2003, Holzinger *et al.*, 2008, Erschbamer *et al.*, 2011,). Alpine vegetation has similarities in species richness, tree line dynamics and resource seasonality in the majority of the world's mountain systems. The Himalayas differ from mountains in the developed world, however, due to climatic differences, overuse of plant species, traditional use of species and a lack of past records and it becomes a bit difficult to make comparisons in a strict way. There are certain similarities between the Himalayas and the Alps in terms of species richness and diversity patterns. Both mountain systems show that biodiversity decreases along the increasing elevation gradient, although the Alps have a more alpine flora than the Himalayas. The vegetation terminates at relatively lower elevations in the Alps as compared to the Himalayas e.g., tree lines reach in the Alps a maximum of 2600m while in the Himalayas they extend up to about 3400m. The Himalayas also differ from the European Alps in that in the former the people still possess an intact traditional health care system and knowledge. In contrast, ethnobotanical knowledge has rapidly decreased in the Alps and there is also a lower population density at high altitudes. Due to the development of tourism, however, many people do value plant biodiversity of the Alps for its aesthetic nature rather its medicinal or other uses (Grabherr, 2009, Niedrist *et al.*, 2009).

Indigenous cultures are rarely discussed in academia, policy and management though these are valuable assets and can be utilized in a proper way to achieve targets of sustainable resource management. Each culture, but especially in the intact valleys of the Himalayas, has a close relationship with their environment for hundreds of years, and has the capacity to be involved in sustainable environmental practices. In the developed world such ethnoecological knowledge is almost lost due to rapidly diminished cultural heritage (Salick & Ross, 2009). Our study suggest that societies living in harsh climates with a lack of life support facilities (e.g. health care etc) possess more integral cultures and traditional knowledge about their surroundings. A similar situation pertains also beyond the Himalayas and the Hindu Kush in the Andes and African mountainous regions (Vandebroek *et al.*, 2004, Bussmann & Sharon, 2006, Yineger *et al.*, 2007, Thomas *et al.*, 2008, Yineger *et al.*, 2008, Thomas *et al.*, 2009).

7.4. Limitations of the present study

The present study was well planned and properly executed up to optimal level in the light of its goal and objectives. Nevertheless, perfection is not achievable especially in survey based studies. I think that due to the short growing season a few ephemeral therophytes may have been missed, though most of the vegetation has other life forms. I suspect that a few species might have been missed in the parts which are above the snowline in locations where for a very short period snow melts and gives way to plant growth. Some plants may have also been missed on inaccessible rocks. Similarly, complete soil analyses were not done for each station due to the remoteness of the area and transportation problems. This study provides information about provisioning services in the paradigm of vegetation abundance and could not be extended to other sorts of ecosystem services with finer detail.

7.5. Implications of the present project for future studies

Observing biodiversity and ecosystem services is a lifelong process and needs inputs from various disciplines from the natural as well as the social sciences. For better ecosystem management and protection, plant biodiversity itself should be studied at species, community and ecosystem levels. The mountainous valleys need more botanical exploration for the complete description of their plant taxa, abundance and conservation status. There are also extensive gaps in information on ecosystem services in the Himalayan region. Most of the vegetation studies have been carried out solitarily either based on scientific approaches or public perception for making inventories. In this project it is emphasized that plant biodiversity can better be understood when both environmental and traditional influences are studied together. This study was formulated to cover optimally all the basic drivers of plant biodiversity whether environmental or anthropogenic. My study suggests that this approach can be adapted from the level of the individual species to the level of the whole plant community for better understanding of present ecosystem services and predicting the future threats. I also believe and propose that such an approach must be communicable to conservationists, planners, politicians and policy makers and statistically sound. Furthermore, I suggest that the identification of indicator species for specific habitats will assist in monitoring and assessment of the biological diversity on the one hand and the effects of climatic change on the other. In addition, a broad scale deterioration of the natural ecosystems due to agriculture, expansion of roads, increases in population and deforestation cause enormous losses to the natural vegetation. In spite of IUCN recommendations, there is very limited and small scale documentation on Red List Categories for plant species in the Himalayas as well as Pakistan more generally (Pant & Samant, 2006, Ali, 2008, Chettri *et al.*, 2008). Being a member state of the CBD, Pakistan should give top priority to this issue. Pakistan is the joining place for three of the world's largest mountains chains i.e., the Himalayas, the Karakorum and the Hindu Kush where the impacts of global warming and climate change may be considerable. Melting glaciers and a rise in temperature will likely cause desertification of the natural mountainous ecosystems and a loss of much of the current plant biodiversity. It is, therefore, imperative to encourage institutions with interests in preserving plant biodiversity to cooperate across the member states of the Himalayan region in order to implement conservation policies for the sustainable use of ecosystem services. At national level good governance, stability and peace could be helpful for implementing biodiversity plans and policies.

7.5.1. Future Conservation of the Valley

The Naran Valley is host not only to present day food, fodder, fuel, timber and medicinal plants, but also to the wild relatives of cultivated plants which may possess useful stress and disease resistant characteristics or provide germplasm resources. Furthermore, species which are not important economically might and must have a significant ecological role in controlling erosion, flood, avalanche movements and over all ecosystem regulating services. Conservation of biodiversity and ecosystems and their sustainable use in the scenario of climatic change can only be possible if the important species and habitats are carefully examined, managed and safeguarded. Summarizing the overall narrative for future management of the Naran Valley or similar mountain ecosystems two broad strategic approaches could be implemented to preserve cultural as well as ecological diversity. Primarily, an achievable policy and basic life facilities must be arranged to stop illegal consumption of natural vegetation and persuade an ecologically satisfactory use of the system. Secondly, measures could be taken for the restoration of plant biodiversity through reforestation, developing protected areas and growing of rare species domestically. Medicinal resources can be preserved by giving basic health care facilities to the people. Studies like the present one can be used as a source of basic data for the management of mountainous regions in the larger-scale conservation planning of the Himalayas and adjacent ranges.

Following are some research areas that need to be studied more extensively than has been possible in this thesis.

- Major challenges to conservation of natural biodiversity and ecosystems in the mountainous parts of the region are inadequate data, weak institutions, lack of planning, incomplete strategies, corruption, poverty and unsustainable use of resources. Governmental policies should be re-examined and implemented within the spirit of safeguarding the present natural ecosystems and preparing for the future effects of climate change and global warming.
- Present biodiversity protection laws should be implemented in the real spirit of the lawand special legislation is required for endangered flora.
- The Himalayas require wide-ranging databases for biodiversity, ecosystems and appropriate recording of indigenous ethnoecological knowledge.
- Least investigated habitats and ecosystems of rare and endangered species should be given top priority.
- Small scale conservation efforts can be coordinated among various stakeholders for the sustainable utilization of the present and future biodiversity and ecosystem services.
- The concept of ecosystem structures, functioning, and goods and services can be broadened to country and regional level.
- Thorough socioeconomic data of the mountainous people could be recorded and steps be taken for the uplift of their life standards so that natural resources could be used wisely.
- Apart from the scientific explorations there is an immediate need of facilitation, social mobilization and education for the people of these remote regions.
- Education and awareness about the climate change, habitat destruction and decreasing biodiversity also needs top priorities which can be achieved by people involvement in conservation efforts. To make aware the people of the region about the fact that they are destroying their coming generations by depleting biodiversity and natural ecosystems.
- In particular the increasing population with an alarming rate is the key cause to the loss of natural biodiversity and ecosystems. This issue has to be given top precedence while designing legislations at national and international level.
- Both *In situ* (on-site) and *Ex situ* (off-site) conservation measures can be taken. Populations of rare and endangered species can be enhanced within habitat by taking local scale protection measures. Conservation of plant species especially the Critically Endangered (CR) and

Endangered (EN) species, outside their natural habitats (*Ex situ*) can be carried out with the help of local people and organizations.

- New protected areas can be established in the priority areas like the Naran Valley and surrounding region as it is the hot spot for endemic species from all of the three mountain ranges i.e., the Himalayas, Hindu Kush and Karakorum.
- Launching nurseries for endangered, rare and endemic species at village levels.
- Establishment of seed and gene banks for important threatened species.

7.5.2. Future Ecosystem Services Studies

The three mountain ranges i.e., the Himalayas, Hindu Kush and Karakorum provide essential ecosystem services to millions of people across 10 countries of the world (Dong *et al.*, 2010). These services include provisioning, regulating, supporting and cultural services. In the present study the main focus was on vegetation mapping and provisioning services in one Himalayan valley. Most of the provisioning services considered in the present study can further be evaluated at molecular and biochemical levels in the future.

Beyond the direct role of plant biodiversity in the socioeconomics of the mountain people, it is indispensable for the people living in the plains and hence this mountain valley can be studied for the evaluation of the other kinds of services that it provides on a broader level, e.g. flood control, erosion control, irrigation water and hydropower development are examples of Regulating Services. These mountains also provide Supporting Services, e.g. soil formation, biogeochemical and nutrient cycling etc. These mountain systems host characteristic biodiversity on the one hand and a long established and typical cultural diversity on the other. Preservation of their indigenous knowledge and its utilization in environmental management is also a target topic for future studies (Fig. 7.1).

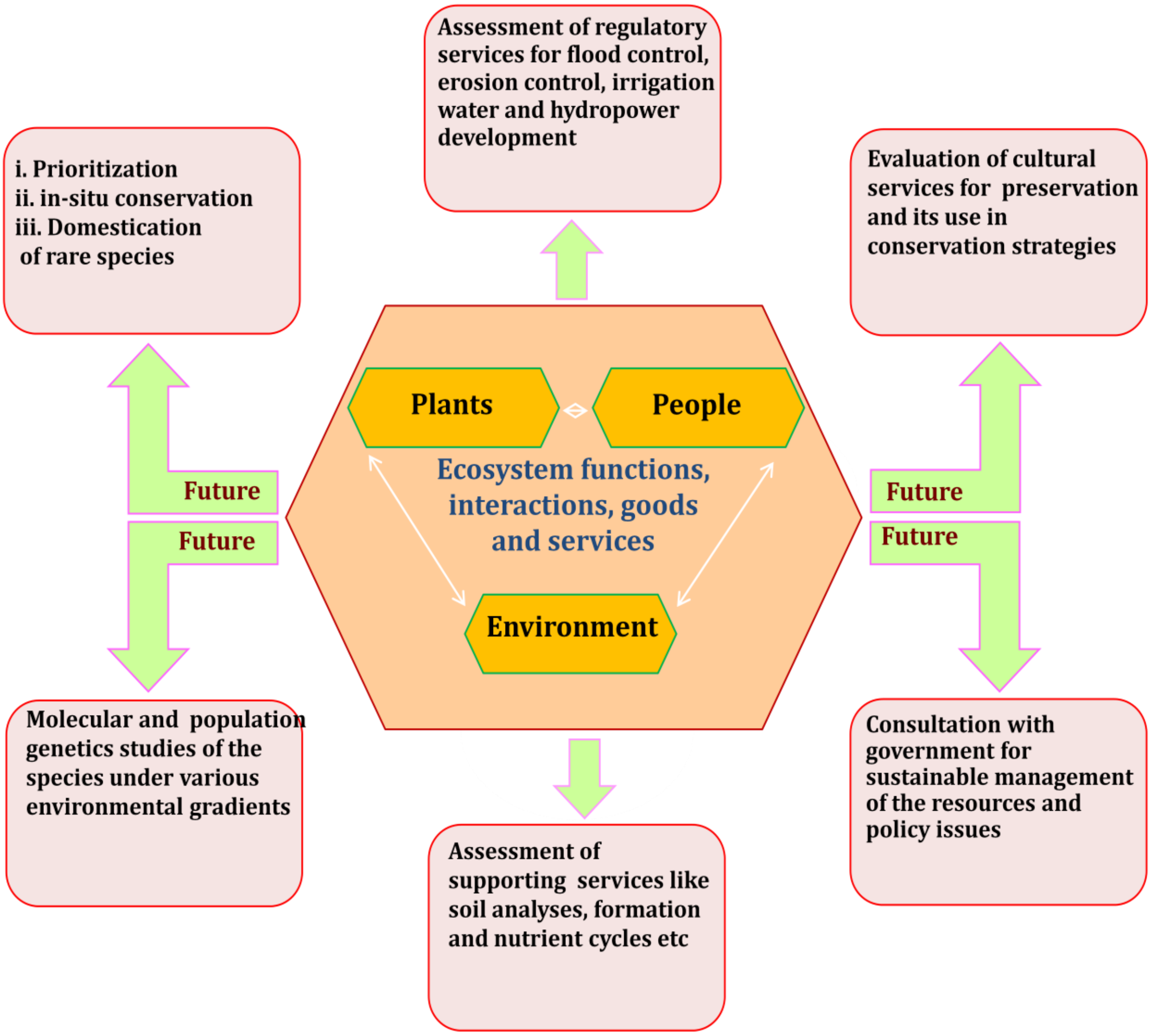


Fig. 7.2 Sketch showing the potential topics to be studied in future

7.6. Conclusions

This study presents the first ever ecological data on plant biodiversity in terms of phytosociological classification, ordination, distribution, richness, diversity, ecosystem services and conservation status in one Himalayan valley, the Naran in Pakistan. The results of the vegetation classification and the identification of the ecological gradients suggest a transitional location for this region amongst three of the world's largest mountain ranges. The valley also hosts endemic, endangered and rare species of the Himalayas, Hindu Kush and Karakorum mountain ranges. Additionally, the study has quantified the provisioning services provided by plant biodiversity on the one hand and documented indigenous traditional knowledge on the other. People use species especially for medicinal and multipurpose uses in a non-random pattern which indicates the prospective loss of endangered and rare species. The anthropogenic pressures on the vegetation lead to an assessment of the conservation status of all the plant species in general and the rare and endemic species in particular. Future work should address the long lasting consequences of the loss of plant biodiversity for the sustainability of ecosystem services other than just provisioning services i.e., also regulatory, supporting and cultural services.

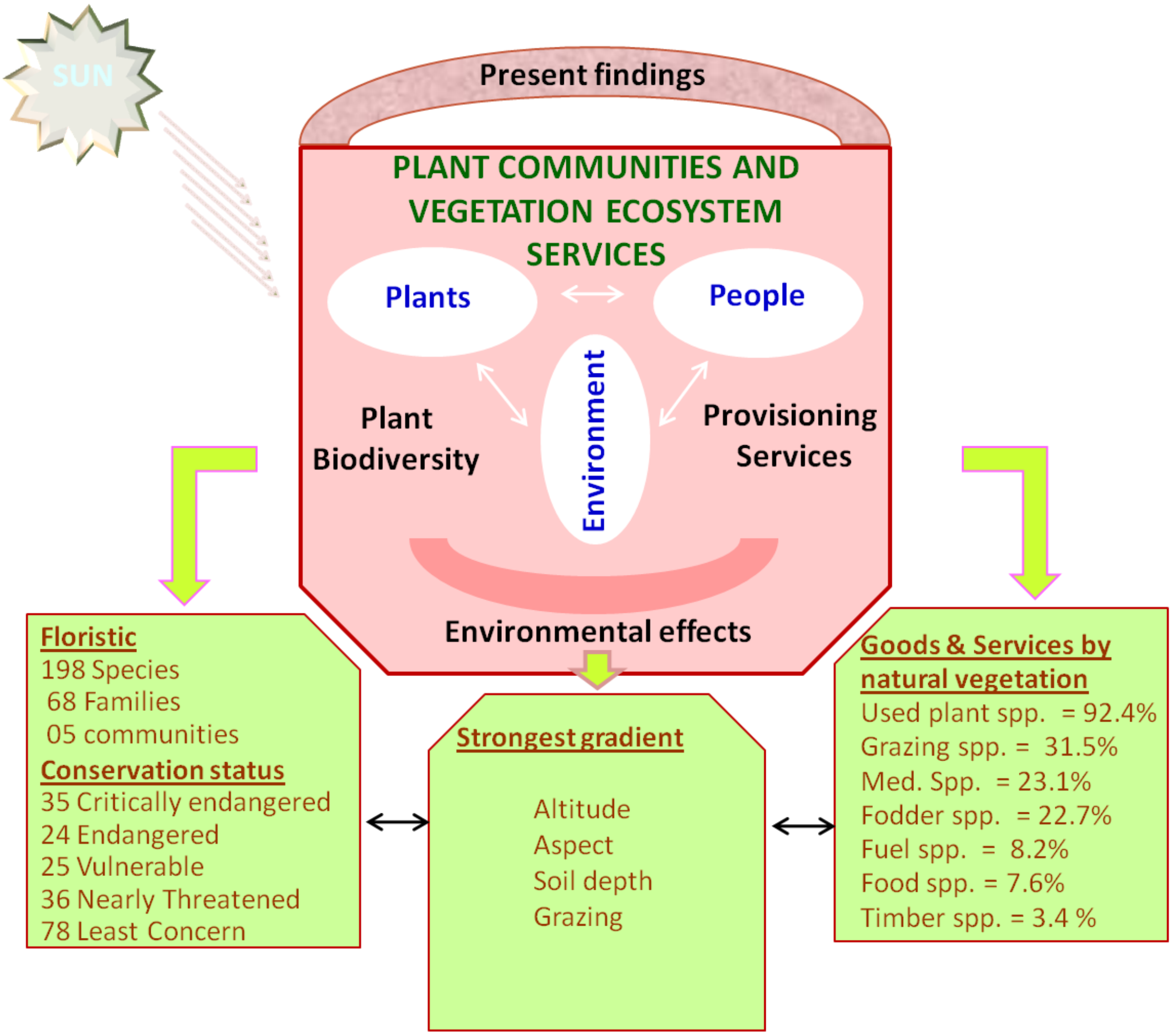


Fig. 7.3 Sketch showing the summary of present studies

Appendix 4.1 Pre-prepared sheet for recording the qualitative and quantitative attributes of plant species

S. No	Botanical Name	Local Name	Qdts Size	No. of Plants and cover per quadrat																	
				Altitude____			Altitude____			Altitude____			Altitude____			Altitude____			Altitude____		
				1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
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and so on																					

Appendix 4.2 Detail values and codes of each environmental variable at each of 144 stations

Each of the 3 characters in station codes have been put in a sense; (1) first character if capital letter (A-L), represent the 12 sites/transects on northern aspect and if small letter (a-l) represent the 12 sites/transects on southern aspect (Names of the localities (A-L) where transects were established can be seen in Fig. 4.1); (2) second character (1-8) represent the altitude along each transect- low to high; (3) third character N or S represent the aspect again N for northern and S for southern.

S. No	Station Nam	Station codes	Alti m.s.l	Aspect 2=N & 1=S	Graz Pres Class	Soil Depth Class	Soil pH Value	S. No	Station Name	Station codes	Alti m.s.l	Aspect 2=N & 1=S	Graz Pres Class	Soil Depth Class	Soil pH Value
1	Naran 1 N	A 1 N	2460	2	4	3	7.5	73	Jalkhad 4 N	K 4 N	3320	2	4	3	6.5
2	Naran 1 S	a 1 S	2480	1	3	3	6	74	Jalkhad 4 S	k 4 S	3310	1	3	3	6
3	Damdama 1 N	B 1 N	2510	2	2	3	6.5	75	Baisal 4 N	L 4 N	3420	2	4	3	6.5
4	Damdama 1 S	b 1 S	2530	1	4	3	6	76	Baisal 4 S	l 4 S	3415	1	3	2	7
5	Soach 1 N	C 1 N	2540	2	3	3	7	77	Naran 5 N	A 5 N	3260	2	3	2	6.5
6	Soach 1 S	c 1 S	2520	1	4	3	6	78	Naran 5 S	a 5 S	3280	1	4	2	6.5
7	L. Batakundi 1 N	D 1 N	2540	2	3	3	7	79	Damdama 5 N	B 5 N	3310	2	3	2	6.5
8	L. Batakundi 1 S	d 1 S	2540	1	3	3	6.5	80	Damdama 5 S	b 5 S	3330	1	4	2	6.5
9	U. Batakundi 1 N	E 1 N	2610	2	1	3	6.5	81	Soach 5 N	C 5 N	3340	2	3	2	6
10	U. Batakundi 1 S	e 1 S	2580	1	4	3	6.5	82	Soach 5 S	c 5 S	3320	1	4	2	7
11	Naran 2 N	A 2 N	2660	2	4	3	7	83	L. Batakundi 5 N	D 5 N	3340	2	3	2	6.5
12	Naran 2 S	a 2 S	2680	1	3	3	6	84	L. Batakundi 5 S	d 5 S	3340	1	4	2	7
13	Damdama 2 N	B 2 N	2710	2	4	3	6	85	U. Batakundi 5 N	E 5 N	3410	2	3	2	6
14	Damdama 2 S	b 2 S	2730	1	3	3	6.5	86	U. Batakundi 5 S	e 5 S	3380	1	4	1	6.5
15	Soach 2 N	C 2 N	2740	2	2	3	6.5	87	Khora 5 N	F 5 N	3370	2	2	2	6
16	Soach 2 S	c 2 S	2720	1	3	3	6	88	Khora 5 S	f 5 S	3560	1	3	2	6.5
17	L. Batakundi 2 N	D 2 N	2740	2	2	3	6.5	89	Dabukan 5 N	G 5 N	3525	2	4	1	6
18	L. Batakundi 2 S	d 2 S	2740	1	3	3	6	90	Dabukan 5 S	g 5 S	3515	1	3	3	7
19	U. Batakundi 2 N	E 2 N	2810	2	2	3	6.5	91	Bans 5 N	H 5 N	3550	2	4	2	7
20	U. Batakundi 2 S	e 2 S	2780	1	3	3	7	92	Bans 5 S	h 5 S	3540	1	4	2	7
21	Khora 2 N	F 2 N	2770	2	2	3	7	93	Barrawae 5 N	I 5 N	3520	2	4	1	6
22	Khora 2 S	f 2 S	2960	1	3	3	7	94	Barrawae 5 S	i 5 S	3520	1	3	2	7
23	Dabukan 2 N	G 2 N	2925	2	3	3	6.5	95	Serian 5 N	J 5 N	3470	2	3	3	6.5
24	Dabukan 2 S	g 2 S	2915	1	4	3	6.5	96	Serian 5 S	j 5 S	3480	1	2	3	7
25	Bans 2 N	H 2 N	2950	2	3	3	6.5	97	Jalkhad 5 N	K 5 N	3520	2	4	2	7

26	Bans 2 S	h 2 S	2940	1	4	3	6.5	98	Jalkhad 5 S	k 5 S	3510	1	3	2	6
27	Barrawae 2 N	I 2 N	2920	2	3	3	6.5	99	Baisal 5 N	L 5 N	3620	2	3	3	7
28	Barrawae 2 S	i 2 S	2915	1	4	3	7	100	Baisal 5 S	l 5 S	3615	1	3	2	7
29	Naran 3 N	A 3 N	2860	2	4	3	6.5	101	Naran 6 N	A 6 N	3460	2	2	2	6
30	Naran 3 S	a 3 S	2880	1	3	2	6	102	Naran 6 S	a 6 S	3480	1	1	1	6.5
31	Damdama 3 N	B 3 N	2910	2	4	3	6	103	Damdama 6 N	B 6 N	3510	2	3	2	6.5
32	Damdama 3 S	b 3 S	2930	1	3	3	6.5	104	Damdama 6 S	b 6 S	3550	1	4	1	6.5
33	Soach 3 N	C 3 N	2940	2	2	3	6.5	105	Soach 6 N	C 6 N	3540	2	4	1	5.5
34	Soach 3 S	c 3 S	2920	1	3	3	6.5	106	Soach 6 S	c 6 S	3550	1	4	2	6.5
35	L. Batakundi 3 N	D 3 N	2940	2	2	3	6	107	L. Batakundi 6 N	D 6 N	3540	2	4	2	6
36	L. Batakundi 3 S	d 3 S	2940	1	4	2	6	108	U. Batakundi 6 N	E 6 N	3610	2	4	2	5.5
37	U. Batakundi 3 N	E 3 N	3010	2	2	3	6	109	U. Batakundi 6 S	e 6 S	3610	1	4	2	6.5
38	U. Batakundi 3 S	e 3 S	2980	1	4	3	6.5	110	Khora 6 N	F 6 N	3570	2	3	2	5.5
39	Khora 3 N	F 3 N	2970	2	3	3	6.5	111	Khora 6 S	f 6 S	3880	1	4	2	6.5
40	Khora 3 S	f 3 S	3160	1	4	3	6.5	112	Dabukan 6 N	G 6 N	3725	2	3	2	6
41	Dabukan 3 N	G 3 N	3125	2	4	2	6.5	113	Dabukan 6 S	g 6 S	3715	1	1	2	7
42	Dabukan 3 S	g 3 S	3115	1	3	3	6.5	114	Bans 6 N	H 6 N	3750	2	3	3	6.5
43	Bans 3 N	H 3 N	3150	2	3	3	7	115	Bans 6 S	h 6 S	3740	1	3	2	6.5
44	Bans 3 S	h 3 S	3140	1	3	3	7	116	Barrawae 6 N	I 6 N	3780	2	4	1	6
45	Barrawae 3 N	I 3 N	3120	2	3	3	6.5	117	Barrawae 6 S	i 6 S	3750	1	4	2	6.5
46	Barrawae 3 S	i 3 S	3120	1	3	3	6.5	119	Serian 6 N	J 6 N	3670	2	4	2	6.5
47	Serian 3 N	J 3 N	3070	2	4	3	6.5	120	Serian 6 S	j 6 S	3680	1	3	2	6.5
48	Serian 3 N	j 3 S	3080	1	3	3	6.5	121	Jalkhad 6 N	K 6 N	3720	2	4	3	7
49	Jalkhad 3 N	K 3 N	3120	2	4	3	6.5	122	Jalkhad 6 S	k 6 S	3710	1	4	2	6.5
50	Jalkhad 3 S	k 3 S	3110	1	4	2	6.5	118	Baisal 6 N	L 6 N	3820	2	3	2	6.5
51	Baisal 3 N	L 3 N	3220	2	1	3	6.5	123	Baisal 6 S	l 6 S	3815	1	4	2	6.5
52	Baisal 3 S	l 3 S	3215	1	4	3	6.5	124	Naran 7 N	A 7 N	3680	2	3	1	6
53	Naran 4 N	A 4 N	3060	2	3	3	6.5	125	Damdama 7 N	B 7 N	3800	2	4	2	6
54	Naran 4 S	a 4 S	3080	1	4	2	6	126	Soach 7 N	C 7 N	3700	2	3	2	6
55	Damdama 4 N	B 4 N	3110	2	4	3	5.5	127	L. Batakundi 7 N	D 7 N	3880	2	4	2	6
56	Damdama 4 S	b 4 S	3130	1	3	2	6	128	Khora 7 N	F 7 N	3770	2	4	1	5.5
57	Soach 4 N	C 4 N	3140	2	3	3	6.5	129	Khora 7 S	f 7 S	3950	1	4	2	6.5
58	Soach 4 S	c 4 S	3120	1	4	3	6.5	130	Dabukan 7 N	G 7 N	3975	2	3	2	6

59	L. Batakundi 4 N	D 4 N	3140	2	2	3	6	131	Dabukan 7 S	g 7 S	3950	1	4	1	6.5
60	L. Batakundi 4 S	d 4 S	3140	1	4	2	6.5	132	Bans 7 N	H 7 N	3980	2	4	1	6.5
61	U. Batakundi 4 N	E 4 N	3210	2	3	2	6	133	Bans 7 S	h 7 S	4000	1	4	2	6.5
63	U. Batakundi 4 S	e 4 S	3180	1	3	2	6	134	Barrawae 7 N	I 7 N	3900	2	4	1	6
62	Khora 4 N	F 4 N	3170	2	2	3	6	135	Barrawae 7 S	i 7 S	3970	1	4	1	7
64	Khora 4 S	f 4 S	3360	1	4	2	6.5	136	Serian 7 N	J 7 N	3870	2	4	2	6
65	Dabukan 4 N	G 4 N	3325	2	4	1	6.5	137	Serian 7 S	j 7 S	3950	1	4	2	6.5
66	Dabukan 4 S	g 4 S	3315	1	4	3	6.5	138	Jalkhad 7 N	K 7 N	3920	2	3	3	6.5
67	Bans 4 N	H 4 N	3350	2	3	2	7	139	Jalkhad 7 S	k 7 S	3910	1	4	1	7
68	Bans 4 S	h 4 S	3340	1	3	3	7	140	Baisal 7 N	L 7 N	4000	2	1	1	6.5
69	Barrawae 4 N	I 4 N	3320	2	1	2	6.5	141	Baisal 7 S	l 7 S	4050	1	4	1	6.5
70	Barrawae 4 S	i 4 S	3320	1	4	2	6	142	Khora 8 N	F 8 N	4050	2	4	1	5.5
71	Serian 4 N	J 4 N	3270	2	3	3	6	143	Serian 8 N	J 8 N	4100	2	4	1	6
72	Serian 4 S	j 4 S	3280	1	3	3	7	144	Jalkhad 8 N	K 8 N	4100	2	3	2	6.5

Appendix 4.3 Alphabetical list of plant species, reported from the Naran valley, western Himalaya during quadrat survey. List also show local names, english names, respective families and habit forms of the reported species

S. N	H. C. N	Botanical Name	Local Name	English Name	Family	Habit
1	6	*Abies pindrow* Royle	Acher		Pinaceae	Tree
2	134	*Acantholimon lycopodioides* Boiss.	Gat butay		Plumbaginaceae	Herb
3	3	*Acer caesium* Wall ex Brandis	Chinar ranga	Maple	Aceraceae	Tree
4	68	*Achillea millefolium* L.	Birangesif/Jarri	Yarrow	Asteraceae	Herb
5	151	*Aconitum heterophyllum* Wall.	Patris/sarba vala	Monk's Hood	Ranunculaceae	Herb
6	154	*Aconitum violaceum* Jacquen ex. Stapf	Atees/Zahar	Monk's Hood	Ranunculaceae	Herb
7	34	*Actaea spicata* L.	Beenakae		Rosaceae	Herb
8	43	*Adiantum venustum* D. Don	Sumbal	Maidenhair Fern	Adiantaceae	Herb
9	7	*Aesculus indica* (Wall. Ex Camb) Hook.	Bankhore/Javaz	Horse Chestnut	Hippocastanceae	Herb
10	118	*Alliaria petiolata* (M. Bieb.) Cavara & Grande	Teeghstargae	Garlic Mustard	Brassicaceae	Herb
11	167	*Allium humile* Kunth.	Jangali Piaz		Alliaceae	Herb
12	112	*Alopecurus arundinaceus* Poir.	Wakha	Alpine Foxtail	Poaceae	Herb
13	155	*Anaphalis triplinervis* (Sims) C. B. Clarke		Everlasting	Asteraceae	Herb
14	168	*Androsace hazarica* R.R. Stewart ex Y. Nasir	Zangali Mekhaki		Primulaceae	Herb
15	156	*Androsace primuloides* Duby	Zangali Mekhaki		Primulaceae	Herb
16	126	*Androsace rotundifolia* Watt	Mekhakay		Primulaceae	Herb
17	82	*Anemone falconeri* Thoms.		Anemone	Ranunculaceae	Herb
18	36	*Anemone obtusiloba* D.Don		Anemone	Ranunculaceae	Herb
19	183	*Anemone rupicola* Cambess		Anemone	Ranunculaceae	Herb
20	169	*Anemone tetrasepala* Royle		Anemone	Ranunculaceae	Herb
21	98	*Angelica glauca* Edgew.	Chora chora	Wild Angelica	Apiaceae	Herb
22	37	*Apluda mutica* (L.) Hack	Chanrr		Poaceae	Herb
23	114	*Aquilegia fragrans* Benth.			Ranunculaceae	Herb
24	178	*Arnebia benthamii* Wallich ex. G. Done	Jogi bacha		Lamiaceae	Herb
25	79	*Artemisia brevifolia* Wall. ex DC	Chahu/tarkha		Asteraceae	Shrub
26	56	*Artemisia vulgaris* L.	Chahu/javkey	wormwood	Asteraceae	Shrub
27	35	*Asparagus racemosus* Willdenow	Nanoor/shalgvatey		Asparagaceae	Herb
28	41	*Asperula oppositifolia* Reg. & Schmalh.			Rubiaceae	Herb
29	91	*Asplenium adiantum-nigrum* L.	Naray Atir	Black Spleenwort	Adiantaceae	Herb
30	159	*Aster falconeri* (C. B. Clarke) Hutch	Bengangul		Asteraceae	Herb
31	55	*Astragalus anisacanthus*Boiss.			Papilionaceae	Herb
32	160	*Astragalus scorpiurus* Bunge	Maswakeey		Papilionaceae	Herb

33	80	*Berberis pseudumbellata* Parker	Sumbal/Kvarey		Berberidaceae	Shrub
34	107	*Bergenia ciliata* (Haw.) Sternb.	But pewa/Zakhme hayat	Hairy Bergenia, Pigsqueak	Saxifragaceae	Herb
35	40	*Bergenia stracheyi* (Hook. f. & Thoms) Engl.	But pewa/Zakhme hayat		Saxifragaceae	Herb
36	109	*Betula utilis* D. Don	Braj/Birch	Himalayan Birch	Betulaceae	Tree
37	100	*Bistorta affinis* (D.Don) Green	Anjabar		Polygonaceae	Herb
38	52	*Bistorta amplexicaulis (D. Don) Green*	Masloon		Polygonaceae	Herb
39	129	*Bromus hordeaceus* L.	Da ghar jawkay	Soft-brome	Poaceae	Herb
40	85	*Caltha alba* Jack. Ex Comb	Kadu Gulay/Baringu	White Marsh Marigold	Ranunculaceae	Herb
41	71	*Capsella bursa-pastoris* (L.) Medic.	Bashka/chambraka	Shepherd's Purse	Brassicaceae	Herb
42	170	*Cassiope fastigiata* (Wallich) D. Done	Geengrri Bhutay	Arctic bell-heather	Ericaceae	Herb
43	1	*Cedrus deodara* (Roxb. Ex Lamb.) G. Don	Diar/Ranzrra	Himalayan Cedar	Pinaceae	Tree
44	64	*Cerastium fontanum* Baumg.	Narae Uulalae	Common mouse-ear	Brassicaceae	Herb
45	75	*Chenopodium album* L.	Sarmay	Fat Hen	Chenopodiaceae	Herb
46	138	*Clematis montana* Buch.-Ham. ex DC	Zelai	Traveller's joy/Clematis	Ranunculaceae	Herb
47	119	*Colchicum luteum* Baker	Qaimat-guley/Suranjane talkh	Colchicum	Colchicaceae	Herb
48	65	*Convolvulus arvensis* L.	Sahar gulay	Lesser Bindweed	Convolulaceae	Herb
49	74	*Corydalis diphylla* Wall.	Dwapaneez	Purple Corydalis	Fumariaceae	Herb
50	171	*Corydalis govaniana* Wall.	Desi mamera		Fumariaceae	Herb
51	182	*Cotoneaster cashmiriensis* G.Klotz	Kharawa	Kashmir Cotoneaster	Rosaceae	Shrub
52	143	*Cotoneaster microphyllus* Wall. ex Lindl	Kharawa/Mamanna	Cotoneaster	Rosaceae	Shrub
53	5	*Crataegus oxyacantha* L.	Tampasa	Hawthorn	Rosaceae	Tree
54	73	*Cynoglossum glochidiatum* Wall. Ex Benth	Jeshkay	hound'stongue	Boraginaceae	Herb
55	77	*Cynoglossum himaltoni*	Da ghar jeeshkay		Boraginaceae	Herb
56	181	*Cynoglossum lanceolatum* L.	Jeshkee butey		Boraginaceae	Herb
57	16	*Cyperus niveus* Retz.	Deela	Brown Cyperus	Cyperaceae	Herb
58	122	*Cypripedium cordigerum* D. Don	Shakalkal	ladyslipper	Orchidaceae	Herb
59	70	*Dactylis glomerata* L.	Wakha	Cocksfoot	Poaceae	Herb
60	121	*Dactylorhiza hatagirea* (D. Don) Soo	Salap	Marsh orchid	Orchidaceae	Herb
61	28	*Dioscorea deltoidea* Wall. ex Kunth	Kirtha	Yam	Dioscoreaceae	Herb
62	94	*Draba oreades* Schrenk		Rock Whitlow Grass	Brassicaceae	Herb
63	161	*Dracocephalum nutans* L.			Lamiaceae	Herb
64	38	*Dryopteris juxtapostia* Christ	Kwanjay		Pteridaceae	Herb

65	33	*Dryopteris stewartii* Fras.-Jenk.	Lewanay Kwanjay	Stewart's Wood Fern	Pteridaceae	Herb
66	172	*Eclipta prostrata* L.		False Daisy	Asteraceae	Herb
67	12	*Ephedra gerardiana* Wall. Ex Stapf		Ephedra	Ephedraceae	Shrub
68	173	*Epilobium angustifolium* L.		Rosebay Willowherb	Onagraceae	Herb
69	90	*Equisetum arvense* L.	Bandakay/Nari	Field Horsetail	Equisetaceae	Herb
70	162	*Eragrostis cilianensis* (All.) Lut. ex F.T. Hubbard		stinkgrass	Poaceae	Herb
71	163	*Eremurus himalaicus* Baker	Sheela	Foxtail Lily seeds	Asphodelaceae	Herb
72	51	*Erigeron multiradiatus* (Lindl. Ex DC) C. B. Clarke		Himalayan fleabane	Asteraceae	Herb
73	174	*Erysimum melicentae* Dunn.	Jangali Sharsham	Treacle Mustard	Brassicaceae	Herb
74	175	*Euphorbia wallichii* Hook. f.	Shangla	Spurge	Euphorbiaceae	Herb
75	127	*Euphrasia himalayica* Wetts.	Arghamala		Lamiaceae	Herb
76	25	*Fragaria nubicola* Lindl. Ex Lacaita	Katal mewa		Rosaceae	Herb
77	101	*Fritillaria roylei* Hook. f.	Da ghra Piaz	Fritillary	Liliaceae	Herb
78	92	*Gagea elegans* Wall. Ex D. Don	Zear gulay	Star-of-Bethlehem	Liliaceae	Herb
79	58	*Galium aparine* L.	Goose grass	Cleavers	Rubiaceae	Herb
80	164	*Galium asperuloides* Edgew.			Rubiaceae	Herb
81	176	*Gentiana carinata* Griseb		Alpine gentian	Gentianaceae	Herb
82	150	*Gentiana kurroo* Royle	Linkath		Gentianaceae	Herb
83	95	*Gentiana moorcroftiana* (Wallich ex G. Don) Airy Shaw	Bhangara		Gentianaceae	Herb
84	135	*Gentianodes argentia* Omer, Ali & Qaiser			Gentianaceae	Herb
85	140	*Geranium nepalense* Sweet.	Sra zeela	cranesbill	Geraniaceae	Herb
86	165	*Geranium polyanthes* (colinum)			Geraniaceae	Herb
87	125	*Geranium wallichianum* D. Don ex. Sweet	Srazeela/Ratanjog		Geraniaceae	Herb
88	30	*Geum elatum* Wall. ex G. Don		Avens	Rosaceae	Herb
89	84	*Gnaphalium affine* D. Don	Tighstergai	Cudweed	Asteraceae	Herb
90	59	*Gratiola officinalis* L.			Scrophulariaceae	Herb
91	123	*Hackelia uncinata* (Royle ex Benth) Fischer			Boraginaceae	Herb
92	141	*Heracleum candicans* Wall. ex DC.		Hogweed	Apiaceae	Herb
93	72	*Hyoscyamus niger* L.	Bargak/Khurasani ajwain	Henbane	Solanaceae	Herb
94	49	*Hypericum perforatum* L.	Shin Chae/Balsana		Hypericaceae	Herb
95	42	*Impatiens edgeworthii* Hook.f.	Gule mehendi/Atraangey	Balsam	Balsaminaceae	Herb
96	17	*Impatiens bicolor* Royle	Gule mehendi/Atraangey	Balsam	Balsaminaceae	Herb

97	13	*Indigofera heterantha* Wall. Ex Brand	Kainthi/Ghvareja		Papilionaceae	Shrub
98	177	*Inula grandiflora* Willd.	Kuth		Asteraceae	Herb
99	142	*Inula multiradiata*			Asteraceae	Herb
100	106	*Iris hookeriana* Foster	Gandechar	Iris	Iridaceae	Herb
101	4	*Juglans regia* L.	Akhor/Ghuz		Juglandaceae	Tree
102	136	*Juncus membranaceus* Royle ex D. Don	Gawag/Jaba	Rush	Juncaceae	Herb
103	83	*Juniperus communis* L.	Gugarr/Bhentri		Juniperaceae	Shrub
104	145	*Juniperus excelsa* M.Bieb	Gugarr		Juniperaceae	Shrub
105	132	*Juniperus squamata* Buch.-Ham. ex D. Don	Gugarr/Bhentri		Juniperaceae	Shrub
106	113	*Lathyrus pratensis* L.		Meadow Vetchling	Papilionaceae	Herb
107	54	*Leucas cephalotes* (Roth) Spreng.	Gomma		Papilionaceae	Herb
108	19	*Malva neglecta* Wallr	Sonchal/panerak	Dwarf Mallow	Malvaceae	Herb
109	61	*Mentha longifolia* (L.) Hudson.	Safid Podina	Mint	Lamiaceae	Herb
110	60	*Mentha royleana* Benth. in Wall.	Podina	Mint	Lamiaceae	Herb
111	180	*Minuartia kashmirica* (Edgew) Mattf		Sandwort	Caryophyllaceae	Herb
112	148	*Morina longifolia* Wall. ex. Dcs	Azghana		Morinaceae	Herb
113	166	*Nepeta laevigata (D. Done) Hand.-Mazz*	Desi jalbhanga/peesho butay		Lamiaceae	Herb
114	27	*Onopordum acanthium* L.	Kandiarai	Scotch Thistle	Asteaceae	Herb
115	158	*Onosma bracteatum* Wall.	Gowzoban		Boraginaceae	Herb
116	144	*Origanum vulgare* L.	Shamakey/Jangali majorum	Wild Marjoram	Lamiaceae	Herb
117	179	*Orobanche alba* Stephen ex Wallid	Yag bootey	Red Broomrape	Orobanchaceae	Herb
118	78	*Oxyria digyna* L.	Tarwa panna	Mountain Sorrel	Polygonaceae	Herb
119	153	*Oxytropis cachemiriana* Camb.		Mountain Milk-vetch	Papilionaceae	Herb
120	157	*Paeonia emodi* Wall. Ex Royle	Mamekh	Paeony	Paeoniaceae	Herb
121	184	*Parnassia nubicola* Wall.			Parnesiaceae	Herb
122	189	*Pedicularis pectinata* Wall. ex. Benth		Red Rattle	Scrophulariaceae	Herb
123	152	*Pennisetum lanatum* Klotzsch	Jangali bajra		Poaceae	Herb
124	62	*Phleum alpinum* L.		Cat's-tail	Poaceae	Herb
125	190	*Phlomis bracteosa* Royle ex Benth.			Lamiaceae	Herb
126	8	*Picea smithiana* (Wall.) Boiss.	Kandal/Mangazae/	Spruce/Himalayan spruce	Pinaceae	Herb
127	120	*Pimpinella acuminata* (Edgew.) C.B. Clarke		Burnet Saxifrage	Apiaceae	Herb
128	128	*Pimpinella diversifolia* (Wall.) DC	Tarpakhi/watani kaga		Apiaceae	Herb
129	2	*Pinus wallichiana* Jackson	Sraf	Blue pine	Pinaceae	Tree

130	185	*Plantago himalaica* Pilger	Jabae		Plantaginaceae	Herb
131	23	*Plantago lanceolata* L.	Ipeghol/Jabae	Ribwort Plantain	Plantaginaceae	Herb
132	99	*Plantago major* L.	Ipeghol/Jabae	Greater Plantain	Plantaginaceae	Herb
133	50	*Poa alpina* L.	Wakha	Alpine Meadow Grass	Poaceae	Herb
134	146	*Poa annua* L.	Wakha	Annual Meadow Grass	Poaceae	Herb
135	44	*Poa stewartiana* Bor in Kew Bull.	Wakha	…. Meadow Grass	Poaceae	Herb
136	191	*Podophyllum hexandrum* Royle	Kakorra/Gangorra/	may apple	Podophyllaceae	Herb
137	32	*Polygonatum verticillatum (*L.) Allioni		Whorled Solomon's Seal	Liliaceae	Herb
138	133	*Polygonum alpinum* Allioni	Zangali Bandakey		Polygonaceae	Herb
139	24	*Polygonum aviculare* L.	Bandakey	Knotgrass	Polygonaceae	Herb
140	139	*Polygonum molle* (D.Done) Hara			Polygonaceae	Herb
141	81	*Polygonum plebejum* R. Br.	Baramol/Noorealam	Knotgrass	Polygonaceae	Herb
142	108	*Populus glauca* H. H. Haines	Jangali sufeda	Poplar	Salicaceae	Tree
143	66	*Potentilla anserina* L.	Spangji	Silverweed	Rosaceae	Herb
144	105	*Potentilla atrosanguinea* Lodd.			Rosaceae	Herb
145	131	*Potentilla nepalensis* Hook. f.			Rosaceae	Herb
146	186	*Primula calderana* Balf. F & cooper		Primrose	Primulaceae	Herb
147	96	*Primula denticulata* Smith	Mamera	Primrose	Primulaceae	Herb
148	192	*Primula glomerata* Pax.		Primrose	Primulaceae	Herb
149	87	*Primula rosea* Royle	Mamera	Primrose	Primulaceae	Herb
150	31	*Prunella vulgaris* L.	Alubaloo	Self-heal	Lamiaceae	Herb
151	187	*Prunus Cerasoides* D. Don	Sraf/Ustakhdus	Sour Cherry	Rosaceae	Herb
152	46	*Pseudomertensia parvifolia* (Decne)	Ghora butti		Boraginaceae	Herb
153	193	*Pseudomertensia moltkioides* Royle & Kazmi			Boraginaceae	Herb
154	198	*Pseudomertensia nemorosa* (D. C) R. Stewart & Kazmi			Boraginaceae	Herb
155	104	*Pteris vittata* L.	Pani butay		Pteridaceae	Herb
156	188	*Ranunculus hirtellus* Royle ex D. Don	Ziarr Gulay	Buttercup	Ranunculaceae	Herb
157	102	*Ranunculus laetus* Wall. Ex Hook.f. & Thoms	Ziarr Gulay	Crowfoot	Ranunculaceae	Herb
158	67	*Ranunculus muricatus* L.	Ziarr Gulay	Buttercup	Ranunculaceae	Herb
159	137	*Rheum australe* D.Don	Chotial		Polygonaceae	Herb
160	194	*Rhododendron hypenanthum* Balf.f	Tazak Tusum/Gul namer		Oleaceae	Shrub
161	97	*Ribes alpestre* Decne	Seabuckton	Red Currant	Grassullariaceae	Shrub
162	124	*Rosa webbiana* Wallich ex Royle	Jangli Gulab		Rosaceae	Shrub

163	57	*Rubus sanctus* Schreber	Karwarra/Alish	Blackberry	Rosaceae	Shrub
164	15	*Rumex dentatus* L.	Shalkhey	Dock	Polygonaceae	Herb
165	116	*Rumex nepalensis* Sprenge	Ambavati		Polygonaceae	Herb
166	111	*Salix flabellaris* Andersson in Kung	Tora wala	Wooly Willow	Salicaceae	Shrub
167	149	*Salvia lanata* Roxb.	Kiyan	Wild Clary	Lamiaceae	Herb
168	21	*Salvia moorcroftiana*Wall. ex Benth	Kalizarri		Lamiaceae	Herb
169	10	*Sambucus wightiana* Wall. Ex Wight & Arn	Mushkiara		Sambucaceae	Shrub
170	197	*Saussurea albescens* Hook. f. & Thoms		Alpine Saw-wort	Asteraceae	Herb
171	117	*Saussurea fastuosa* (Decne.) Schultz-Bip	Kuth		Asteraceae	Herb
172	195	*Saussurea graminifolia* Wallich ex DC			Asteraceae	Herb
173	45	*Scirpus palustris* L.			Juncaceae	Herb
174	110	*Sedum album* L.		White Stonecrop	Crassulaceae	Herb
175	147	*Sedum ewersii* Ledeb			Crassulaceae	Herb
176	48	*Senecio chrysanthemoides* DC	Ragwort	Ragwort	Asteraceae	Herb
177	93	*Sibbaldia cuneata* O. Kuntze		Sibbaldia	Rosaceae	Herb
178	29	*Silene vulgaris* Garck	Bashka/Barra takla	Bladder Campion	Caryophyllaceae	Herb
179	9	*Sorbaria tomentosa* (Lindl.) Rehder	Jeejrai		Rosaceae	Shrub
180	39	*Stipa himalaica* Rozhev.	Wakha		Poaceae	Herb
181	53	*Strobilanthes glutinosus* Nees			Acanthaceae	Herb
182	115	*Swertia ciliata* (D. Don ex G. Don) B. L. Burtt	Chirita		Gentianaceae	Herb
183	86	*Swertia speciosa* D. Don			Gentianaceae	Herb
184	130	*Sisymbrium irio* L.	Khubkalan	Hedge Mustard	Brassicaceae	Herb
185	47	*Tamarix dioica* Roxb. ex Roch	Ghaz	Tamarisk	Tamaricaceae	Shrub
186	69	*Taraxacum officinale* Weber	Hand/Gulsag/Booda boodae	Dandelion	Asteaceae	Herb
187	76	*Thymus linearis* Benth.	Sperkae/Bezori	Wild Thyme	Lamiaceae	Herb
188	22	*Trifolium repens* L.	Chapatra/Dutch clover	White Clover	Papilionaceae	Herb
189	103	*Trillidium govanianum* (Wall. Ex D. Don) Kunth	Tandhi jarri		Trilliaceae	Herb
190	88	*Tussilago farfara* L.	Funjiwam	Coltsfoot	Asteraceae	Herb
191	196	*Ulmus wallichiana* Planch.	Kahey	Elm	Ulmaceae	Tree
192	18	*Urtica dioica* L.	Seezunkay/Bichhu bhutty	Stinging Nettle	Urticaceae	Herb
193	89	*Valeriana pyrolifolia* Decne	Mushkebala/Shangitai	Valerian	Valerianaceae	Herb
194	20	*Verbascum thapsus* L.	Khar ghwag/Jangali Tamakoo	Common Mullein	Scrophulariaceae	Herb
195	14	*Viburnum cotinifolium* D. Don	Ghazmewa/Taliana		Caprifoliaceae	Shrub

196	11	*Viburnum grandiflorum* Wall. Ex DC.	Ghazmewa/Guch		Caprifoliaceae	Shrub
197	63	*Vicia bakeri* Ali.	Marghai Khpa/Jamdar	Fodder Vetch	Papilonaceae	Herb
198	26	*Viola canescens* Wall. Ex Roxb.	Banafsha	Violet	Violaceae	Herb

Appendix 4.4 Results of Indicator species analyses (ISA) through PC-ORD, showing Indicator (Characteristic) plant species (with bold font) for each of the 5 plant communities (1-5) at a threshold level of indicator value 20% and Monte Carlo test of significance for observed maximum indicator value of Species (p value ≤ 0.05).

S. No	Botanical name	*Pinus wallichiana - S. weightiana* community			*Abies pindrow- Betula utilis* community			*Juniperus excels -A. brevifolia* community			*Rheum australe- Sibbaldia cuneata* community			*Aster falconeri-Iris hookeriana* community		
		Group was defined by values of Soil depth classes; Max grp = 3 = highest soil depth			Group was defined by values of Aspect; Max grp = 1 = Northern aspect			Group were defined by values of Aspect; Max grp = 0 = Southern aspect			Group was defined by values of Altitude at m.a.s.l; Max grp = 36-41 = 3600-3900 m.a.s.l i.e., higher altitudes			Group was defined by values of Altitude at m.a.s.l; Max grp = 40-41 = above 4000 m.a.s.l i.e., highest altitudes		
		Max grp	Obs IV	p * value	Max grp	Obs IV	p * value	Max grp	Obs IV	p * value	Max grp	Obs IV	p * value	Max grp	Obs IV	p * value
1	**[2]*Abies pindrow* Royle**	3	28	0.001	**1**	**34**	**0.000**	1	34	0.000	28	12.6	0.2102	28	12.6	0.2102
2	*Acer caesium* Wall ex Brandis	3	4	0.193	1	4	0.246	1	4	0.246	24	17	0.131	24	17	0.131
3	*Aesculus indica* (Wall. Ex Camb) Hook.	3	2	1.000	1	1	1.000	1	1	1.000	26	25	0.0524	26	25	0.0524
4	**[2]*Betula utilis* D. Don**	2	10	0.201	**1**	**24**	**0.000**	1	24	0.000	32	12.6	0.2629	32	12.6	0.2629
5	*Cedrus deodara* (Roxb. Ex Lamb.) G. Don	3	12	0.031	1	6	0.284	1	6	0.284	24	15	0.218	24	15	0.218
6	*Crataegus oxyacantha* L.	3	2	1.000	1	1	1.000	1	1	1.000	24	50	0.0256	24	50	0.0256
7	*Juglans regia* L.	3	4	0.214	1	2	1.000	1	2	1.000	24	25.6	0.094	24	25.6	0.094
8	*Picea smithiana* (Wall.) Boiss.	3	9	0.156	1	15	0.001	1	15	0.001	28	25.4	0.0314	28	25.4	0.0314
9	**[1]*Pinus wallichiana* Jackson**	**3**	**32**	**0.000**	**1**	22	0.001	1	22	0.001	25	18.1	0.0638	25	18.1	0.0638
10	*Poplus glauca* H. Haines	3	3	0.617	1	3	0.494	1	3	0.494	26	19.4	0.096	26	19.4	0.096
11	*Prunus cerasoides* D. Don	3	2	1.000	0	2	0.463	0	2	0.463	25	16.7	0.3151	25	16.7	0.3151
12	*Ulmus wallichiana* Planch.	3	2	1.000	1	1	1.000	1	1	1.000	29	6.7	0.7664	29	6.7	0.7664
13	**[3]*Artemisia brevifolia* Wall. ex DC**	3	26	0.052	0	50	0.000	**0**	**50**	**0.000**	33	13.8	0.229	33	13.8	0.229
14	*Artemisia vulgaris* L.	3	8	0.115	0	10	0.013	0	10	0.013	25	16.4	0.1818	25	16.4	0.1818
15	*Berberis pseudumbellata* Parker	2	10	0.346	1	12	0.318	1	12	0.318	32	8.9	0.5021	32	8.9	0.5021
16	*Cotoneaster cashmiriensis* G.Klotz	3	6	0.146	0	6	0.040	0	6	0.040	25	43.5	0.0024	25	43.5	0.0024
17	*Cotoneaster microphyllus* Wall. ex Lindl	3	12	0.063	0	19	0.000	0	19	0.000	27	15.9	0.1786	27	15.9	0.1786

18	*Ephedra gerardiana* Wall. Ex Stapf	3	10	0.114	1	6	0.544	1	6	0.544	26	32.3	0.0114	26	32.3	0.0114
19	*Indigofera heterantha* Wall. Ex Brand	3	2	1.000	1	1	1.000	1	1	1.000	24	50	0.0256	24	50	0.0256
20	*Juniperus communis* L.	2	32	0.009	0	22	0.719	0	22	0.719	34	9.7	0.4577	34	9.7	0.4577
21	[3]***Juniperus excelsa* M. Bieb**	3	15	0.124	0	35	0.000	**0**	**35**	**0.000**	27	5.8	0.8542	27	5.8	0.8542
22	*Juniperus squamata* Buch.-Ham. ex D. Don	2	20	0.005	0	6	0.703	0	6	0.703	37	4.5	0.9346	37	4.5	0.9346
23	*Rhododendron hypenanthum* Balf.f	2	8	0.081	1	8	0.026	1	8	0.026	36	7.1	0.5899	36	7.1	0.5899
24	*Ribies alpestre* Decne	3	4	0.268	0	2	0.620	0	2	0.620	24	15.5	0.196	24	15.5	0.196
25	*Rosa webbiana* Wallich ex Royle	3	19	0.126	0	17	0.495	0	17	0.495	31	10.2	0.4175	31	10.2	0.4175
26	*Rubus sanctus* Schreber	3	3	0.611	0	1	0.747	0	1	0.747	26	19.4	0.087	26	19.4	0.087
27	[2]***Salix flabellaris* Andersson in Kung**	3	7	0.508	**1**	**20**	**0.000**	1	20	0.000	30	5.8	0.7906	30	5.8	0.7906
28	[1]***Sambucus wightiana* Wall. Ex Wight & Arn**	**3**	**59**	**0.000**	1	21	0.282	1	21	0.282	25	22.9	0.03	25	22.9	0.03
29	*Sorbaria tomentosa* (Lindl.) Rehder	3	12	0.058	0	4	0.962	0	4	0.962	24	49.5	0.0036	24	49.5	0.0036
30	*Tamarix dioica* Roxb. ex Roch	3	6	0.160	0	2	1.000	0	2	1.000	24	23.6	0.1308	24	23.6	0.1308
31	*Viburnum cotinifolium* D. Don	3	4	0.437	1	3	0.781	1	3	0.781	32	12.7	0.2691	32	12.7	0.2691
32	*Viburnum grandiflorum* Wall. Ex DC.	3	3	0.633	1	1	1.000	1	1	1.000	24	100	0.0004	24	100	0.0004
33	*Acantholimon lycopodioides* Boiss.	1	2	0.650	0	2	0.365	0	2	0.365	30	14.6	0.1564	30	14.6	0.1564
34	[2]***Achillea millefolium* L.**	3	27	0.002	**1**	**25**	**0.001**	1	25	0.001	26	8	0.5693	26	8	0.5693
35	*Aconitum heterophyllum* Wall.	2	7	0.108	1	5	0.125	1	5	0.125	40	9.3	0.3971	40	9.3	0.3971
36	*Aconitum violaceum* Jacquen ex. Stapf	2	6	0.380	1	12	0.011	1	12	0.011	34	9.7	0.4517	34	9.7	0.4517
37	*Actaea spicata* L.	3	3	0.513	1	3	0.499	1	3	0.499	26	23.2	0.0592	26	23.2	0.0592
38	*Adiantum venustum* D. Don	3	17	0.011	1	10	0.089	1	10	0.089	24	24.4	0.0496	24	24.4	0.0496
39	*Alliaria petiolata* (M. Bieb.) Cavara & Grande	3	3	0.506	1	3	0.493	1	3	0.493	31	4.6	0.9448	31	4.6	0.9448
40	*Allium humile* Kunth.	1	4	0.816	1	8	0.105	1	8	0.105	38	15.4	0.2062	38	15.4	0.2062
41	*Alopecurus arundinaceus* Poir.	1	3	0.799	1	4	0.699	1	4	0.699	28	7.6	0.5681	28	7.6	0.5681
42	*Anaphalis triplinervis* (Sims) C. B. Clarke	2	13	0.017	0	8	0.086	0	8	0.086	40	14.1	0.2635	40	14.1	0.2635
43	*Androsace hazarica* R.R. Stewart ex Y. Nasir	2	4	0.358	1	7	0.059	1	7	0.059	41	22.1	0.1194	41	22.1	0.1194
44	*Androsace primuloides* Duby	1	11	0.033	1	3	0.859	1	3	0.859	41	19.7	0.1506	41	19.7	0.1506
45	*Androsace rotundifolia* Watt	3	20	0.086	0	16	0.611	0	16	0.611	28	8.2	0.5859	28	8.2	0.5859
46	*Anemone falconeri* Thoms.	3	5	0.678	1	7	0.542	1	7	0.542	41	12.2	0.2833	41	12.2	0.2833
47	*Anemone obtusiloba* D.Don	2	6	0.490	0	5	0.945	0	5	0.945	40	3.1	0.9906	40	3.1	0.9906
48	*Anemone rupicola* Cambess	2	6	0.452	1	5	0.673	1	5	0.673	32	5.1	0.8554	32	5.1	0.8554
49	*Anemone tetrasepala* Royle	1	14	0.034	1	8	0.380	1	8	0.380	41	14.1	0.1858	41	14.1	0.1858
50	*Angelica glauca* Edgew.	3	10	0.063	1	5	0.513	1	5	0.513	29	7.7	0.6317	29	7.7	0.6317
51	*Apluda mutica* (L.) Hack	3	18	0.007	0	6	0.558	0	6	0.558	28	16.1	0.174	28	16.1	0.174
52	*Aqueligia fragrans* Benth.	3	1	1.000	1	1	1.000	1	1	1.000	39	5.1	0.8312	39	5.1	0.8312

53	*Arnebia benthamii* Wallich ex. G. Done	2	14	0.018	1	12	0.003	1	12	0.003	41	15.9	0.201	41	15.9	0.201
54	*Asparagus racemosus* Willd.	3	9	0.040	1	8	0.029	1	8	0.029	26	9.2	0.3601	26	9.2	0.3601
55	*Asperula oppositifolia* Reg. & Schmalh.	3	6	0.264	0	4	0.487	0	4	0.487	27	7.4	0.6331	27	7.4	0.6331
56	*Asplenium adiantum-nigrum*	3	3	0.573	1	3	0.489	1	3	0.489	30	11.5	0.4199	30	11.5	0.4199
57	[5]***Aster falconeri* (C. B. Clarke) Hutch**	1	20	0.005	0	9	0.225	0	9	0.225	41	43.2	0.0056	**41**	**43.2**	**0.0056**
58	*Astragalus anisacanthus* Boiss.	3	16	0.028	0	7	0.848	0	7	0.848	24	12.2	0.2775	24	12.2	0.2775
59	*Astragalus scorpiurus* Bunge	3	11	0.207	1	9	0.499	1	9	0.499	26	13	0.223	26	13	0.223
60	*Bergenia ciliata* (Haw.) Sternb.	3	4	0.209	1	4	0.237	1	4	0.237	28	12.4	0.2841	28	12.4	0.2841
61	[4]***Bergenia stracheyi* (Hook. f. & Thoms) Engl**	1	32	0.001	1	31	0.000	1	31	0.000	**38**	**14.7**	**0.1614**	41	14.7	0.1614
62	*Bistorta affinis* (D.Don) Green	2	21	0.052	1	14	0.790	1	14	0.790	36	16.2	0.155	36	16.2	0.155
63	*Bistorta amplexicaulis* (D. Don)	3	18	0.008	1	5	0.990	1	5	0.990	26	9.4	0.4779	26	9.4	0.4779
64	*Bromus hordeaceus* L.	3	16	0.024	0	10	0.122	0	10	0.122	26	9.6	0.4453	26	9.6	0.4453
65	*Caltha alba* Jack. Ex Comb	3	16	0.023	1	12	0.043	1	12	0.043	25	14.2	0.2284	25	14.2	0.2284
66	*Capsella bursa-pastoris* (L.) Medic.	3	10	0.053	0	4	0.562	0	4	0.562	24	20.4	0.1232	24	20.4	0.1232
67	*Cassiope fastigiata* (Wallich) D. Done	2	4	0.414	1	3	0.493	1	3	0.493	36	12.1	0.3937	36	12.1	0.3937
68	*Cerastium fontanum* Baumg.	3	11	0.575	0	11	0.773	0	11	0.773	27	11.7	0.3079	27	11.7	0.3079
69	*Chenopodium album* L.	3	10	0.057	1	5	0.476	1	5	0.476	25	10.4	0.3865	25	10.4	0.3865
70	*Clematis montana* Buch.-Ham. ex DC	3	4	0.581	0	12	0.002	0	12	0.002	28	19.2	0.1112	28	19.2	0.1112
71	*Colchicum luteum* Baker	2	7	0.358	1	6	0.710	1	6	0.710	31	4.4	0.9182	31	4.4	0.9182
72	*Convolulus arvensis* L.	3	2	0.826	0	2	0.751	0	2	0.751	25	12	0.3107	25	12	0.3107
73	*Corydalis diphylla* Wall.	2	5	0.738	0	7	0.461	0	7	0.461	32	11.4	0.3359	32	11.4	0.3359
74	*Corydalis govaniana* Wall.	2	11	0.037	0	6	0.269	0	6	0.269	30	9.2	0.4655	30	9.2	0.4655
75	*Cynoglossum glochidiatum* Wall. Ex Benth	3	31	0.008	1	24	0.245	1	24	0.245	27	16.5	0.108	27	16.5	0.108
76	*Cynoglossum himaltoni*	3	7	0.536	1	7	0.739	1	7	0.739	24	14.4	0.1938	24	14.4	0.1938
77	*Cynoglossum lanceolatum* L.	3	2	1.000	0	2	0.470	0	2	0.470	31	5.9	1	31	5.9	1
78	*Cyperus niveous*	3	14	0.080	1	13	0.155	1	13	0.155	24	9.2	0.5087	24	9.2	0.5087
79	*Cypripedium cordigerum* D. Don	3	4	0.385	1	5	0.122	1	5	0.122	30	7.8	0.6163	30	7.8	0.6163
80	*Dactylis glomerata* L.	3	22	0.004	1	6	0.883	1	6	0.883	27	14.1	0.1522	27	14.1	0.1522
81	*Dactylorhiza hatagirea* (D. Don) Soo	3	6	0.158	0	2	0.815	0	2	0.815	24	24.8	0.1084	24	24.8	0.1084
82	*Dioscorea deltoidea* Wall.	3	7	0.085	0	2	1.000	0	2	1.000	24	14.8	0.2248	24	14.8	0.2248
83	*Draba oreades* Schrenk	3	3	0.788	0	6	0.161	0	6	0.161	30	4.2	0.946	30	4.2	0.946
84	*Dracocephalum nutans* L.	1	3	0.829	0	6	0.151	0	6	0.151	40	7.7	0.5017	40	7.7	0.5017
85	*Dryopteris juxtapostia* Christ	3	7	0.209	1	11	0.011	1	11	0.011	26	10.1	0.3943	26	10.1	0.3943
86	[3]***Dryopteris stewartii* Fras.-Jenk.**	3	26	0.008	0	40	0.000	**0**	**40**	**0.000**	28	10.8	0.2961	28	10.8	0.2961
87	*Eclipta prostrata* L.	3	9	0.044	0	7	0.053	0	7	0.053	24	20.4	0.1432	24	20.4	0.1432
88	*Epilobium angustifolium* L.	3	6	0.150	1	5	0.122	1	5	0.122	24	17.5	0.1558	24	17.5	0.1558
89	*Equisetum arvense* L.	3	10	0.051	1	7	0.108	1	7	0.108	24	17.3	0.1908	24	17.3	0.1908
90	*Eragrostis cilianensis* (All.) Lut. ex F.T.	3	9	0.050	0	2	0.917	0	2	0.917	24	34.2	0.0302	24	34.2	0.0302

	Hubbard															
91	[3]***Eremurus himalaicus* Baker**	3	12	0.350	0	35	0.000	**0**	**35**	**0.000**	27	9.2	0.4671	27	9.2	0.4671
92	*Erigeron multiradiatus* (Lindl. Ex DC) C. B. Clarke	3	7	0.098	1	4	0.230	1	4	0.230	26	9	0.4277	26	9	0.4277
93	*Erysimum melicentae* Dunn.	3	9	0.037	0	3	0.664	0	3	0.664	24	20.8	0.126	24	20.8	0.126
94	*Euphorbia wallichii* Hook. f.	2	8	0.181	0	11	0.019	0	11	0.019	36	8.4	0.5323	36	8.4	0.5323
95	*Euphrasia himalayica* Wetts.	3	17	0.046	1	10	0.649	1	10	0.649	26	8.3	0.5799	26	8.3	0.5799
96	[2]***Fragaria nubicola* Lindl. Ex Lacaita**	3	49	0.000	**1**	**47**	**0.000**	1	47	0.000	25	10.6	0.4115	25	10.6	0.4115
97	*Fritillaria roylei* Hook. f.	2	1	1.000	0	1	1.000	0	1	1.000	26	15.9	0.1146	26	15.9	0.1146
98	*Gagea elegans* Wall. Ex D. Don	2	14	0.029	0	6	0.765	0	6	0.765	37	13.7	0.2194	37	13.7	0.2194
99	*Galium aparine* L.	3	9	0.096	1	5	0.557	1	5	0.557	31	10.9	0.5091	31	10.9	0.5091
100	*Galium asperuloides*	3	13	0.032	0	6	0.457	0	6	0.457	27	26.2	0.033	27	26.2	0.033
101	*Gentiana carinata* Griseb	1	22	0.003	1	10	0.392	1	10	0.392	40	13.8	0.1648	40	13.8	0.1648
102	*Gentiana kurroo* Royle	3	2	0.681	1	1	1.000	1	1	1.000	31	4.2	0.9532	31	4.2	0.9532
103	*Gentiana moorcroftiana* (Wallich ex G. Don) Airy Shaw	2	14	0.027	0	12	0.023	0	12	0.023	32	4.3	0.9166	32	4.3	0.9166
104	*Gentianodes argentia* Omer, Ali & Qaiser	2	3	0.702	0	5	0.187	0	5	0.187	38	2.6	0.993	38	2.6	0.993
105	*Geranium nepalense* Sweet.	2	4	0.419	0	2	0.803	0	2	0.803	39	1.9	0.9994	39	1.9	0.9994
106	*Geranium polyanthes* Edgew & Hook. F	2	10	0.230	1	16	0.007	1	16	0.007	28	11	0.3847	28	11	0.3847
107	*Geranium wallichianum* D. Don ex. Sweet	3	3	0.979	0	7	0.494	0	7	0.494	26	9.3	0.4721	26	9.3	0.4721
108	*Geum elatum* Wall. Ex G. Don	3	3	0.680	0	3	0.815	0	3	0.815	28	6.5	0.7011	28	6.5	0.7011
109	*Gnaphalium affine* D. Don	2	11	0.506	1	20	0.022	1	20	0.022	36	7.4	0.6835	36	7.4	0.6835
110	*Gratiola officinalis* L.	3	3	0.627	1	3	0.494	1	3	0.494	28	10.9	0.5101	28	10.9	0.5101
111	*Hackelia uncinata* (Royle ex Benth) Fischer	3	11	0.842	1	15	0.649	1	15	0.649	36	13.2	0.1882	36	13.2	0.1882
112	*Heracleum candicans* Wall. ex DC.	3	6	0.149	0	6	0.046	0	6	0.046	26	6.6	0.7187	26	6.6	0.7187
113	*Hyoscyamus niger* L.	3	2	1.000	1	1	1.000	1	1	1.000	28	20	0.1938	28	20	0.1938
114	*Hypericum perforatum* L.	3	24	0.002	0	18	0.001	0	18	0.001	24	29.8	0.0218	24	29.8	0.0218
115	*Impatiens edgeworthii* Hook.f.	3	12	0.028	1	10	0.035	1	10	0.035	28	14.3	0.233	28	14.3	0.233
116	[1]***Impatiens bicolor* Royle**	**3**	**50**	**0.000**	1	27	0.020	1	27	0.020	24	32	0.016	24	32	0.016
117	*Inula grandiflora* Willd.	3	2	1.000	1	1	1.000	1	1	1.000	37	9.1	0.5627	37	9.1	0.5627
118	*Inula multiradiata*	3	2	1.000	0	2	0.466	0	2	0.466	29	6.7	0.7754	29	6.7	0.7754
119	[5]***Iris hookeriana* Foster**	1	38	0.001	0	16	0.853	0	16	0.853	41	20	0.0702	**41**	**20**	**0.0702**
120	*Juncus membranaceus* Royle ex D. Don	2	7	0.313	0	7	0.234	0	7	0.234	36	13.7	0.3535	36	13.7	0.3535
121	*Lathyrus pratensis* L.	3	4	0.201	1	2	0.487	1	2	0.487	27	8.3	0.6169	27	8.3	0.6169
122	*Leucas cephalotes* (Roth) Spreng.	3	4	0.207	0	2	0.733	0	2	0.733	26	18.4	0.1272	26	18.4	0.1272
123	*Malva neglecta* Wallr	3	26	0.042	0	25	0.181	0	25	0.181	24	22.8	0.0268	24	22.8	0.0268
124	*Mentha longifolia* (L.) Hudson.	3	4	0.196	1	4	0.246	1	4	0.246	30	8.1	0.6395	30	8.1	0.6395

125	*Mentha royleana* Benth. in Wall.	3	2	1.000	1	1	1.000	1	1	1.000	26	25	0.0564	26	25	0.0564
126	*Minuartia kashmirica* (Edgew) Mattf	2	3	0.853	1	3	0.917	1	3	0.917	36	8.5	0.5081	36	8.5	0.5081
127	*Morina longifolia* Wall. ex. Dcs	3	2	0.773	1	4	0.301	1	4	0.301	29	3.4	0.9614	29	3.4	0.9614
128	*Nepeta laevigata (D. Done) Hand.-Mazz*	3	5	0.571	1	7	0.163	1	7	0.163	34	5	0.871	34	5	0.871
129	[1]***Onopordum acanthium* L.**	**3**	**34**	**0.001**	0	18	0.606	0	18	0.606	24	14	0.1664	24	14	0.1664
130	*Onosma bracteatum* Wall.	3	8	0.199	1	8	0.199	1	8	0.199	30	5.4	0.7708	30	5.4	0.7708
131	*Origanum vulgare* L.	3	14	0.030	0	17	0.000	0	17	0.000	27	27.2	0.0218	27	27.2	0.0218
132	*Orobanche alba* Stephen ex Wallid	3	1	1.000	0	1	0.747	0	1	0.747	36	8.6	0.6151	36	8.6	0.6151
133	*Oxyria digyna* L.	3	22	0.019	1	21	0.010	1	21	0.010	33	9	0.4993	33	9	0.4993
134	*Oxytropis cachemiriana* Camb.	3	19	0.006	0	7	0.384	0	7	0.384	24	18.5	0.0994	24	18.5	0.0994
135	*Paeonia emodi* Wall. Ex Royle	3	2	1.000	1	1	1.000	1	1	1.000	26	25	0.0524	26	25	0.0524
136	*Parnassia nubicola* Wall.	2	7	0.169	1	3	0.931	1	3	0.931	30	8.2	0.4709	30	8.2	0.4709
137	*Pedicularis pectinata* Wall. ex. Benth	2	3	0.514	0	2	0.806	0	2	0.806	38	6.6	0.7295	38	6.6	0.7295
138	*Pennisetum lanatum* Klotzsch	3	3	0.563	0	2	0.757	0	2	0.757	31	4.9	0.8816	31	4.9	0.8816
139	*Phleum alpinum* L.	3	4	0.478	0	4	0.313	0	4	0.313	28	6.5	0.6191	28	6.5	0.6191
140	*Phlomis bracteosa* Royle ex Benth.	2	5	0.092	0	4	0.103	0	4	0.103	37	4.7	0.9016	37	4.7	0.9016
141	*Pimpinella acuminata* (Edgew.) C.B. Clarke	3	4	0.215	1	2	0.495	1	2	0.495	29	8.9	0.5585	29	8.9	0.5585
142	*Pimpinella diversifolia* (Wall.) DC	3	7	0.088	0	3	0.446	0	3	0.446	25	34.1	0.0106	25	34.1	0.0106
143	*Plantago himalaica* Pilger	1	7	0.112	1	3	0.700	1	3	0.700	34	3.9	0.9722	34	3.9	0.9722
144	[1]***Plantago lanceolata* L.**	**3**	**30**	**0.002**	0	18	0.309	0	18	0.309	24	20.9	0.0496	24	20.9	0.0496
145	*Plantago major* L.	3	16	0.098	0	10	0.986	0	10	0.986	36	14.1	0.2062	36	14.1	0.2062
146	[4]***Poa alpina* L.**	2	24	0.146	1	28	0.174	1	28	0.174	**38**	**15.5**	**0.079**	38	15.5	0.079
147	*Poa annua* L.	3	7	0.100	1	3	0.446	1	3	0.446	27	39.1	0.0074	27	39.1	0.0074
148	*Poa stewartiana* Bor in Kew Bull.	3	20	0.010	1	14	0.090	1	14	0.090	27	13.5	0.2547	27	13.5	0.2547
149	*Podophyllum hexandrum* Royle	3	4	0.602	1	5	0.356	1	5	0.356	31	5.8	0.7638	31	5.8	0.7638
150	*Polygonum aviculare* L.	3	10	0.364	1	10	0.459	1	10	0.459	26	13.9	0.2178	26	13.9	0.2178
151	*Polygonum alpinum* (All.) Schur	2	18	0.036	0	13	0.229	0	13	0.229	38	13.8	0.2042	38	13.8	0.2042
152	*Polygonum molle* (D.Done) Hara	3	7	0.458	1	11	0.069	1	11	0.069	28	12.2	0.3267	28	12.2	0.3267
153	*Polygonum plebejum* R. Br	3	14	0.033	1	9	0.190	1	9	0.190	26	11.7	0.3391	26	11.7	0.3391
154	*Polygonatum verticillatum (*L.) Allioni	3	11	0.336	0	11	0.663	0	11	0.663	34	4	0.9872	34	4	0.9872
155	*Potentilla anserina* L.	2	10	0.779	0	13	0.709	0	13	0.709	36	4.9	0.9536	36	4.9	0.9536
156	*Potentilla atrosanguinea* Lodd.	2	8	0.269	1	8	0.246	1	8	0.246	34	16.8	0.1292	34	16.8	0.1292
157	*Potentilla nepalensis* Hook. f.	1	13	0.280	0	15	0.248	0	15	0.248	36	15.6	0.1236	36	15.6	0.1236
158	*Primula calderana* Balf. F & cooper	1	6	0.149	1	4	0.306	1	4	0.306	38	21.5	0.1234	38	21.5	0.1234
159	*Primula denticulata* Smith	1	11	0.073	1	16	0.000	1	16	0.000	34	5.8	0.7223	34	5.8	0.7223
160	*Primula glomerata* Pax.	2	6	0.215	1	8	0.029	1	8	0.029	41	22.2	0.1172	41	22.2	0.1172
161	*Primula rosea* Royle	2	11	0.115	1	14	0.019	1	14	0.019	38	15.1	0.135	38	15.1	0.135
162	*Prunella vulgaris* L.	3	6	0.183	1	6	0.148	1	6	0.148	25	5.6	0.7652	25	5.6	0.7652
163	*Pseudomertensia parvifolia* (Decne)	3	6	0.141	1	4	0.311	1	4	0.311	26	43	0.0114	26	43	0.0114

164	*Pseudomertensia moltkioides* Royle & Kazmi	1	6	0.275	1	3	0.726	1	3	0.726	41	27.8	0.0354	41	27.8	0.0354
165	*Pseudomertensia nemorosa* (D. C) R. Stewart & Kazmi	1	2	0.962	1	7	0.056	1	7	0.056	37	8.3	0.4811	37	8.3	0.4811
166	*Pteris vittata* L.	3	3	0.780	1	6	0.149	1	6	0.149	36	7.7	0.5213	36	7.7	0.5213
167	[5]***Ranunculus hirtellus* Royle ex D. Don**	1	14	0.008	1	7	0.066	1	7	0.066	41	67.1	0.0022	**41**	**67.1**	**0.0022**
168	*Ranunculus laetus* Wall. Ex Hook.f. & Thoms	3	3	0.827	1	5	0.255	1	5	0.255	36	3.8	0.9666	36	3.8	0.9666
169	*Ranunculus muricatus* L.	3	5	0.269	1	2	1.000	1	2	1.000	24	31	0.0396	24	31	0.0396
170	[4]***Rheum australe* D.Don**	1	32	0.004	1	21	0.231	1	21	0.231	**38**	**20.3**	**0.0588**	41	20.3	0.0588
171	*Rumex dentatus* L.	3	32	0.014	1	26	0.340	1	26	0.340	28	10.1	0.4855	28	10.1	0.4855
172	*Rumex nepalensis* Sprenge	3	5	0.646	1	7	0.235	1	7	0.235	24	14.5	0.2282	24	14.5	0.2282
173	*Salvia lanata* Roxb.	3	7	0.104	1	3	0.716	1	3	0.716	32	3.4	0.9818	32	3.4	0.9818
174	*Salvia moorcroftiana* Wallich ex Benth	3	5	0.518	0	5	0.414	0	5	0.414	38	5.2	0.7676	38	5.2	0.7676
175	*Saussurea albescens* Hook. f. & Thoms	3	6	0.233	1	4	0.518	1	4	0.518	24	15.6	0.195	24	15.6	0.195
176	*Saussurea fastuosa* (Decne.) Schultz-Bip	1	4	0.340	1	4	0.249	1	4	0.249	31	2.8	0.9922	31	2.8	0.9922
177	*Saussureagraminifolia* Wallich ex DC	1	3	0.701	0	3	0.786	0	3	0.786	30	5.3	0.8038	30	5.3	0.8038
178	*Scirpus palustris* L.	3	7	0.260	1	10	0.022	1	10	0.022	26	9.3	0.4385	26	9.3	0.4385
179	*Sedum album* L.	2	10	0.461	1	12	0.355	1	12	0.355	41	9.2	0.4759	41	9.2	0.4759
180	*Sedum ewersii* Ledeb	2	18	0.008	0	8	0.320	0	8	0.320	36	8.4	0.5751	36	8.4	0.5751
181	*Senecio chrysanthemoides* DC	3	6	0.126	1	3	0.420	1	3	0.420	27	11.6	0.3789	27	11.6	0.3789
182	[4]***Sibbaldia cuneata* O. Kuntze**	2	29	0.013	1	25	0.048	1	25	0.048	**39**	**20**	**0.0584**	41	19.7	0.0584
183	*Silene vulgaris* Garck	3	7	0.090	0	3	0.612	0	3	0.612	24	23.6	0.0972	24	23.6	0.0972
184	*Stipa himalaica* Rozhev.	3	10	0.038	1	3	0.824	1	3	0.824	26	25.7	0.0598	26	25.7	0.0598
185	*Strobilanthes glutinosus* Nees	3	4	0.211	0	2	0.362	0	2	0.362	30	10.2	0.4137	30	10.2	0.4137
186	*Swertia ciliata* (D. Don ex G. Don) B. L. Burtt	3	11	0.047	1	4	0.798	1	4	0.798	26	46.2	0.0058	26	46.2	0.0058
187	*Swertia speciosa* D. Don	3	3	0.632	1	3	0.493	1	3	0.493	31	11.8	0.4251	31	11.8	0.4251
188	*Sisymbrium irio* L.	1	3	0.543	0	2	0.754	0	2	0.754	25	7.2	0.6433	25	7.2	0.6433
189	[3]***Taraxacum officinale* Weber**	3	44	0.001	0	36	0.033	**0**	**36**	**0.033**	27	9.1	0.6165	27	9.1	0.6165
190	*Thymus linearis* Benth.	2	32	0.101	1	33	0.992	1	33	0.992	32	12.7	0.1444	32	12.7	0.1444
191	[1]***Trifolium repens* L.**	**3**	**28**	**0.000**	0	8	0.884	0	8	0.884	24	22.3	0.0512	24	22.3	0.0512
192	*Trillidium govanianum* (Wall. Ex D. Don) Kunth	3	1	1.000	1	4	0.246	1	4	0.246	32	7.7	0.6701	32	7.7	0.6701
193	*Tussilago farfara* L.	3	4	0.205	1	2	0.749	1	2	0.749	24	21.7	0.1044	24	21.7	0.1044
194	*Urtica dioica* L.	3	15	0.061	0	9	0.708	0	9	0.708	24	34.7	0.011	24	34.7	0.011
195	*Valeriana pyrolifolia* Decne	1	6	0.631	1	21	0.000	1	21	0.000	41	5.5	0.8296	41	5.5	0.8296
196	*Verbascum thapsus* L.	3	23	0.055	0	20	0.466	0	20	0.466	24	17.8	0.0766	24	17.8	0.0766
197	*Vicia bakeri* Ali.	3	3	0.627	1	1	1.000	1	1	1.000	26	17.9	0.1072	26	17.9	0.1072
198	*Viola canescens* Wall. Ex Roxb.	1	31	0.252	1	42	0.133	1	42	0.133	40	9	0.6625	40	9	0.6625

Appendix 4.5 Importance Value Index (IVI), constancy (Cons), percent constancy (% Cons) of species for each of the 5 plant communities/habitat types and total Importance value (TIV) & Fidelity (Fid) level of each species in the whole set of data

				1			**2**			**3**			**4**			**5**		
S. No	Botanical name	***Pinus wallichiana - S. wightiana* community**			***Abies pindrow-Betula utilis* community**			***Juniperus excels -A. brevifolia* Community**			***Rheum australe-Sibbaldia cuneata* Community**			***Aster falconeri-Iris hookeriana* Community**			**TIV**	**Fid**
		IVI	**Cons**	**% Cons**	**IVI**	**Cons**	**% Cons**	**IVI**	**Cons**	**% Cons**	**IVI**	**Cons**	**% Cons**	**IVI**	**Cons**	**% Cons**		
1	[2]***Abies pindrow* Royle**	910	8	33	1986	14	41	0	0	0	131	2	6	0	0	0	3027	3
2	*Acer caesium* Wall ex Brandis	49	2	8	0	0	0	0	0	0	0	0	0	0	0	0	49	1
3	*Aesculus indica* (Wall. Ex Camb) Hook.	11	1	3	0	0	0	0	0	0	0	0	0	0	0	0	11	1
4	[2]***Betula utilis* D. Don**	0	0	0	1475	10	29	0	0	0	1160	4	13	0	0	0	2635	4
5	*Cedrus deodara* (Roxb. Ex Lamb.) G. Don	516	4	17	65	4	12	0	1	4	82	1	3	0	0	0	663	3
6	*Crataegus oxyacantha* L.	10	1	4	0	0	0	0	0	0	0	0	0	0	0	0	10	1
7	*Juglans regia* L.	200	2	8	14	1	3	0	0	0	0	0	0	0	0	0	214	1
8	*Picea smithiana* (Wall.) Boiss.	64	1	4	155	9	26	0	0	0	68	1	3	0	0	0	287	4
9	[1]***Pinus wallichiana* Jackson**	1560	11	46	471	10	29	0	0	0	84	1	3	0	0	0	2116	4
10	*Poplus glauca* H. Haines	310	2	8	23	2	6	0	0	0	0	0	0	0	0	0	333	1
11	*Prunus cerasoides* D. Don	124	1	4	0	0	0	0	0	0	0	0	0	0	0	0	124	1
12	*Ulmus wallichiana* Planch.	0	0	0	21	1	3	0	0	0	0	0	0	0	0	0	21	1
13	[3]***Artemisia brevifolia* L.**	874	15	63	520	3	9	2148	27	96	842	9	29	0	1	4	4385	3
14	*Artemisia vulgaris* L.	256	5	21	0	0	0	125	3	11	0	0	0	0	0	0	381	3
15	*Berberis pseudumbellata* Parker	128	2	8	227	12	35	215	5	18	409	4	13	0	0	0	979	3
16	*Cotoneaster cashmiriensis* G.Klotz	79	4	17	0	0	0	0	0	0	0	0	0	0	0	0	79	1
17	*Cotoneaster microphyllus* Wall. ex Lindl	129	6	25	0	0	0	136	7	25	26	3	10	0	0	0	291	3
18	*Ephedra gerardiana* Wall. Ex Stapf	224	3	13	230	5	15	44	2	7	106	2	6	0	0	0	604	2
19	*Indigofera heterantha* Wall. Ex Brand	17	1	4	0	0	0	0	0	0	0	0	0	0	0	0	17	1
20	*Juniperus communis* L.	110	1	4	729	18	53	713	14	50	3953	21	68	0	5	19	5505	3
21	[3]***Juniperus excelsa* M. Bieb**	400	7	29	106	0	0	433	19	68	124	3	10	0	0	0	1063	4
22	*Juniperus squamata* Buch.-Ham. ex D. Don	0	0	0	132	2	6	59	1	4	1191	8	26	20	5	19	1399	3

23	*Rhododendron hypenanthum* Balf.f	0	0	0	48	2	6	0	0	0	898	4	13	0	0	0	946	4
24	*Ribies alpestre* Decne	9	1	4	63	1	3	26	1	4	0	0	0	0	0	0	98	1
25	*Rosa webbiana* Wallich ex Royle	366	5	21	748	13	38	491	19	68	338	4	13	0	0	0	1943	2
26	*Rubus sanctus* Schreber	72	2	8	0	0	0	0	0	0	0	0	0	0	0	0	72	1
27	[2]***Salix flabellaris* Andersson in Kung**	150	3	13	380	10	29	38	2	7	532	6	19	0	0	0	1100	3
28	[1]***Sambucus wightiana* Wall. Ex Wight & Arn**	2766	23	96	1482	16	47	678	8	29	0	0	0	0	0	0	4926	3
29	*Sorbaria tomentosa* (Lindl.) Rehder	186	2	8	318	6	18	226	4	14	0	0	0	0	0	0	730	3
30	*Tamarix dioica* Roxb. ex Roch	131	3	13	65	1	3	0	0	0	0	0	0	0	0	0	195	3
31	*Viburnum cotinifolium* D. Don	21	2	8	106	4	12	28	3	11	0	0	0	0	0	0	163	3
32	*Viburnum grandiflorum* Wall. Ex DC.	79	2	8	0	0	0	0	0	0	0	0	0	0	0	0	79	1
33	*Acantholimon lycopodioides* Boiss.	0	0	0	0	0	0	125	1	4	29	2	6	0	0	0	154	1
34	[2]***Achillea millefolium* L.**	88	7	29	198	15	44	39	1	4	40	2	6	0	0	0	364	4
35	*Aconitum heterophyllum* Wall.	0	0	0	0	0	0	0	0	0	46	4	13	12	1	4	58	1
36	*Aconitum violaceum* Jacquen ex. Stapf	0	0	0	54	8	24	0	1	4	84	2	6	17	2	8	154	3
37	*Actaea spicata* L.	26	1	4	7	1	3	0	0	0	0	0	0	0	0	0	33	1
38	*Adiantum venustum* D. Don	51	5	21	51	7	21	6	1	4	0	0	0	0	0	0	108	3
39	*Alliaria petiolata* (M. Bieb.) Cavara & Grande	0	0	0	13	2	6	0	0	0	0	0	0	0	0	0	13	1
40	*Allium humile* Kunth.	0	0	0	0	0	0	0	0	0	65	6	19	90	4	15	155	5
41	*Alopecurus arundinaceus* Poir.	89	4	17	97	2	6	18	2	7	0	0	0	0	0	0	194	2
42	*Anaphalis triplinervis* (Sims) C. B. Clarke	0	0	0	0	0	0	0	0	0	89	5	16	44	4	15	132	5
43	*Androsace hazarica* R.R. Stewart ex Y. Nasir	0	0	0	5	2	6	0	0	0	15	2	6	42	3	11	62	1
44	*Androsace primuloides* Duby	0	0	0	0	0	0	13	1	4	32	2	6	89	4	15	133	1
45	*Androsace rotundifolia* Watt	97	9	38	79	15	44	108	9	32	128	5	16	43	1	4	456	2
46	*Anemone falconeri* Thoms.	14	3	13	42	6	18	62	2	7	26	2	6	11	1	4	155	2
47	*Anemone obtusiloba* D.Don	19	3	13	22	3	9	52	3	11	43	4	13	6	0	0	143	2
48	*Anemone rupicola* Cambess	0	0	0	35	3	9	55	3	11	122	3	10	12	3	11	227	2
49	*Anemone tetrasepala* Royle	0	0	0	5	2	6	0	0	0	151	1	3	141	12	44	304	3

50	*Angelica glauca* Edgew.	77	2	8	40	4	12	13	2	7	37	1	3	0	0	0	167	2
51	*Apluda mutica* (L.) Hack	88	3	13	40	3	9	61	6	21	0	0	0	0	0	0	188	2
52	*Aqueligea fragrans* Benth.	0	0	0	13	1	3	0	0	0	16	1	3	0	0	0	29	1
53	*Arnebia benthamii* Wallich ex. G. Done	0	0	0	0	1	3	0	0	0	95	5	16	12	3	11	107	1
54	*Asparagus racemosus* Willd.	13	1	4	23	5	15	0	0	0	0	0	0	0	0	0	36	3
55	*Asperula oppositifolia* Reg. & Schmalh.	60	2	8	24	3	9	28	1	4	13	1	3	0	0	0	125	2
56	*Asplenium adiantum-nigrum*	0	0	0	18	1	3	0	0	0	0	0	0	0	0	0	18	1
57	[5]***Aster falconeri* (C. B. Clarke) Hutch**	0	0	0	0	0	0	0	0	0	78	3	10	165	13	48	243	5
58	*Astragalus anisacanthus* Boiss.	77	6	25	63	5	15	92	5	18	39	2	6	0	0	0	271	2
59	*Astragalus scorpiurus* Bunge	97	5	21	93	6	18	69	7	25	37	1	3	0	0	0	296	2
60	*Bergenia ciliata* (Haw.) Sternb.	0	0	0	37	3	9	9	1	4	0	0	0	0	0	0	45	4
61	[4]***Bergenia stracheyi* (Hook. f. & Thoms) Engl**	0	0	0	100	4	12	0	0	0	550	13	42	308	9	33	958	4
62	*Bistorta affinis* (D.Don) Green	0	0	0	110	12	35	31	2	7	450	10	32	197	14	52	788	4
63	*Bistorta amplexicaulis* (D. Don)	95	9	38	30	3	9	39	2	7	16	1	3	0	0	0	180	4
64	*Bromus hordeaceus* L.	134	10	42	65	2	6	80	3	11	0	0	0	0	0	0	279	4
65	*Caltha alba* Jack. Ex Comb	111	8	33	52	4	12	0	1	4	19	1	3	0	0	0	182	4
66	*Capsella bursa-pastoris* (L.) Medic.	62	5	21	18	1	3	6	1	4	0	0	0	0	0	0	86	3
67	*Cassiope fastigiata* (Wallich) D. Done	0	0	0	0	0	0	0	0	0	49	2	6	0	0	0	49	1
68	*Cerastium fontanum* Baumg.	193	11	46	147	6	18	167	11	39	159	2	6	0	0	0	667	2
69	*Chenopodium album* L.	132	5	21	27	3	9	38	1	4	0	0	0	0	0	0	196	2
70	*Clematis montana* Buch.-Ham. ex DC	15	1	4	0	0	0	78	5	18	17	2	6	0	0	0	110	4
71	*Colchicum luteum* Baker	0	0	0	19	2	6	59	2	7	153	10	32	30	0	0	261	3
72	*Convolulus arvensis* L.	40	3	13	0	0	0	0	0	0	18	1	3	0	0	0	57	1
73	*Corydalis diphylla* Wall.	0	0	0	57	4	12	57	6	21	72	3	10	9	1	4	194	2
74	*Corydalis govaniana* Wall.	0	0	0	16	2	6	36	2	7	78	4	13	0	0	0	130	2
75	*Cynoglossum glochidiatum* Wall. Ex Benth	219	15	63	156	18	53	154	9	32	159	9	29	104	1	4	792	2
76	*Cynoglossum himaltoni*	59	5	21	56	5	15	29	3	11	107	4	13	11	1	4	261	2
77	*Cynoglossum lanceolatum* L.	0	0	0	0	0	0	7	1	4	0	0	0	0	0	0	7	1

78	*Cyperus niveous*	126	8	33	146	9	26	42	3	11	65	4	13	0	0	0	379	3
79	*Cypripedium cordigerum* D. Don	6	1	4	28	4	12	0	0	0	0	0	0	0	0	0	34	1
80	*Dactylis glomerata* L.	262	11	46	31	3	9	68	3	11	0	0	0	0	0	0	361	3
81	*Dactylorhiza hatagirea* (D. Don) Soo	21	3	13	0	0	0	8	1	4	0	0	0	0	0	0	29	1
82	*Dioscorea deltoidea* Wall.	25	1	4	0	1	3	5	3	11	0	0	0	0	0	0	30	1
83	*Draba oreades* Schrenk	9	3	13	28	2	6	17	2	7	13	1	3	19	1	4	85	2
84	*Dracocephalum nutans* L.	0	0	0	25	2	6	0	0	0	51	3	10	39	2	7	115	1
85	*Dryopteris juxtapostia* Christ	49	3	13	66	6	18	32	1	4	0	0	0	0	0	0	147	2
86	[3]***Dryopteris stewartii* Fras.-Jenk.**	176	8	33	49	3	9	509	22	79	57	2	6	0	0	0	791	3
87	*Eclipta prostrata* L.	46	5	21	3	1	3	0	0	0	0	0	0	0	0	0	49	3
88	*Epilobium angustifolium* L.	40	3	13	0	1	3	0	0	0	0	0	0	0	0	0	40	1
89	*Equisetum arvense* L.	75	5	21	9	2	6	0	0	0	0	0	0	0	0	0	84	3
90	*Eragrostis cilianensis* (All.) Lut. ex F.T. Hubbard	85	5	21	24	1	3	0	0	0	0	0	0	0	0	0	109	3
91	[3]***Eremurus himalaicus* Baker**	54	3	13	14	0	0	577	22	79	149	3	10	0	0	0	794	4
92	*Erigeron multiradiatus* (Lindl. Ex DC) C. B. Clarke	37	1	4	11	3	9	0	0	0	0	0	0	0	0	0	48	1
93	*Erysimum melicentae* Dunn.	38	5	21	0	0	0	19	1	4	0	0	0	0	0	0	57	3
94	*Euphorbia wallichii* Hook. f.	0	0	0	17	3	9	9	1	4	139	5	16	0	2	7	165	1
95	*Euphrasia himalayica* Wetts.	83	7	29	84	11	32	57	5	18	104	1	3	0	0	0	328	2
96	[2]***Fragaria nubicola* Lindl. Ex Lacaita**	354	17	71	507	28	82	225	20	71	389	12	39	154	4	15	1629	2
97	*Fritillaria roylei* Hook. f.	15	1	4	9	1	3	0	0	0	0	0	0	0	0	0	24	1
98	*Gagea elegans* Wall. Ex D. Don	0	0	0	30	3	9	18	1	4	151	8	26	15	2	7	214	3
99	*Galium aparine* L.	67	4	17	81	3	9	22	1	4	37	0	0	0	0	0	206	3
100	*Galium asperuloides*	63	2	8	66	2	6	93	6	21	7	1	3	0	0	0	230	2
101	*Gentiana carinata* Griseb	0	0	0	0	3	9	65	1	4	158	1	3	199	15	56	421	4
102	*Gentiana kurroo* Royle	0	0	0	0	0	0	0	0	0	44	2	6	26	3	11	70	1
103	*Gentiana moorcroftiana* (Wallich ex G. Don) Airy Shaw	0	0	0	32	3	9	18	2	7	152	5	16	10	4	15	201	3
104	*Gentianodes argentia* Omer, Ali & Qaiser	0	0	0	0	1	3	89	3	11	18	1	3	8	1	4	115	3
105	*Geranium nepalense* Sweet.	0	0	0	17	1	3	5	1	4	64	3	10	0	0	0	86	1
106	*Geranium polyanthes* Edgew & Hook. F	0	0	0	13	7	21	26	2	7	140	4	13	9	3	11	188	3

107	*Geranium wallichianum* D. Don ex. Sweet	30	3	13	8	3	9	13	1	4	103	5	16	0	1	4	154	2
108	*Geum elatum* Wall. Ex G. Don	25	2	8	14	2	6	7	1	4	28	2	6	0	0	0	74	2
109	*Gnaphalium affine* D. Don	12	1	4	97	10	29	22	3	11	157	8	26	165	7	26	453	3
110	*Gratiola officinalis* L.	6	1	4	3	1	3	0	0	0	0	0	0	0	0	0	9	1
111	*Hackelia uncinata* (Royle ex Benth) Fischer	50	3	13	108	12	35	120	12	43	156	8	26	28	2	7	462	2
112	*Heracleum candicans* Wall. ex DC.	28	4	17	0	0	0	0	0	0	0	0	0	0	0	0	28	1
113	*Hyoscyamus niger* L.	15	1	4	0	0	0	0	0	0	0	0	0	0	0	0	15	1
114	*Hypericum perforatum* L.	152	10	42	0	1	3	90	5	18	0	0	0	0	0	0	242	4
115	*Impatiens edgeworthii* Hook.f.	57	1	4	57	9	26	0	0	0	0	0	0	0	0	0	114	4
116	[1]***Impatiens bicolor*** **Royle**	214	14	58	154	15	44	67	9	32	45	3	10	0	0	0	480	3
117	*Inula grandiflora* Willd.	11	0	0	0	0	0	0	0	0	20	1	3	0	0	0	31	1
118	*Inula multiradiata*	30	1	4	0	0	0	0	0	0	0	0	0	0	0	0	30	1
119	[5]***Iris hookeriana*** **Foster**	0	0	0	52	5	15	29	2	7	526	12	39	967	25	93	1574	4
120	*Juncus membranaceus* Royle ex D. Don	13	1	4	17	1	3	11	1	4	156	3	10	0	0	0	198	2
121	*Lathyrus pratensis* L.	8	1	4	6	2	6	0	0	0	0	0	0	0	0	0	14	1
122	*Leucas cephalotes* (Roth) Spreng.	40	1	4	0	0	0	23	2	7	0	0	0	0	0	0	63	1
123	*Malva neglecta* Wallr	167	18	75	118	11	32	236	17	61	144	6	19	3	1	4	669	2
124	*Mentha longifolia* (L.) Hudson.	5	1	4	76	2	6	0	0	0	0	0	0	0	0	0	81	1
125	*Mentha royleana* Benth. in Wall.	10	1	4	0	0	0	0	0	0	0	0	0	0	0	0	10	1
126	*Minuartia kashmirica* (Edgew) Mattf	0	0	0	16	3	9	0	0	0	77	3	10	16	2	7	109	1
127	*Morina longifolia* Wall. ex. Dcs	0	0	0	20	2	6	0	0	0	16	1	3	0	0	0	36	1
128	*Nepeta laevigata (D. Done) Hand.-Mazz*	0	0	0	46	5	15	19	3	11	50	1	3	0	0	0	114	2
129	[1]***Onopordum acanthium*** **L.**	143	18	75	112	16	47	139	10	36	76	1	3	0	0	0	469	2
130	*Onosma bracteatum* Wall.	8	1	4	47	6	18	55	3	11	23	1	3	0	0	0	134	2
131	*Origanum vulgare* L.	102	10	42	4	1	3	57	3	11	0	0	0	0	0	0	163	4
132	*Orobanche alba* Stephen ex Wallid	0	0	0	0	0	0	9	1	4	15	1	3	0	0	0	24	1
133	*Oxyria digyna* L.	48	6	25	165	15	44	91	4	14	79	3	10	0	0	0	383	3
134	*Oxytropis cachemiriana* Camb.	144	8	33	40	2	6	7	3	11	0	0	0	0	0	0	191	4
135	*Paeonia emodi* Wall. Ex Royle	0	0	0	17	2	6	0	0	0	0	0	0	0	0	0	17	1
136	*Parnassia nubicola* Wall.	0	0	0	24	4	12	36	2	7	41	1	3	0	0	0	100	1

137	*Pedicularis pectinata* Wall. ex. Benth	0	0	0	0	0	0	0	0	0	63	1	3	49	3	11	112	1
138	*Pennisetum lanatum* Klotzsch	0	1	4	12	2	6	69	1	4	3	1	3	0	0	0	84	1
139	*Phleum alpinum* L.	5	1	4	7	2	6	23	2	7	28	1	3	0	0	0	63	1
140	*Phlomis bracteosa* Royle ex Benth.	0	0	0	0	0	0	4	1	4	60	2	6	0	0	0	60	1
141	*Pimpinella acuminata* (Edgew.) C.B. Clarke	11	1	4	6	1	3	3	1	4	0	0	0	0	0	0	20	3
142	*Pimpinella diversifolia* (Wall.) DC	40	2	8	0	0	0	18	1	4	0	0	0	0	0	0	58	1
143	*Plantago himalaica* Pilger	6	2	8	39	2	6	0	0	0	46	2	6	0	0	0	92	1
144	[1]***Plantago lanceolata* L.**	143	14	58	69	10	29	124	12	43	69	3	10	0	0	0	406	2
145	*Plantago major* L.	58	7	29	67	8	24	46	4	14	106	5	16	11	4	15	287	2
146	[4]***Poa alpina* L.**	82	5	21	158	14	41	49	5	18	898	19	61	406	16	59	1593	2
147	*Poa annua* L.	40	4	17	0	0	0	21	1	4	0	0	0	0	0	0	61	1
148	*Poa stewartiana* Bor in Kew Bull.	98	3	13	97	11	32	61	6	21	53	1	3	0	0	0	309	2
149	*Podophyllum hexandrum* Royle	21	2	8	26	3	9	0	0	0	26	1	3	0	0	0	72	1
150	*Polygonum aviculare* L.	85	2	8	126	10	29	111	5	18	163	3	10	85	2	7	569	2
151	*Polygonum alpinum* (All.) Schur	0	0	0	0	0	0	0	0	0	513	9	29	128	15	56	641	1
152	*Polygonum molle* (D.Done) Hara	126	6	25	98	3	9	47	3	11	79	2	6	0	0	0	351	2
153	*Polygonum plebejum* R. Br	105	6	25	26	5	15	14	2	7	21	0	0	0	0	0	166	4
154	*Polygonatum verticillatum (*L.) Allioni	59	5	21	77	7	21	98	10	36	122	4	13	30	1	4	386	2
155	*Potentilla anserina* L.	29	4	17	109	5	15	102	11	39	255	9	29	72	3	11	567	2
156	*Potentilla atrosanguinea* Lodd.	0	0	0	25	4	12	10	2	7	181	7	23	0	0	0	216	2
157	*Potentilla nepalensis* Hook. f.	33	2	8	54	5	15	58	9	32	272	7	23	132	7	26	549	2
158	*Primula calderana* Balf. F & cooper	0	0	0	0	0	0	0	0	0	7	1	3	75	4	15	82	1
159	*Primula denticulata* Smith	0	0	0	29	7	21	0	0	0	82	4	13	34	2	8	145	3
160	*Primula glomerata* Pax.	0	0	0	0	2	6	0	0	0	39	2	6	19	2	7	58	1
161	*Primula rosea* Royle	0	0	0	29	3	9	0	0	0	66	4	13	128	8	30	223	1
162	*Prunella vulgaris* L.	36	1	4	18	4	12	17	1	4	0	0	0	0	0	0	71	1
163	*Pseudomertensia parvifolia* (Decne)	26	3	13	11	1	3	0	0	0	0	0	0	0	0	0	37	1
164	*Pseudomertensia moltkioides* Royle & Kazmi	0	0	0	0	0	0	0	0	0	34	2	6	51	4	15	85	1
165	*Pseudomertensia nemorosa* (D. C) R. Stewart & Kazmi	0	0	0	0	0	0	0	0	0	31	1	3	47	4	15	79	1

166	*Pteris vittata* L.	0	0	0	4	4	12	7	1	4	35	3	9	0	0	0	47	2
167	[5]***Ranunculus hirtellus* Royle ex D. Don**	0	0	0	16	1	3	0	0	0	0	0	0	164	6	22	180	1
168	*Ranunculus laetus* Wall. Ex Hook.f. & Thoms	9	1	4	20	3	9	0	0	0	20	1	3	32	1	4	80	1
169	*Ranunculus muricatus* L.	47	2	8	26	3	9	0	0	0	0	0	0	0	0	0	73	1
170	[4]***Rheum australe* D.Don**	0	0	0	89	8	24	28	5	18	433	13	42	765	20	74	1320	4
171	*Rumex dentatus* L.	195	13	54	105	22	65	126	16	57	114	5	16	92	6	22	632	2
172	*Rumex nepalensis* Sprenge	45	4	17	23	3	9	0	0	0	51	1	3	28	3	11	147	1
173	*Salvia lanata* Roxb.	20	1	4	24	2	6	44	2	7	0	0	0	0	0	0	88	1
174	*Salvia moorcroftiana* Wallich ex Benth	12	1	4	30	3	9	50	4	14	8	1	3	0	0	0	103	2
175	*Saussurea albescens* Hook. f. & Thoms	4	1	4	24	3	9	21	2	7	0	0	0	0	0	0	59	1
176	*Saussurea fastuosa* (Decne.) Schultz-Bip	0	0	0	24	2	6	5	1	4	0	0	0	0	0	0	29	1
177	*Saussureagraminifolia* Wallich ex DC	0	0	0	21	2	6	0	0	0	27	3	10	37	1	4	85	1
178	*Scirpus palustris* L.	19	2	8	72	5	15	0	0	0	35	2	6	0	0	0	126	1
179	*Sedum album* L.	35	1	4	54	8	24	20	5	18	145	4	13	50	7	26	304	3
180	*Sedum ewersii* Ledeb	0	0	0	7	1	3	43	2	8	68	6	19	77	6	22	195	4
181	*Senecio chrysanthemoides* DC	0	0	0	80	3	9	14	1	4	0	0	0	0	0	0	94	1
182	[4]***Sibbaldia cuneata* O. Kuntze**	23	3	13	77	7	21	0	0	0	672	16	52	390	19	70	1162	3
183	*Silene vulgaris* Garck	17	4	17	0	0	0	22	1	4	0	0	0	0	0	0	39	2
184	*Stipa himalaica* Rozhev.	43	2	8	24	4	12	5	1	4	0	0	0	0	0	0	72	2
185	*Strobilanthes glutinosus* Nees	23	1	4	0	0	0	36	2	7	0	0	0	0	0	0	59	1
186	*Swertia ciliata* (D. Don ex G. Don) B. L. Burtt	48	4	17	19	5	15	0	0	0	16	1	3	0	0	0	82	2
187	*Swertia speciosa* D. Don	7	1	4	12	1	3	0	0	0	0	0	0	0	0	0	19	1
188	*Sisymbrium irio* L.	44	3	13	0	0	0	0	0	0	23	1	3	0	0	0	67	1
189	[3]***Taraxacum officinale* Weber**	194	19	79	104	16	47	205	26	93	161	7	23	24	5	19	689	2
190	*Thymus linearis* Benth.	186	11	46	274	24	71	363	18	64	1000	26	84	509	15	56	2333	2
191	[1]***Trifolium repens* L.**	251	16	67	14	2	6	92	3	11	0	0	0	0	0	0	357	4
192	*Trillidium govanianum* (Wall. Ex D. Don) Kunth	0	0	0	48	3	9	0	0	0	0	0	0	0	0	0	48	1
193	*Tussilago farfara* L.	27	2	8	16	1	3	0	0	0	0	0	0	0	0	0	43	1

194	*Urtica dioica* L.	144	12	50	52	7	21	137	1	4	48	1	3	25	1	4	407	3
195	*Valeriana pyrolifolia* Decne	4	1	4	51	5	15	0	0	0	86	7	23	42	3	11	185	2
196	*Verbascum thapsus* L.	102	12	50	77	12	35	154	20	71	101	3	10	0	0	0	434	3
197	*Vicia bakeri* Ali.	43	2	8	0	0	0	0	0	0	0	0	0	0	0	0	43	1
198	*Viola canescens* Wall. Ex Roxb.	161	11	46	166	27	79	183	17	61	626	22	71	519	23	85	1656	2

University of Leicester Ethics Review Sign Off Document

To: **SHUJAUL M KHAN**

Subject: Ethical Application Ref: **smk26-7a99**

(Please quote this ref on all correspondence)

10/04/2010 10:14:20

Biology

Project Title: **PLANT COMMUNITIES AND VEGETATION ECOSYSTEM SERVICES IN THE NARAN VALLEY, WESTERN HIMALAYA**

Thank you for submitting your application which has been considered.

This study has been given ethical approval, subject to any conditions quoted in the attached notes.

Any significant departure from the programme of research as outlined in the application for research ethics approval (such as changes in methodological approach, large delays in commencement of research, additional forms of data collection or major expansions in sample size) must be reported to your Departmental Research Ethics Officer.

Approval is given on the understanding that the University Research Ethics Code of Practice and other research ethics guidelines and protocols will be compiled with

- http://www2.le.ac.uk/institution/committees/research-ethics/code-of-practice

- http://www.le.ac.uk/safety/

The following is a record of correspondence notes from your application **smk26-7a99.** Please ensure that any proviso notes have been adhered to:-

--- END OF NOTES ---

Appendix 5.2 Sample of questionnaire used durindg ethnobotanical data collection

Name ___________________________ Gender _____________ Age _________ Date. / /

Level of Education: Illiterate/ Primary/middle/secondary/Diploma/University Role in Village: Chief/Elder/Councillor/Farmer/other

S. N	Botanical Name	Local Name	Traditional/indigenous uses									Preferen ce	Access	If medicinal		Recipe	Market informations			Tre nd	Thre ats
			1 F	2 Fd	3 Gr	4 Ti	5 Fu	6 Ae	7 Md	8, 9 Ot		1,2, 3	DS/NB/ FA	Part used	Uses						
1	*Abie pind*	Partal/achar																			
2	*Acer caes*	Chinar ranga																			
3	*Aesc indi*	Bankhore/Javaz																			
4	*Betu util*	Braj/Birch																			
5	*Cedr deod*	Diar/Ranzrra																			
6	*Craet oxy*	Tampasa																			
7	*Jugl reg*	Akhor/Ghuz																			
8	*Picea smit*	Kandal																			
9	*Pinus wall*	Sraf																			
10	*Popl gla*	Jangali sufeda																			
11	*Prun cer*	Alubaloo																			
12	*Ulmus wall*	Kahey																			
13	*Artem abse*	Chahu/tarkha																			
14	*Artem vulg*	Chahu/javkey																			
15	*Berbe pseud*	Sumbal/Kvarey																			
16	*Coton cash*	Kharava																			
17	*Coton micr*	Mamanna/Kharava																			
18	*Ephed gera*																				
19	*Indig heter*	Kainthi/Ghvareja																			
20	*Junip comm*	Gugarr/Bhentri																			
21	*Junip exce*	Gugarr																			
22	*Junip squam*	Gugarr/Bhentri																			
23	*Rhodo hype*	Gul namer																			

24	*Ribie alp*																				
25	*Rosa webb*	Jangali Gulab																			
26	*Rubus sanc*	Alish																			
27	*Salix flab*	Tora wala																			
28	*Sambu wigh*	Mushkiara																			
29	*Sorba tome*	Jeejrae																			
30	*Tamar dio*	Ghaz																			
31	*Vibur coti*	Taliana																			
32	*Vibur gran*	Guch																			
33	*Acan lyco*	Gat butay																			
34	*Achil mill*	Birangesif/Jarri																			
35	*Acon het*	Patris/sarba vala																			
36	*Acon viol*	Atees/Zahar																			
37	*Acta spica*	Beenakae																			
38	*Adian ven*	Sumbal																			
39	*Allia pet*																				
40	*Alliu hum*	Jangali piaz																			
41	*Alop arun*																				
42	*Anaph trip*																				
43	*Andro haz*																				
44	*Andro prim*																				
45	*Andro rotu*																				
46	*Anem falc*																				
47	*Anem obtu*																				
48	*Anem rupi*																				
49	*Anem tetra*																				
50	*Ang glau*	Chora chora																			
51	*Aplu muti*																				
52	*Aquel fra*																				
53	*Arneb bent*																				
54	*Aspar race*	Nanoor/shalgvatey																			
55	*Asper oppo*																				

56	*Asple adia*																				
57	*Aster falc*																				
58	*Astr anis*																				
59	*Astr scor*																				
60	*Berg cili*	But pewa/Zakhme hayat																			
61	*Berg strac*	But pewa/Zakhme hayat																			
63	*Bist affi*	Anjabar																			
62	*Bist ampl*	Masloon																			
64	*Brom hord*																				
65	*Calt alba*	Baringu																			
66	*Caps burs*	Chambraka																			
67	*Cass fast*																				
68	*Ceras font*																				
69	*Chen alb*	Sarmay																			
70	*Clem mont*																				
71	*Colch lute*	Qaimat-guley																			
72	*Conv arve*	Sahar gulay																			
73	*Coryd dip*																				
74	*Coryd gov*	Desi mamera																			
75	*Cynog gloc*																				
76	*Cynog him*																				
77	*Cynog lanc*																				
78	*Cyper niv*	Deela																			
79	*Cypr cord*	Shakalkal																			
80	*Dact glom*																				
81	*Dacty hat*	Salap																			
82	*Dios delt*	Kirtha																			
83	*Drab orea*																				
84	*Draco nut*																				
85	*Dryop juxt*	Kwanjay																			
86	*Dryop stew*	Lewaney kwanjey																			
87	*Eclip pros*																				

88	*Epil angu*																				
89	*Equi arve*	Nari/Bandakey																			
90	*Erag cili*																				
91	*Erem hima*	Sheela																			
92	*Erig mult*																				
93	*Erys mel*																				
94	*Euph him*																				
95	*Euph wal*	Arghamala/shangla																			
96	*Frag nub*	Jangali strawberry																			
97	*Frit royl*																				
98	*Gag eleg*																				
99	*Gali apar*	Goose grass																			
100	*Gali aspe*																				
101	*Gent car*																				
102	*Gent kur*	Linkath																			
103	*Gent moor*	Bhangara																			
104	*Genti arg*																				
105	*Gera nep*																				
106	*Gera poly*																				
107	*Gera wall*	Ratan jog/srazela																			
108	*Geum elat*																				
109	*Gnap affi*																				
110	*Grat offic*																				
111	*Hack unci*																				
112	*Hera cand*																				
113	*Hyos niger*	Khurasani ajwain																			
114	*Hyp perf*	Balsana/shin chae																			
115	*Impat edge*	Gule mehendi/Atraangey																			
116	*Impet bico*	Gule mehendi/Atraangey																			
117	*Inul grand*	Kuth																			
118	*Inul mult*																				
119	*Iris hook*	Gandechar																			

120	*Junc memb*	Gawag/Jaba																			
121	*Lath prat*																				
122	*Leu ceph*	Gomma																			
123	*Malv negl*	Sonchal/panerak																			
124	*Ment long*	Safid Podina																			
125	*Ment royl*	Podina																			
126	*Minu kash*																				
127	*Mori longi*																				
128	*Nepet laev*	Desi jalbhanga/																			
129	*Onop acan*																				
130	*Onos bract*	Gowzoban																			
131	*Orig vulg*	Jangali majorum																			
132	*Orob alba*																				
133	*Oxyr digy*																				
134	*Oxyt cach*																				
135	*Paeo emod*	Mamekh																			
136	*Parn nubic*																				
137	*Pedic pect*																				
138	*Penn lanat*	Jangali bajra																			
139	*Phle alpi*																				
140	*Phlom brac*																				
141	*Pimp acum*																				
142	*Pimp divers*	Tarpakhi/watani kaga																			
144	*Plant hima*	Jabae																			
143	*Plant lanc*	Ipeghol/Jabae																			
145	*Plant major*	Ipeghol/Jabae																			
146	*Poa alpin*	Wakha																			
147	*Poa annu*	Wakha																			
148	*Poa stew*	Wakha																			
149	*Podo hex*	Kakorra/Gangorra																			
150	*Poly alpi*																				
151	*Poly avic*	Bandakey																			

152	*Poly moll*																				
153	*Poly pleb*																				
154	*Polyg vert*	Baramol/Noorealam																			
155	*Pote ans*	Spangji																			
156	*Pote atro*																				
157	*Pote nep*																				
158	*Prim cald*																				
159	*Prim dent*	Mamera																			
160	*Prim glum*																				
161	*Prim rose*	Da Zmake gul																			
162	*Prun vulg*	Ustakhdus																			
163	*Pseod par*																				
164	*Pseud mol*																				
165	*Pseud nem*																				
166	*Pter vitt*	Pani butay																			
167	*Ranu hirt*																				
168	*Ranu laet*																				
169	*Ranu muri*	Ziarr gulay																			
170	*Rheu aust*	Chotial																			
171	*Rume dent*	Shalkhey																			
172	*Rume nepa*	Ambavati																			
173	*Salv lana*	Kiyan																			
174	*Salv moor*	Kalizarri																			
175	*Saus fast*																				
176	*Saus albe*	Kuth																			
177	*Saus gram*																				
178	*Scirp pal*																				
179	*Sedum alb*																				
180	*Sedum ewe*																				
181	*Sene chry*	Ragwort																			
182	*Sibb cune*																				
183	*Sile vulg*	Barra takla																			

184	*Stip himal*																				
185	*Stro glut*																				
186	*Swer cili*	Chirita																			
187	*Swer spec*																				
188	*Sisym irio*	Khubkalan																			
189	*Tarax offic*	Hand/Gulsag/Booda boodae																			
190	*Thym line*	Bazori/Sperkae/Ban ajwain																			
191	*Trifo repe*	Chapatra/Dutch clover																			
192	*Tril gova*	Tandhi jarri																			
193	*Tuss farf*	Funjiwam																			
194	*Urti dioi*	Seezunkey/bichu bhuti																			
195	*Vale pyrol*	Mushk bala/shangitae																			
196	*Verb thap*	Kharghvag/																			
197	*Vici bak*	Rawari/jamdar																			
198	*Viol cane*	Gule banafsha																			

Local traditional uses:

1 *F* Food
2 *Fd* Fodder
3 *Gr* Grazing
4 *Ti* Timber
5 *Fu* Fuel
6 *Ae* Aesthetic
7 *Md* Medicinal
8,9 *Ot* Any other

If Medicinal; Then Part used and recipe preparation (form of use)
Preference ; Preference of plant for specific use; 1,2,3,4,5,6,7,8,9.
Accessibility/Easiness; Time to reach and collect; Door step (DS), Nearby (NB), Far away (FA)
Market information; Selling in market; if Yes (Y) then price etc
Trend; Extent of Species: Increasing (I), Decreasing (D) or No visible Change (NC), (In light of past history)
Threats; With reference to traditional wisdom/ available information Cutting/collection/disease/climatic change

Appendix 5.3 Plant species with their local names, part used and traditional medicinal uses

S. N	Botanical Name	Loccal Name	Part used	Uses
1	*Aesculus indica* (Wall. Ex Camb) Hook.	Bankhore/Javaz	Fruit	Powder of the dried fruit is used in colic.
2	*Betula utilis* D. Don	Braj/Birch	Leaves, bark	Tea made up of young leaves is used as diuretic and rheumatism; rarely used for gall bladder stone.
3	*Cedrus deodara* (Roxb. Ex Lamb.) G. Don	Diar/Ranzrra	oil	Oil are extracted from wood through burning and used to cure skin disorders.
4	*Craetegus oxycantha* L.	Tampasa	Fruits and flowers	Fruit and flowers are considered as heart tonic.
5	*Juglans regia* L.	Akhor/Ghuz	Fruits, bark	Nuts are believed to use as brain tonic, bark in toothache.
6	*Pinus wallichiana* Jackson	Sraf	Resin, woods	Resin is considered as diaphoretic, also applied to the cracked (wounded) heels.
7	*Prunus cerasoides* D. Don	Alubaloo	Bark, fruit	Decoction of the bark is taken as astringent and fruit as nerve tonic
8	*Ulmus wallichiana* Planch.	Kahey	Bark	Considered highly medicinal for digestive tract diseases.
9	*Artemisia absinthium* L	Chahu/tarkha	Flowering tops	Crushed powders are used as purgative and anthelmintic.
10	*Artemisia vulgaris* L.	Chahu/javkey	young shoots	Extract of its young shoots is used to regulate monthly cycle.
11	*Berberis pseudumbellata* Parker	Sumbal/Kvarey	Root, bark & fruit	Powder of roots bark is used in fever, backache, jaundice, and UTI. Fruit is considered as tonic.
12	*Cotoneaster microphyllus* Wall. ex Lindl	Mamanna/Kharava	Leaves and shoots	Tea prepared from leaves is used as astringent.
13	*Ephedra gerardiana* Wall. Ex Stapf	Epedra	Whole plant	Powder of the crushed plant and some time its tea is used for TB, asthma, astringent, relaxation of bronchial muscles.
14	*Indigofera heterantha* Wall. Ex Brand	Kainthi/Ghvareja	Whole plant	Powder of the root bark and also is used in hepatitis, whooping cough. Its extract is used as dye for blackening of hairs.
15	*Juniprus communis* L.	Gugarr/Bhentri	Berries	Berry powder is considered as diuretic, carminative and stimulant
16	*Juniprus excelsa* M.Bieb	Gugarr	Fruits	Fruits are used as diuretic, Carminative in gonorrhoea, Leucorrhoea and gleets.
17	*Rhododendron hypenanthum* Balf.f	Tazak Tusum/Gul namer	Leaves	Fresh leaves of it are aromatic and stimulant.
18	*Ribies alpestre* Decne		Berries	Berry fruits are considered as cardiac tonic.
19	*Rosa webbiana* Wallich ex Royle	Jangali Gulab	Flowerss, bark	Processed flowers (Arq) are used in asthma While bark is considered as mild astringent.
20	*Rubus sanctus* Schreber	Alish	Whole plant	Fruit is laxative and dysentery; Decoction of leaves and young shoots

				is used in whooping cough.
21	*Sambucus wightiana* Wall. Ex Wight & Arn	Mushkiara	Whole plant	Decoction and powder is used as expectorant and diaphoretic.
22	*Viburnum cotinifolium* D. Don	Taliana	Fruits	Fruits are taken as uterine sedative and haemostatic usually by female
23	*Viburnum grandiflorum* Wall. Ex DC.	Guch	Fruits	Fruits are antispasmodic and uterine sedative.
24	*Achillia millefolium* L.	Birangesif/Jarri	Whole plant	Less concentrated decoction mixed with milk is taken in stomach disorders and diarrhoea.
25	*Aconitum heterophyllum* Wall.	Patris/sarba vala	Rhizome	Pills of rhizome powder coated in local butter are used as aphrodisiac and general body tonic.
26	*Aconitum violaceum* Jacquen ex. Stapf	Atees/Zahar	Paired roots	Powders are used in sciatica and as pain killer.
27	*Actaea spicata* L.	Beenakae	Root, berries	Berries are used as sedative; Extract is applied externally for the treatment of rheumatism.
28	*Adiantum venustum* D. Don	Sumbal	Whole plant	Decoction is taken orally for pulmonary disorders.
29	*Allium humile* Kunth.	Jangali piaz	Whole plant	Fresh plant is taken as salad for gastrointestinal disorders and UTI.
30	*Angelica glauca* Edgew.	Chora chora	Dried roots	Powdered roots are taken with milk for gastrointestinal disorders.
31	*Asparagus racemosus* Willd.	Nanoor/shalgvatey	Root & stem	Paste of powder is applied for wounds healing (Antisepticc); powders are taken orally as diuretic, aphrodisiac and antidysentric.
32	*Bergenia ciliata* (Haw.) Sternb.	But pewa/Zakhme hayat	Latex & Rhizome	Latex is applied externally for gum diseases and decoction of rhizome is used in kidney stones.
33	*Bergenia stracheyi* (Hook. f. & Thoms) Engl	But pewa/Zakhme hayat	Rhizome, Latex	Latex is applied externally for gum diseases; Decoction of rhizome is used in kidney stones and as astringent.
34	*Bistorta affinis* (D.Don) Green	Anjabar	Rhizome	Powders prepared from rhizome taken with milk as anti-inflammatory & astringent.
35	*Bistorta amplexicaulis* (D. Don)	Masloon	Rhizome	Powder mixed with little salt is used for sore throat, inflammation of mouth and tongue.
36	*Caltha alba* Jack. Ex Comb	Baringu	Roots & airial parts	Roots decoction is used as mouth wash; young shoots and leaves are cooked as vegetable for and considered as digestive.
37	*Capsella bursa-pastoris* (L.) Medic.	Chambraka	Aerial parts, seeds	Aerial parts are cooked and used in diarrhoea; Seeds powder is taken with water to cure hypertension.
38	*Chenopodium album* L.	Sarmay	Leaves & shoots	Leaves and shoots are cooked and taken as anthelmentic, laxative and diuretic.
39	*Clematis montana* Buch.-Ham. ex DC	Zelae	Flowers & Fruits	Flowers and fruits powder is taken for treating the diarrhoea & dysentery.
40	*Colchicum luteum* Baker	Qaimat-guley/Suranjane talkh	Dried corms	Very small amount of powder is given by Hakims (specialist people) in local oils as aphrodisiac and in rheumatism, spleen & liver diseases.

41	*Convolulus arvensis* L.	Sahar gulay	Roots	Powder is considered as purgative & used in evacuation of bowels.
42	*Corydalis govaniana* Wall.	Desi mamera	Whole plant	Juice o the plant is used as diuretic powders of flowers are used in treating ophthalmic.
43	*Cypripedium cordigerum* D. Don	Shakalkal	Rhizome	Powders are used by experts as anti spasmodic and nerve stimulant
44	*Dactylorhiza hatagirea* (D. Don) Soo	Salap	Tubers	Tubers powders are used by hakims as aphrodisiac & nerve tonic.
45	*Dioscorea deltoidea* Wall.	Kirtha	Tubers	Tubers are crushed to powder form and uses as diuretic, and anthelmentic; Also used in butter as tonic.
46	*Dryopteris juxtapostia* Christ	Kwanjay	Young shoots	Young shoots are cooked as pot herb and considered as digestive and purgative.
47	*Equisetum arvense* L.	Nari/Bandakey	Aerial parts	Powder prepare from aerial parts are used for bone strengthening, hairs and nail development and weakness caused by TB.
48	*Eremurus himalaicus* Baker	Sheela	Young shoots	Young shoots are cooked and used as digestive.
49	*Euphorbia wallichii* Hook. f.	Arghamala/shangla	Latex	Latex is extracted and mixed with milk in small amount and used against worms, as cathartic, purgative and diaphoretic.
50	*Euphrasia himalayica* Wetts.		Whole Plant	Local people cook and use it against cold, cough, sore throat
51	*Fragaria nubicola* Lindl. Ex Lacaita	Jangali strawberry	Fruits	Juice of it is considered as anti diarrhoeal, anti dysenteric. Also used in diabetes and gonorrhoea.
52	*Fritillaria roylei* Hook. f.		Bulb	Powder of the dry bulb or in fresh form mixed with butter is used as diuretic and emollient.
53	*Galium aparine* L.	Goose grass	Whole plant	Its decoction is used in urinary tract infection.
54	*Gentiana kurroo* Royle	Linkath	Root	Powdered root is used in stomach-ache, as tonic and astringent
55	*Gentiana moorcroftiana* (Wallich ex G. Don) Airy Shaw	Bhangara	Rhizome	Powder is used to stimulant appetite.
56	*Gentianodes argentia* Omer, Ali & Qaiser		Root	Decoction is used in urinary problems.
57	*Geranium nepalense* Sweet.	Lijaharri	Whole plant	Rhizome's powder and decoction of aerial parts are used for the treatment of renal infections and as astringent.
58	*Geranium wallichianum* D. Don ex. Sweet	Lijaahari/Ratan jog/srazela	Rhizome	Boiled powder is used in hypertension, gonorrhoea, and ulceration. Also considered as tonic.
59	*Hyoscyamus niger* L.	Khurasani ajwain	Leaves/seeds	Decoction extracted from boiled leaves in diluted form is used as sedative, and pain killer. Powders of the seeds are used to treat whooping cough.
60	*Hypericum perforatum* L.	Balsana/shin chae	Whole plnt	Tea prepared of young shoots is used in gastric disorders, asthma, as diuretic. Roots powders are used in irregular menstruation.
61	*Impatiens bicolor* Royle	Gule mehendi/Atraangey	Whole plant	Paste of leaves is used in rheumatism. Extract of the plant is regarded as cooling agent and cathartic.

62	*Inula grandiflora* Willd.	Kuth	Rhizome	Both powdered and fresh rhizome is used in gastric disorders, in appetite and as diuretic
63	*Iris hookeriana* Foster	Gandechar	Rhizome	Minute amount of powder of dried rhizome is used as diuretic, cathartic and in gall bladder diseases.
64	*Leucas cephalotes* (Roth) Spreng.	Gomma	Whole plant	Extraction of the plant is believed as diaphoretic and also used in scabies, cough and cold.
65	*Malva neglecta* Wallr	Sonchal/panerak	Whole plant	As a local vegetable believed as purgative and anti haemorrhoid.
66	*Mentha longifolia* (L.) Hudson.	Safid Podina	Whole plant	Fresh leaves and shoots and also its powder are used in sauces with belief of carminative, anti diarrhoeal, and anti colic effect.
67	*Mentha royleana* Benth. in Wall.	Podina	Leaves	Mixed in green teas and are used in vomiting, as cooling agent and carminative.
68	*Nepeta laevigata (D. Done) Hand.-Mazz*	Dei jalbhanga/peesho butay	Whole plant	Powders of the dried plant are used to cure cold, fever and headache.
69	*Onosma bracteatum* Wall.	Gowzoban	Whole plant	Powders are taken with water as cordial stimulant while decoction is used as anti dandruff.
70	*Origanum vulgare* L.	Jangali majorum	Whole plant	Powder mixed with milk is taken in stomach-ache, antispasmodic. Also taken with milk as antimicrobial and flavouring agent.
71	*Oxyria digyna* L.	Tarwakay	Aerial parts	Young leaves and aerial parts are used as source of vitamin C.
72	*Oxytropis cachemiriana* Camb.		Rhizome	Rhizome of the plant is traditionally used as a tooth brush to prevent toothache.
73	*Paeonia emodi* Wall. Ex Royle	Mamekh	Seeds & tubers	Paste prepared from seeds is used in rheumatism. Powdered rhizome is mixed with sweet dishes and used for the treatment of UTI and backache.
74	*Parnassia nubicola* Wall.		Whole plant	Whole plant is cooked as an vegetable (pot herb) and is exercised in digestive disorders.
75	*Pimpinella diversifolia* (Wall.) DC	Tarpakhi/watani kaga	Whole plant	Dried plant is crushed to powdered form and used as carminative and diuretic. Also used for aroma.
76	*Plantago himalaica* Pilger	Jabae	Leaves	Paste prepare from fresh leaves is used in skin problems especially soured feet.
77	*Plantago lanceolata* L.	Ipeghol/Jabae	Leave/ seeds	Decoction of boiled leaves is used in bronchitis. Seeds are taken with milk as purgative.
78	*Plantago major* L.	Ipeghol/Jabae	Root, seeds, leaves	Leaves are cooked and taken orally to cure seasonal fevers. Chopped leaves are used as poultice to cure wounds. Seeds are considered as tonic. Root decoction is taken as anti dysenteric and leaves decoction in bronchitis.
79	*Podophyllum hexandrum* Royle	Kakorra/Gangorra/may apple	Rhizome & Fruits	A poisonous plant but expert healers use it in a minute amount in mixture with other plants. Its fruit is considered as purgative and

				laxative whilst rhizome is used as anti cancer.
80	*Polygonum aviculare* L.	Bandakey	Whole plant	Aerial parts of the plant are cooked as pot herband considered as purgative and emitic
81	*Polygonum plebejum* R. Br	Baramol/Noorealam	Root	Root is boiled and mixed with butter locally for stimulate mammary glands; Also considered as demulcent.
82	*Potentilla anserina* L.	Spangji	Whole plant	Whole plant is used as anti-diarrhoeal and also in intestinal infections
83	*Primula denticulata* Smith	Mamera	Rhizome	Powdered rhizome mixed with honey is used to cure Opthalmia and Leucoderma.
84	*Prunella vulgaris* L.	Ustakhdus	Whole plant	Whole plant both in fresh and dry form is thought as expectorant, antispasmodic and anti rheumatic.
85	*Rheum australe* D.Don	Chotial	Rhizome & shoots	Leaves and shoots are used as salad for heart beating, asthma, sore eyes and body strength. Rhizome is cooked and used as astringent and diuretic
86	*Rumex dentatus* L.	Shalkhey	Roots & leaves	Root powder is considered as emollient
87	*Rumex nepalensis* Sprenge	Ambavati	Roots & leaves	Leaves are used as substitute of Rheum austral whilst its root is believed as purgative.
88	*Salvia lanata* Roxb.	Kiyan	Whole plant	Aerial parts are used as vegetable and its root powders are considered as diuretic; also used in cough & cold.
89	*Salvia moorcroftiana* Wallich ex Benth	Kalizarri	Leaves, seeds, roots	Fresh leaves are put in hot ash for a while and then used as poultice for abscesses. Cooked leaves are used in dysentery and colic.
90	*Saussurea albescens* Hook. f. & Thoms	Kuth	Roots	Roots are cooked in local butters and used as tonic, also use in treatment of stomach-ache, rheumatism and skin diseases.
91	*Silene vulgaris* Garck	Barra takla	Whole plant	Juice of it is used as digestive, fumigant and ophthalmic.
92	*Swertia ciliata* (D. Don ex G. Don) B. L. Burtt	Chirita	Whole plant	Powders are used in constipation & dyspepsia.
93	*Sisymbrium irio* L.	Khubkalan	Leaves & seeds	Seeds are used in asthma, throat & chest infection; Paste of leaves is applied to cure sunburn & enhance skin beauty
94	*Taraxacum officinale* Weber	Hand/Gulsag/Booda boodae	Roots	Roots decoction is taken as diuretic and other kidney disorders whilst powders are taken as tonic.
95	*Thymus linearis* Benth.	Bazori/Sperkae/Ban ajwain	Whole plant	Plant is used to make tea, drink, juice to cure stomach & liver complaints; Powder of aerial parts are used in cough
96	*Trifolium repens* L.	Chapatra/Dutch clover	Whole plant	Fresh plant is used as anti-anthelmentic (Cattles poison)
97	*Trillidium govanianum* (Wall. Ex D. Don) Kunth	Tandhi jarri	Roots	Powdered plant is used as tonic and emetic.
98	*Tussilago farfara* L.	Funjiwam	Whole plant	Aerial parts are cooked and used in respiratory infections

99	*Urtica dioica* L.	Seezunkey/bichu bhuti	Whole plant	Fresh leaves and shoots are cooked as pot herb and considered as diuretic also used in haemturia, menorrhoea, leucorrhoea.
100	*Valeriana pyrolifolia* Decne	Mushk bala/shangitae	Rhizome	Powdered rhizome is used to treat spasm and habitual constipation.
101	*Verbascum thapsus* L.	Kharghvag/jangali tamakoo	Whole plant	Root's powder is considered as aphrodisiac; leaves, paste is used in skin problems; leaves are also smoked as narcotic and sedative.
102	*Viola canescens* Wall. Ex Roxb.	Gule banafsha	Whole plant	Young shoots are used as diaphoretic and demulcent whilst decoction is used in sore throat and as diuretic.

Appendix 5.4 Residual values analysis (Regression analysis) of 68 plant families of the Naran Valley. The number of plant species for each family refered to the quadrat (first year) data set (No. of Repres. Spp.) and in the questionnaire data set (No. of Medic. Spp.) presented with predicted and residual values.

Case No	Family Name	No. of Repres. Spp.	No. of Medic. Spp.	Predicted Value	Residual Value
1	Polygonaceae	10	8	4.6	3.4
2	Gentianaceae	6	6	2.86	3.141
3	Lamiaceae	13	9	5.91	3.094
4	Rosaceae	14	8	6.34	1.659
5	Plantaginaceae	3	3	1.55	1.447
6	Fumariaceae	8	5	3.73	1.271
7	Pinaceae	4	3	1.99	1.012
8	Caprifoliaceae	2	2	1.12	0.882
9	Caryophyllaceae	2	2	1.12	0.882
10	Orchidaceae	2	2	1.12	0.882
11	Saxifragaceae	2	2	1.12	0.882
12	Cupressaceae	3	2	1.55	0.447
13	Alliaceae	1	1	0.68	0.317
14	Asparagaceae	1	1	0.68	0.317
15	Asphodelaceae	1	1	0.68	0.317
16	Berberidaceae	1	1	0.68	0.317
17	Betulaceae	1	1	0.68	0.317
18	Chenopodiaceae	1	1	0.68	0.317
19	Colchicaceae	1	1	0.68	0.317
20	Convolulaceae	1	1	0.68	0.317
21	Dioscoreaceae	1	1	0.68	0.317
22	Ephedraceae	1	1	0.68	0.317
23	Equisetaceae	1	1	0.68	0.317
24	Euphorbiaceae	1	1	0.68	0.317
25	Grossulariaceae	1	1	0.68	0.317
26	Hippocastanceae	1	1	0.68	0.317
27	Hypericaceae	1	1	0.68	0.317
28	Iridaceae	1	1	0.68	0.317
29	Malvaceae	1	1	0.68	0.317
30	Oleaceae	1	1	0.68	0.317
31	Paeoniaceae	1	1	0.68	0.317
32	Podophyllaceae	1	1	0.68	0.317
33	Sambucaceae	1	1	0.68	0.317
34	Solanaceae	1	1	0.68	0.317
35	Trilliaceae	1	1	0.68	0.317

36	Ulmaceae	1	1	0.68	0.317
37	Urticaceae	1	1	0.68	0.317
38	Valerianaceae	1	1	0.68	0.317
39	Violaceae	1	1	0.68	0.317
40	Apiaceae	4	2	1.99	0.012
41	Adiantaceae	2	1	1.12	-0.118
42	Balsaminaceae	2	1	1.12	-0.118
43	Fumariaceae	2	1	1.12	-0.118
44	Scrophulariaceae	2	1	1.12	-0.118
45	Liliaceae	3	1	1.55	-0.553
46	Pteridaceae	3	1	1.55	-0.553
47	Rubiaceae	3	1	1.55	-0.553
48	Asteraceae	17	7	7.65	-0.647
49	Acanthaceae	1	0	0.68	-0.683
50	Aceraceae	1	0	0.68	-0.683
51	Cyperaceae	1	0	0.68	-0.683
52	Ericaceae	1	0	0.68	-0.683
53	Juglandaceae	1	0	0.68	-0.683
54	Morinaceae	1	0	0.68	-0.683
55	Onagraceae	1	0	0.68	-0.683
56	Orobanchaceae	1	0	0.68	-0.683
57	Parnassiaceae	1	0	0.68	-0.683
58	Plumbaginaceae	1	0	0.68	-0.683
59	Tamaricaceae	1	0	0.68	-0.683
60	Brassicaceae	6	2	2.86	-0.859
61	Crassulaceae	2	0	1.12	-1.118
62	Juncaceae	2	0	1.12	-1.118
63	Salicaceae	2	0	1.12	-1.118
64	Ranunculaceae	12	4	5.47	-1.47
65	Geraniaceae	3	0	1.55	-1.553
66	Primulaceae	7	1	3.29	-2.294
67	Boraginaceae	8	1	3.73	-2.729
68	Poaceae	11	0	5.04	-5.035

Appendix 6.1 Casewise diagnostics and residual values analysis to assess predicted and residual values for each of the 198 plant species in the region

Case Number	Bot Names	Std. Residual	Use Values (UV)	Predicted Value	Residual
1	*Jugl reg*	2.674	43	14.49	28.513
2	*Polyg vert*	2.558	43	15.72	27.283
3	*Orig vulg*	2.422	40	14.17	25.830
4	*Cedr deod*	2.318	42	17.28	24.724
5	*Malv negl*	2.124	40	17.35	22.649
6	*Rume nepa*	2.056	36	14.07	21.929
7	*Rheu aust*	1.913	42	21.59	20.406
8	*Gera wall*	1.771	33	14.11	18.886
9	*Chen alb*	1.746	33	14.37	18.625
10	*Poly avic*	1.675	35	17.14	17.861
11	*Paeo emod*	1.663	31	13.26	17.737
12	*Calt alba*	1.661	32	14.29	17.712
13	*Hype perf*	1.532	31	14.66	16.339
14	*Plant major*	1.517	31	14.82	16.178
15	*Prun cer*	1.507	30	13.93	16.072
16	*Trif repe*	1.465	31	15.38	15.625
17	*Plant lanc*	1.437	31	15.68	15.320
18	*Dryo juxt*	1.400	29	14.07	14.929
19	*Impat bico*	1.393	31	16.14	14.861
20	*Berb pseud*	1.384	34	19.24	14.761
21	*Sali flab*	1.360	35	20.49	14.506
22	*Abie pind*	1.316	46	31.96	14.038
23	*Oxyt cach*	1.280	28	14.34	13.656
24	*Bist ampl*	1.278	28	14.37	13.625
25	*Rume dent*	1.208	30	17.11	12.885
26	*Vibu coti*	1.203	27	14.17	12.830
27	*Vale pyrol*	1.190	27	14.31	12.693
28	*Gali apar*	1.084	26	14.44	11.563
29	*Sisy irio*	1.071	25	13.57	11.426
30	*Prun vulg*	1.069	25	13.6	11.402
31	*Swer cili*	1.063	25	13.67	11.333
32	*Oxyr digy*	0.981	26	15.54	10.463
33	*Rubu sanc*	0.975	24	13.6	10.395
34	*Popl gla*	0.916	25	15.23	9.774
35	*Frag nub*	0.889	33	23.52	9.481
36	*Phle alpi*	0.886	23	13.55	9.451
37	*Urti dioi*	0.873	25	15.69	9.314
38	*Betu util*	0.873	40	30.69	9.312
39	*Coto micr*	0.847	24	14.97	9.035
40	*Lath prat*	0.821	22	13.24	8.756
41	*Indi heter*	0.819	22	13.26	8.737
42	*Pimp divers*	0.795	22	13.52	8.482

43	*Phlom brac*	0.794	22	13.53	8.470
44	*Poa annu*	0.794	22	13.54	8.464
45	*Viol cane*	0.785	32	23.63	8.369
46	*Vibu gran*	0.783	22	13.65	8.352
47	*Prim dent*	0.745	22	14.06	7.942
48	*Bist affi*	0.734	26	18.17	7.829
49	*Euph him*	0.733	22	14.18	7.818
50	*Erem hima*	0.731	26	18.21	7.792
51	*Pimp acum*	0.724	21	13.28	7.718
52	*Hera cand*	0.719	21	13.33	7.669
53	*Junc memb*	0.714	22	14.39	7.613
54	*Erig mult*	0.707	21	13.46	7.544
55	*Acer caes*	0.707	21	13.46	7.538
56	*Onos bract*	0.657	21	13.99	7.010
57	*Poa stew*	0.639	22	15.18	6.817
58	*Dact glom*	0.619	22	15.4	6.600
59	*Tuss farf*	0.617	20	13.42	6.576
60	*Pote atro*	0.610	21	14.5	6.501
61	*Ribi alp*	0.585	20	13.77	6.234
62	*Juni exce*	0.556	26	20.07	5.935
63	*Hack unci*	0.555	22	16.08	5.923
64	*Aesc indi*	0.541	19	13.23	5.774
65	*Ulmu wall*	0.536	19	13.29	5.712
66	*Pinu wall*	0.534	32	26.30	5.698
67	*Aspa race*	0.527	19	13.38	5.619
68	*Pseu mol*	0.498	19	13.69	5.315
69	*Thym line*	0.465	33	28.04	4.964
70	*Rosa webb*	0.436	30	25.35	4.648
71	*Alop arun*	0.435	19	14.36	4.637
72	*Pseu nem*	0.408	18	13.65	4.352
73	*Caps burs*	0.404	18	13.69	4.308
74	*Nepe laev*	0.381	18	13.94	4.060
75	*Anap trip*	0.377	18	13.98	4.023
76	*Alli hum*	0.370	18	14.06	3.942
77	*Cyno gloc*	0.363	22	18.13	3.873
78	*Epil angu*	0.337	17	13.41	3.594
79	*Tara offic*	0.328	21	17.51	3.494
80	*Penn lanat*	0.311	17	13.68	3.321
81	*Pote ans*	0.311	20	16.68	3.320
82	*Colc lute*	0.302	18	14.78	3.221
83	*Pedic pect*	0.295	17	13.85	3.147
84	*Impa edge*	0.294	17	13.87	3.134
85	*Brom hord*	0.292	18	14.89	3.109
86	*Verb thap*	0.292	19	15.89	3.109
87	*Leu ceph*	0.230	16	13.55	2.451

88	*Rhod hype*	0.155	20	18.35	1.649
89	*Pseod par*	0.151	15	13.39	1.613
90	*Gent moor*	0.149	16	14.41	1.594
91	*Pote nep*	0.129	18	16.62	1.376
92	*Pice smit*	0.099	16	14.94	1.060
93	*Salv moor*	0.096	15	13.97	1.029
94	*Grat offic*	0.074	14	13.21	0.787
95	*Conv arve*	0.046	14	13.51	0.489
96	*Poa alpin*	0.030	23	22.68	0.319
97	*Erag cili*	0.016	14	13.83	0.166
98	*Genti arg*	0.012	14	13.87	0.128
99	*Clem mont*	-0.079	13	13.84	-0.841
100	*Ephe gera*	-0.085	16	16.91	-0.910
101	*Cyno him*	-0.086	14	14.92	-0.915
102	*Cory gov*	-0.090	13	13.96	-0.965
103	*Crae oxy*	-0.119	12	13.27	-1.269
104	*Orob alba*	-0.124	12	13.33	-1.325
105	*Euph wal*	-0.206	13	15.19	-2.195
106	*Saus albe*	-0.219	11	13.34	-2.337
107	*Sile vulg*	-0.225	11	13.4	-2.400
108	*Ment long*	-0.249	11	13.66	-2.661
109	*Drab orea*	-0.252	11	13.69	-2.685
110	*Cyno lanc*	-0.300	10	13.2	-3.201
111	*Cory dip*	-0.315	11	14.36	-3.363
112	*Gali aspe*	-0.336	11	14.59	-3.586
113	*Podo hex*	-0.338	10	13.60	-3.605
114	*Plant hima*	-0.350	10	13.73	-3.729
115	*Ang glau*	-0.393	10	14.19	-4.195
116	*Ment royl*	-0.396	9	13.22	-4.219
117	*Dios delt*	-0.407	9	13.34	-4.344
118	*Gera poly*	-0.408	10	14.36	-4.356
119	*Prim glum*	-0.411	9	13.39	-4.387
120	*Erys mel*	-0.423	9	13.51	-4.511
121	*Prim cald*	-0.438	9	13.67	-4.667
122	*Salv lana*	-0.446	9	13.75	-4.754
123	*Adia ven*	-0.453	9	13.83	-4.828
124	*Astr anis*	-0.454	10	14.84	-4.841
125	*Drac nut*	-0.457	9	13.87	-4.872
126	*Cypr cord*	-0.503	8	13.37	-5.369
127	*Achi mill*	-0.508	10	15.42	-5.419
128	*Prim rose*	-0.520	9	14.54	-5.543
129	*Parn nubic*	-0.547	8	13.83	-5.834
130	*Acon viol*	-0.560	8	13.98	-5.977
131	*Dryo stew*	-0.581	12	18.20	-6.195
132	*Inul grand*	-0.595	7	13.35	-6.350

133	*Acon het*	-0.600	7	13.40	-6.400
134	*Berg cili*	-0.604	7	13.44	-6.437
135	*Tril gova*	-0.605	7	13.46	-6.456
136	*Juni comm*	-0.607	23	29.48	-6.477
137	*Stro glut*	-0.612	7	13.52	-6.524
138	*Equi arve*	-0.626	7	13.68	-6.679
139	*Gera nep*	-0.627	7	13.69	-6.692
140	*Gent car*	-0.635	9	15.77	-6.773
141	*Cera font*	-0.688	10	17.34	-7.338
142	*Anem obtu*	-0.754	6	14.05	-8.046
143	*Sibb cune*	-0.771	12	20.22	-8.221
144	*Acta spica*	-0.784	5	13.36	-8.362
145	*Arte vulg*	-0.799	7	15.52	-8.524
146	*Minu kash*	-0.828	5	13.83	-8.834
147	*Berg strac*	-0.861	10	19.18	-9.183
148	*Hyos niger*	-0.867	4	13.25	-9.251
149	*Frit royl*	-0.873	4	13.31	-9.306
150	*Aque fra*	-0.876	4	13.34	-9.337
151	*Dacty hat*	-0.876	4	13.34	-9.337
152	*Gent kur*	-0.899	4	13.59	-9.592
153	*Anem falc*	-0.949	4	14.12	-10.120
154	*Andr rotu*	-0.949	6	16.12	-10.121
155	*Aplu muti*	-0.968	4	14.33	-10.325
156	*Tama dio*	-0.972	4	14.37	-10.369
157	*Anem tetra*	-1.036	4	15.05	-11.046
158	*Poly moll*	-1.063	4	15.34	-11.338
159	*Andr haz*	-1.082	2	13.54	-11.543
160	*Andr prim*	-1.124	2	13.98	-11.984
161	*Scir pal*	-1.128	2	14.03	-12.033
162	*Allia pet*	-1.148	1	13.24	-12.238
163	*Aspl adia*	-1.150	1	13.27	-12.269
164	*Swer spec*	-1.151	1	13.28	-12.275
165	*Anem rupi*	-1.154	2	14.31	-12.307
166	*Cass fast*	-1.156	1	13.33	-12.325
167	*Inul mult*	-1.157	1	13.34	-12.344
168	*Mori longi*	-1.161	1	13.38	-12.381
169	*Vici bak*	-1.165	1	13.42	-12.424
170	*Ecli pros*	-1.168	1	13.46	-12.462
171	*Saus fast*	-1.174	1	13.52	-12.524
172	*Pter vitt*	-1.175	1	13.54	-12.536
173	*Stip himal*	-1.182	1	13.6	-12.605
174	*Geum elat*	-1.183	1	13.62	-12.617
175	*Coto macr*	-1.186	1	13.65	-12.648
176	*Saus gram*	-1.189	1	13.69	-12.685
177	*Sorb tome*	-1.190	5	17.69	-12.692

178	*Arneb bent*	-1.192	1	13.71	-12.710
179	*Sene chry*	-1.195	1	13.74	-12.741
180	*Aspe oppo*	-1.213	1	13.93	-12.934
181	*Poly pleb*	-1.237	1	14.19	-13.189
182	*Gag eleg*	-1.265	1	14.49	-13.487
183	*Ranu muri*	-1.276	0	13.61	-13.611
184	*Ranu laet*	-1.280	0	13.65	-13.654
185	*Aster falc*	-1.282	1	14.67	-13.667
186	*Astr scor*	-1.312	1	15	-13.996
187	*Acan lyco*	-1.323	0	14.11	-14.114
188	*Ranu hirt*	-1.339	0	14.28	-14.276
189	*Sedu awe*	-1.347	0	14.37	-14.369
190	*Cype niv*	-1.361	1	15.51	-14.512
191	*Juni squam*	-1.392	7	21.85	-14.848
192	*Iris hook*	-1.405	8	22.98	-14.979
193	*Gnap affi*	-1.415	1	16.09	-15.090
194	*Sedu alb*	-1.419	0	15.13	-15.133
195	*Poly alpi*	-1.485	1	16.83	-15.835
196	*Onop acan*	-1.507	0	16.07	-16.071
197	*Arte brev*	-1.740	16	34.55	-18.552
198	*Samb wigh*	-2.134	21	43.76	-22.759

Dependent Variable: Use Values (UV)
The importance values (IV) refered to the quadrat (first year) data set and the use value (UV) to the questionnaires (second year) data set. Both the sets were brought together to calculate predicted and residual values for each plant species.

Appendix 7.1 Categorization conservation status of species based on their residual values (descending order), perception (trend mentioned by indigenous people) with constancy, fidelity level, IUCN criteria at regional level and data on endemism and threat from published literature

Categories generated from Residual value analysis	**Botanical Name of the species**	**Residual Values (high to low)**	**Trend**	**% Const-ancy**	**Fidelity class**	**IUCN criteria applied to my results**	**Endemic & Threatened status (IUCN) at regional and global level (from published literature)**
Category 1 (Residual value ≥ 20) (07 species)	*Juglans regia* L.	28.513	D	2.2	1	CR A3+4; C1+2; D; E	Vulnerable species of the Pakistan
	Polygonatum verticillatum (L.) Allioni	27.283	D	9.4	4	EN A3; C1; E	Vulnerable in Pakistan /on CITES list
	Origanum vulgare L.	25.83	NC	11.2	4	LC	
	Cedrus deodara (Roxb. Ex Lamb.) G. Don	24.724	D	7.2	3	CR A3+4; C1; E	Endemic to the Himalaya and Hindu Kush; National tree of the Pakistan {{904 Ali,S.I. 2008; 321 Takhtadzhian,A.L. 1986; 1072 Singh,A. 2010}}
	Malva neglecta Wallr	22.649	NC	38.2	2	LC	
	Rumex nepalensis Sprenge	21.929	NC	8	1	NT	
	Rheum australe D.Don	20.406	NC	31.6	4	CR A3+4; 2ab; E	Endemic species of the Himalayas, Hindu Kush and Karakorum also Vulnerable/Near threatened (Shrestha *et al.*, 2006, Samant & Dhar, 1997)
Category 2 (Residual values = 15-20) (10 species)	*Geranium wallichianum* D. Don ex. Sweet	18.886	D	9.2	2	EN A3+4; C1+2; E	Endemic to the Himalaya and Hindu Kush {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}} /Vulnerable species of the Pakistan
	Chenopodium album L.	18.625	NC	6.8	2	LC	
	Polygonum alpinum (All.) Schur	17.861	NC	17	1	LC	
	Paeonia emodi Wall. Ex Royle	17.737	D	1.2	1	CR A3+4; C1+2; D; E	Endemic to the Himalaya and Hindu Kush (Samant & Dhar, 1997) / Vulnerable species of the Pakistan
	Caltha alba Jack. Ex Comb	17.712	D	10.4	4	NT	
	Hypericum perforatum L.	16.339	D	12.6	4	EN A3+4; C1; D; E	
	Plantago major L.	16.178	D	19.6	2	EN A3+4; C1; E	Rare species of the Pakistan
	Prunella vulgaris L.	16.072	NC	4	1	LC	
	Trifolium repens L.	15.625	I	16.8	4	LC	Alien
	Plantago lanceolata L.	15.32	NC	28	2	LC	

Category 3 (Residual values = 10-15) (16 species)	*Dryopteris juxtapostia* Christ	14.929	D	7	2	NT	
	Impatiens edgeworthii Hook.f.	14.861	NC	6	4	LC	
	Berberis pseudumbellata Parker	14.761	NC	14.8	3	VU A3+4; C1; D; E	Near Endemic to the Himalaya (Samant & Dhar, 1997, Singh & Samant, 2010)
	Salix flabellaris Andersson in Kung	14.506	D	13.6	3	EN A3+4; C1+2; D; E	Endemic to the Himalaya, Hindu Kush and Karakorum {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
	Abies pindrow Royle	14.038	D	16	3	NT	
	Oxytropis cachemiriana Camb.	13.656	I	10	4	LC	
	Bistorta amplexicaulis (D. Don)	13.625	NC	11.4	4	NT	Endemic to the Himalaya and Hindu Kush (Rana & Samant, 2009)/Endangered species of the Pakistan
	Rumex dentatus L.	12.885	I	42.8	2	LC	
	Viburnum cotinifolium D. Don	12.83	D	6.2	3	EN A3+4; C1+2; D; E	Endemic to the Himalaya {{985 Pant,S. 2006; 1073 Rana,M.S. 2009; 1072 Singh,A. 2010}}
	Valeriana pyrolifolia Decne	12.693	NC	10.6	2	LC	
	Galium aparine L.	11.563	NC	6	3	LC	
	Sisymbrium irio L.	11.426	D	3.2	1	LC	
	Prunus cerasoides D. Don	11.402	NC	0.8	1	CR A3+4; C1+2; D; E	
	Swertia ciliata (D. Don ex G. Don) B. L. Burtt	11.333	NC	7	2	NT	Endemic to the Himalayas and Hindu Kush (Shrestha *et al.*, 2006)
	Oxyria digyna L.	10.463	NC	18.6	3	LC	Alien
	Rubus sanctus Schreber	10.395	D	1.6	1	NT	
Category 4 (Residual values = 05-10) (35 species)	*Poplus glauca* H. Haines	9.774	NC	2.8	1	LC	
	Fragaria nubicola Lindl. Ex Lacaita	9.481	I	55.6	2	LC	
	Phleum alpinum L.	9.451	NC	4	1	LC	
	Urtica dioica L.	9.314	I	16.4	3	LC	Alien
	Betula utilis D. Don	9.312	D	8.4	4	CR A3+4; C1+2a; D; E	Endangered species in the Himalaya and Hindu Kush {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
	Cotoneaster microphyllus Wall. ex Lindl	9.035	D	12	3	VU A3+4; C1; D; E	
	Lathyrus pratensis L.	8.756	D	2	1	LC	Alien (indigenous to Europe)

	Indigofera heterantha Wall. Ex Brand	8.737	D	0.8	1	CR A3+4; C1+2; D; E	
	Pimpinella diversifolia (Wall.) DC	8.482	D	2.4	1	NT	
	Phlomis bracteosa Royle ex Benth.	8.47	D	2	1	LC	Endemic to the Himalayas, Hindu Kush and Karakorum {{1065 Shrestha,M.R. 2006; 1072 Singh,A. 2010}}
	Poa annua L.	8.464	NC	4.2	1	LC	
	Viola canescens Wall. Ex Roxb.	8.369	NC	68.4	2	VU A3+4; C1; D; E	Endemic to the Himalayas (Rana & Samant, 2009) and Vulnerable species of the Pakistan
	Viburnum grandiflorum Wall. Ex DC.	8.352	D	1.6	1	VU A3+4; C1; E	
	Primula denticulata Smith	7.942	D	8.4	3	EN A3+4; C1+2; D; E	
	Bistorta affinis (D.Don) Green	7.829	I	25.2	4	LC	Endemic to the Himalayas, Hindu Kush and Karakorum (Shrestha *et al.*, 2006, Rana & Samant, 2009)
	Euphorbia wallichii Hook. f.	7.818	NC	7.2	1	CR A3+4; C1+2; D; E	
	Eremurus himalaicus Baker	7.792	I	20.4	4	LC	Endemic to the western Himalaya {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
	Pimpinella acuminata (Edgew.) C.B. Clarke	7.718	D	2.2	3	CR A3+4; C1+2; D; E	Endemic to the Himalaya {{1073 Rana,M.S. 2009; 817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
	Heracleum candicans Wall. ex DC.	7.669	D	3.4	1	CR A3+4; C1+2; D; E	Endemic to the Himalaya and Hindu Kush {{985 Pant,S. 2006; 626 Nasir,E. 19711998}}
	Juncus membranaceus Royle ex D. Don	7.613	NC	4.2	2	LC	
	Erigeron multiradiatus (Lindl. Ex DC) C. B. Clarke	7.544	D	2.6	1	EN A3+4; C1+2; D; E	
	Acer caesium Wall ex Brandis	7.538	D	1.6	1	CR A3+4; C1+2; D; E	Vulnerable in the Himalaya
	Onosma bracteatum Wall.	7.01	D	7.2	2	NT	Endemic to the Himalayas (Shrestha *et al.*, 2006)
	Poa stewartiana Bor in Kew Bull.	6.817	D	13.8	2	LC	
	Dactylis glomerata L.	6.6	NC	13.2	3	LC	
	Tussilago farfara L.	6.576	D	2.2	1	EN A3+4; C1+2; D; E	
	Potentilla atrosanguinea Lodd.	6.501	NC	8.4	2	NT	Endemic to the Himalayas and Hindu Kush (Rana & Samant, 2009)
	Ribies alpestre Decne	6.234	D	2.2	1	CR A3+4; C1+2; D; E	

	Juniperus excelsa M. Bieb	5.935	D	21.4	4	NT	
	Hackelia uncinata (Royle ex Benth) Fischer	5.923	NC	24.8	2	LC	
	Aesculus indica (Wall. Ex Camb) Hook.	5.774	D	0.6	1	CR A3+4; C1+2; D; E	
	Ulmus wallichiana Planch.	5.712	D	0.6	1	CR A3+4; C1+2; D; E	Endemic to the Himalaya {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
	Pinus wallichiana Jackson	5.698	D	15.6	4	VU A3+4; C1+2; E	Endemic to the Himalaya, Hindu Kush and Karakorum {{321 Takhtadzhian,A.L. 1986; 1072 Singh,A. 2010}}
	Asparagus racemosus Willd.	5.619	D	3.8	3	CR A3+4; C1+2; D; E	
	Pseudomertensia moltkioides Royle & Kazmi	5.315	D	4.2	1	CR A3+4; C1+2; E	Endemic to the Pakistan {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
Category 5 (Residual values = 00-05) (30 species)	*Thymus linearis* Benth.	4.964	NC	64.2	2	LC	
	Rosa webbiana Wallich ex Royle	4.648	D	28	2	LC	
	Alopecurus arundinaceus Poir.	4.637	D	6	2	**LC**	
	Pseudomertensia nemorosa (D. C) R. Stewart & Kazmi	4.352	D	3.6	1	NT	
	Capsella bursa-pastoris (L.) Medic.	4.308	NC	5.6	3	LC	
	Nepeta laevigata (D. Done) Hand.-Mazz	4.06	D	5.8	2	EN A3+4; C1+2; D; E	Native to the Himalaya and Karakorum {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
	Anaphalis triplinervis (Sims) C. B. Clarke	4.023	D	6.2	5	**NT**	
	Alliaria petiolata (M. Bieb.) Cavara & Grande	3.942	D	1.2	1	CR A3+4; C1+2; D; E	
	Cynoglossum glochidiatum Wall. Ex Benth	3.873	NC	36.2	2	LC	
	Epilobium angustifolium L.	3.594	D	3.2	1	VU A3+4; C1+2; D; E	
	Taraxacum officinale Weber	3.494	NC	52.2	2	LC	Alien
	Pennisetum lanatum Klotzsch	3.321	D	3.4	1	NT	
	Potentilla anserina L.	3.32	NC	22.2	2	LC	
	Colchicum luteum Baker	3.221	NC	9	3	EN A3+4; C1; E	Endangered species of the Pakistan {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
	Pedicularis pectinata Wall. ex. Benth	3.147	D	2.8	1	CR A3+4; C1+2; D; E	Endemic to the Himalaya (Kumar *et al.*, 2011)

	Impatiens bicolor Royle	3.134	D	28.8	3	LC	
	Bromus hordeaceus L.	3.109	NC	11.8	4	LC	
	Verbascum thapsus L.	3.109	NC	33.2	3	LC	Alien
	Leucas cephalotes (Roth) Spreng.	2.451	D	2.2	1	VU A3+4; C1; E	
	Rhododendron hypenanthum Balf.f	1.649	D	3.8	4	EN A3+4; C1+2; D; E	Endemic to the Himalayas, Hindu Kush and Karakorum (Shrestha *et al.*, 2006, Rana & Samant, 2009) Vulnerable/Near threatened/
	Pseudomertensia parvifolia (Decne)	1.613	D	3.2	1	VU A3+4; C1; E	
	Gentiana moorcroftiana (Wallich ex G. Don) Airy Shaw	1.594	D	9.4	3	VU A3+4; C1+2a; D; E	Endemic to the Himalaya and Hindu Kush {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
	Potentilla nepalensis Hook. f.	1.376	NC	20.8	2	LC	
	Picea smithiana (Wall.) Boiss.	1.06	D	6.6	4	EN A3+4; C1+2a; E	Endemic to the Himalaya, Hindu Kush and Karakorum {{321 Takhtadzhian,A.L. 1986; 1072 Singh,A. 2010}}
	Salvia moorcroftiana Wallich ex Benth	1.029	NC	6	2	EN A3+4; C1+2; D; E	Endemic to the Himalaya and Hindu Kush {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
	Gratiola officinalis L.	0.787	D	1.4	1	EN A3+4; C1+2; D; E	
	Convolulus arvensis L.	0.489	NC	3.2	1	VU A3+4; C1+2a; E	
	Poa alpina L.	0.319	NC	40	2	LC	
	Eragrostis cilianensis (All.) Lut. ex F.T. Hubbard	0.166	NC	4.8	3	VU A3+4; C1; E	
	Gentianodes argentia Omer, Ali & Qaiser	0.128	D	4.2	3	EN A3+4; C1+2; D; E	Endemic to Pakistan {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
Category 6 (Residual values < 0) (100species)	*Clematis montana* Buch.-Ham. ex DC	-0.841	D	5.6	4	NT	
	Ephedra gerardiana Wall. Ex Stapf	-0.91	D	8.2	2	EN A3+4; C1+2; D; E	Endangered species of the Pakistan
	Cynoglossum himaltoni	-0.915	D	12.8	2	LC	
	Corydalis govaniana Wall.	-0.965	D	5.2	2	EN A3+4; C1+2; D; E	Endemic to the Himalayas {{1070 Kumar,A. 2011; 1073 Rana,M.S. 2009; 817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}} Pakistan
	Crataegus oxyacantha L.	-1.269	D	0.8	1	CR A3+4; C1+2; D; E	
	Orobanche alba Stephen ex Wallid	-1.325	D	1.4	1	CR A3+4; C1+2; D; E	
	Euphrasia himalayica Wetts.	-2.195	D	16.4	2	NT	Endemic to the Himalaya and Hindu Kush (Shrestha *et al.*, 2006)

	Saussurea fastuosa (Decne.) Schultz-Bip	-2.337	D	2	1	NT	
	Silene vulgaris Garck	-2.4	D	4.2	2	NT	
	Mentha longifolia (L.) Hudson.	-2.661	I	2	1	LC	
	Draba oreades Schrenk	-2.685	NC	6.6	2	LC	
	Cynoglossum lanceolatum L.	-3.201	NC	0.8	1	LC	
	Corydalis diphylla Wall.	-3.363	NC	9.4	2	LC	
	Galium asperuloides	-3.586	NC	7.6	2	LC	Endemic to the Himalayas and Hindu Kush {{1072 Singh,A. 2010}}
	Podophyllum hexandrum Royle	-3.605	D	4	1	CR A3+4; C1+2; D; E	Critically Endangered/on CITES list; Endemic to the Himalayas, Hindu Kush and Karakorum (Shrestha *et al.*, 2006)
	Plantago himalaica Pilger	-3.729	D	4	1	CR A3+4; C1+2; E	Endemic to the Himalayas {{985 Pant,S. 2006; 626 Nasir,E. 19711998}}
	Angelica glauca Edgew.	-4.195	D	6	2	EN A3+4; C1+2; D; E	Endemic to the Himalaya and Hindu Kush (Samant & Dhar, 1997, Rana & Samant, 2009)
	Mentha royleana Benth. in Wall.	-4.219	NC	0.8	1	EN A3+4; C1+2; D; E	
	Dioscorea deltoidea Wall.	-4.344	D	3.6	1	CR A3+4; C1+2; D; E	Vulnerable/ on CITES list
	Geranium polyanthes Edgew & Hook. F	-4.356	D	10.4	3	LC	
	Primula glomerata Pax.	-4.387	D	3.8	1	VU A3+4; C1; E	Endemic to the Himalaya (Shrestha *et al.*, 2006)
	Erysimum melicentae Dunn.	-4.511	NC	5	3	VU A4; C1; E	Endemic to the Himalaya and the Hindu Kush {{1065 Shrestha,M.R. 2006; 626 Nasir,E. 19711998}}
	Primula calderana Balf. F & cooper	-4.667	D	3.6	1	VU A3; C1; E	
	Salvia lanata Roxb.	-4.754	NC	3.4	1	NT	Alien
	Adiantum venustum D. Don	-4.828	NC	9.2	3	LC	
	Astragalus anisacanthus Boiss.	-4.841	NC	12.8	2	LC	
	Dracocephalum nutans L.	-4.872	D	4.6	1	NT	
	Cypripedium cordigerum D. Don	-5.369	D	3.2	1	CR A3+4; E	Endemic to the Himalaya {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}} /Endangered/ on CITES list
	Achillea millefolium L.	-5.419	NC	16.6	4	LC	
	Primula rosea Royle	-5.543	D	10.4	1	VU A3+4; C1; D; E	Endemic to the Himalaya and Hindu Kush {{817

							Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
	Parnassia nubicola Wall.	-5.834	NC	4.4	1	NT	Endemic to the Himalayas (Pant & Samant, 2006, Shrestha *et al.*, 2006)
	Aconitum violaceum Jacquen ex. Stapf	-5.977	D	8.4	3	VU A3+4; C1+2; D; E	Endemic to the Himalaya also Vulnerable (Kumar *et al.*, 2011)
	Dryopteris stewartii Fras.-Jenk.	-6.195	I	25.4	3	LC	Endemic to Pakistan {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
	Inula grandiflora Willd.	-6.35	D	0.6	1	CR A3+4; C1+2; D; E	Near threatened in Himalayas {{626 Nasir,E. 19711998}}
	Aconitum heterophyllum Wall.	-6.4	D	3.4	1	EN A3+4; C1+2; D; E	Endemic to the Himalaya and Hindu Kush /Vulnerable species of Pakistan
	Bergenia ciliata (Haw.) Sternb.	-6.437	D	2.6	4	VU A3+4; C1; E	Endemic to the Himalaya (Shaheen *et al.*, 2011a)
	Trillidium govanianum (Wall. Ex D. Don) Kunth	-6.456	D	1.8	1	EN A3+4; C1+2; D; E	Endemic to the Himalaya (Rana & Samant, 2009)
	Juniperus communis L.	-6.477	D	38.8	3	LC	
	Strobilanthes glutinosus Nees	-6.524	D	2.2	1	VU A3+4; C1+2; D; E	Endemic to the Himalaya {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
	Equisetum arvense L.	-6.679	NC	5.4	3	LC	
	Geranium nepalense Sweet.	-6.692	D	3.4	1	VU A3+4; C1; E	
	Gentiana carinata Griseb	-6.773	NC	14.4	4	LC	
	Cerastium fontanum Baumg.	-7.338	NC	21.8	2	LC	
	Anemone obtusiloba D.Don	-8.046	D	9.2	2	NT	Endemic to the Himalayas, Hindu Kush and Karakorum (Shrestha *et al.*, 2006, Rana & Samant, 2009)
	Sibbaldia cuneata O. Kuntze	-8.221	NC	31.2	3	LC	
	Actaea spicata L.	-8.362	D	1.4	1	**NT**	
	Artemisia vulgaris L.	-8.524	NC	6.4	3	LC	
	Minuartia kashmirica (Edgew) Mattf	-8.834	NC	5.2	1	LC	Native to the Himalaya and Karakorum {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
	Bergenia stracheyi (Hook. f. & Thoms) Engl	-9.183	I	17.4	4	LC	Nearly endemic to the Himalayas and Hindu Kush also Vulnerable in the Himalaya {{1070 Kumar,A. 2011; 817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009; 1072 Singh,A. 2010}}
	Hyoscyamus niger L.	-9.251	D	0.8	1	CR A3+4; C1; E	Near Threatened/Alien {{626 Nasir,E. 19711998}}
	Fritillaria roylei Hook. f.	-9.306	D	1.4	1	CR A3+4; C1+2; D; E	Endemic to the Himalaya and Hindu Kush/ also rare and critically endangered {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}

	Aquilegia fragrans Benth.	-9.337	D	1.2	1	CR A3+4; C1+2; D; E	Endemic to the Himalaya and Hindu Kush {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
	Dactylorhiza hatagirea (D. Don) Soo	-9.337	D	3.4	1	CR A3+4; C1; E	Endemic to the Himalaya and Hindu Kush/Critically Endangered (Singh & Samant, 2010, Kumar *et al*., 2011)
	Gentiana kurroo Royle	-9.592	D	3.4	1	CR A3+4; E	Endemic to the Himalaya and Hindu Kush/ also endangered {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
	Anemone falconeri Thoms.	-10.12	D	9.6	2	EN A4; C1+2a; D; E	Endemic to the Himalaya and Hindu Kush {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
	Androsace rotundifolia Watt	-10.121	D	26.8	2	LC	
	Apluda mutica (L.) Hack	-10.325	D	8.6	2	LC	
	Tamarix dioica Roxb. ex Roch	-10.369	NC	3.2	3	LC	
	Anemone tetrasepala Royle	-11.046	D	10.6	3	NT	Endemic to the Himalayas and Hindu Kush (Rana & Samant, 2009)
	Polygonum aviculare L.	-11.338	NC	14.4	2	LC	
	Androsace hazarica R.R. Stewart ex Y. Nasir	-11.543	D	4.6	1	CR A4; C1; E	Endemic to Pakistan {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
	Androsace primuloides Duby	-11.984	D	5	1	CR A3+4; C1+2a; E	Endemic to the Himalaya and Hindu Kush
	Scirpus palustris L.	-12.033	NC	5.8	1	LC	
	Allium humile Kunth.	-12.238	D	6.8	5	NT	Endemic to the Himalaya (Samant & Dhar, 1997, Pandey *et al*., 2008)
	Asplenium adiantum-nigrum	-12.269	D	0.6	1	NT	
	Swertia speciosa D. Don	-12.275	NC	1.4	1	NT	
	Anemone rupicola Cambess	-12.307	D	8.2	2	NT	
	Cassiope fastigiata (Wallich) D. Done	-12.325	D	1.2	1	EN A3+4; C1+2; D; E	Endemic to the Himalayas, Hindu Kush and Karakorum (Shrestha *et al*., 2006)
	Inula multiradiata	-12.344	D	0.8	1	NT	
	Morina longifolia Wall. ex. Dcs	-12.381	NC	1.8	1	LC	
	Vicia bakeri Ali.	-12.424	D	1.6	1	CR A3+4; C1+2; D; E	Endemic to the Himalaya/Pakistan {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
	Eclipta prostrata L.	-12.462	NC	4.8	3	LC	
	Saussurea albescens Hook. f. & Thoms	-12.524	NC	4	1	NT	
	Pteris vittata L.	-12.536	NC	5	2		Endemic to the Himalaya {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
	Stipa himalaica Rozhev.	-12.605	D	4.8	2	LC	Endemic to the Himalaya and Karakorum {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
	Geum elatum Wall. Ex G. Don	-12.617	D	4.8	2	VU A3+4; D; E	Endemic to the Himalaya (Shrestha *et al*., 2006,

							Rana & Samant, 2009, Kumar *et al.*, 2011)
	Cotoneaster cashmiriensis G.Klotz	-12.648	D	3.4	1	VU A3+4; C1; D; E	
	Saussurea graminifolia Wallich ex DC	-12.685	NC	4	1	NT	
	Sorbaria tomentosa (Lindl.) Rehder	-12.692	D	8	3	EN A3+4; C1; E	
	Arnebia benthamii Wallich ex. G. Done	-12.71	D	6	1	CR A3+4; C1+2; D; E	Endemic to the Himalaya/Critically endangered in the Himalaya (Shrestha *et al.*, 2006, Kumar *et al.*, 2011)
	Senecio chrysanthemoides DC	-12.741	NC	2.6	1	LC	
	Asperula oppositifolia Reg. & Schmalh.	-12.934	D	4.8	2	NT	
	Polygonum molle (D.Done) Hara	-13.189	D	10.2	2	LC	
	Gagea elegans Wall. Ex D. Don	-13.487	D	9.2	3	NT	
	Ranunculus muricatus L.	-13.611	NC	3.4	1	LC	
	Ranunculus laetus Wall. Ex Hook.f. & Thoms	-13.654	D	4	1	VU A3+4; C1+2; D; E	
	Aster falconeri (C. B. Clarke) Hutch	-13.667	NC	11.6	5	NT	Endemic to the Himalaya and Hindu Kush (Shrestha *et al.*, 2006, Rana & Samant, 2009)
	Astragalus scorpiurus Bunge	-13.996	D	13.4	2	LC	
	Acantholimon lycopodioides Boiss.	-14.114	NC	2	1	VU A4	
	Ranunculus hirtellus Royle ex D. Don	-14.276	D	5	1	CR A3+4; C1; E	Endemic to the Himalaya (Kumar & Singhal, 2011)
	Sedum ewersii Ledeb	-14.369	NC	10.4	4	LC	
	Cyperus niveous	-14.512	D	16.6	3	LC	
	Juniperus squamata Buch.-Ham. ex D. Don	-14.848	D	11	3	VU A4; C1; E	Native to the Himalaya and Karakorum
	Iris hookeriana Foster	-14.979	NC	30.8	4	NT	Endemic to the Himalaya and Hindu Kush/Vulnerable species of the Pakistan {{817 Ali,S.I.,Nasir,E.,Qaiser,M. 1972-2009}}
	Gnaphalium affine D. Don	-15.09	NC	19.2	3	LC	
	Sedum album L.	-15.133	NC	17	3	LC	
	Polygonum plebejum R. Br	-15.835	NC	19	2	LC	
	Onopordum acanthium L.	-16.071	I	32.2	2	LC	
	Artemisia brevifolia L.	-18.552	I	40.2	3	LC	
	Sambucus wightiana Wall. Ex Wight & Arn	-22.759	I	34.4	3	LC	

IUCN red list criteria; CR = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Nearly Threatened, LC = Least Concern (IUCN, 2003)
Trend: (people perception about the decrease or increase in species abundance); D = Decreasing, I = Increasing, NC = No visible Change.

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