Ecological and Geoinformatics Evaluation of Vegetation Dynamics in the Murree Forests; a step towards Biodiversity Conservation

By

Amjad ur Rahman

Department of Plant Sciences

Faculty of Biological Sciences,

Quaid-i-Azam University

Islamabad, Pakistan

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A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy

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2021

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Student name: **Mr. Amjad ur Rahman** Signature: ____________

Examination Committee:

External Examiner 1:

Prof. Dr. Muhammad Arshad Signature: ____________
Professor
Department of Botany,
PMAS Arid Agriculture University Rawalpindi
Pakistan

External Examiner 2:

Dr. Muhammad Ibrar Shinwari Signature: ____________
Associate Professor
Department of Environmental Sciences
International Islamic University Islamabad
Pakistan

Internal Examiner/Supervisor:

Dr. Shujaul Mulk Khan Signature: ____________
Associate Professor
Department of Plant Sciences
Quaid-i-Azam University Islamabad
Pakistan

Chairman:

Prof. Dr. Mushtaq Ahmad Signature: ____________
Professor
Department of Plant Sciences
Quaid-i-Azam University, Islamabad

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Supervisor

Associate Professor

Department of Plant Sciences,

Quaid-i-Azam University,

Islamabad, Pakistan

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DEDICATED

TO

MY LOVING PARENTS,

FAMILY

AND

ALL WELL-WISHERS WHO HELPED AND SUPPORTED ME IN THIS LONG JOURNEY

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AMJAD UR RAHMAN

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PUBLICATIONS ARISING TO DATE FROM THIS THESIS

The following papers have been published/processed based on some results presented in Chapters 3 and 4.

i. Rahman, A., **S. M. Khan*,** Z. Saqib, Z. Ullah, Z. Ahmad, S. Ekercin, A.S. Mumtaz, and A. Ahmad, 2020. Diversity and abundance of climbers in relation to their hosts and elevation in the monsoon forests of Murree in the Himalayas. Pakistan. Pakistan Journal of Botany, 52(2): 601-612. **(IF = 0.80)**

ii. Rahman, A., **S. M. Khan*,** Z. Ullah, Z. Ahmad, S. Ekercin, A. Aksoy, 2020. A novel study to assess the impact of multiple environmental factors on species abundance of various forest layers using integrative modelling approach. Global Ecology and Conservation, GECCO-D-21-00055 (under review). **(IF = 2.526)**

iii. Rahman, A., **S. M. Khan*,** S. Ekercin, A.S. Mumtaz, and A. Ahmad, 2020. Spatial diversity, patterns of forest vegetation and sustainability analyses of the Murree mountains of Western Himalayas; In the Ozturk, M, S.M. Khan, and A.Volkan (Eds.) "Biodiversity, Conservation and Sustainability in Asia Volume 2: Prospects and Challenges in South Asia", ISBN 978-3-030-59927-0. (Book chapter in Springer Book accepted).

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

i. Delivered a talk entitled *"Climbers in Relation to their host and Elevation Gradient in the Murree Forests of the Western Himalayas"* in the 7th International and 16th National Conference of PBS on "Plant Resources: Current Trends, Challenges and Solutions" (March 23-27, 2018) at Islamia College University Peshawar Pakistan.

ii. Poster presentation with titled, "Spatial Vegetation Cover with Remote Sensing in the Western Himalaya, Pakistan" in the National Association of Photogrammetry and Remote Sensing (TUFUAB) Technical Symposium X. held during 25-27 April 2019 hosted by Aksaray University, Turkey.

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

GLOSSARY OF ABBREVIATIONS

CA	Cluster Analysis
CCA	Canonical Correspondence Analysis
Cl	Chlorine
DCA	Detrended Correspondence Analysis
ETM	Enhanced Thematic Mapper
GIS	Geographic information system
ISA	Indicator Species Analyses
IVI	Important value indices
MFD	Murree Forest Division
NDVI	Normalized Difference Vegetation Index
OLI	Operational Land Imager Plus
OM	Organic matter
PPM	Parts per million
EC	Electrical Conductivity
EC	Elevation class
RS	Remote sensing
SACs	Species Area Curves
Spp	Species
TM	Thematic Mapper
TSS	Total Soluble Solute
TWCA	Two-way Cluster Analysis

ABSTRACT

It is imperative to understand floristic composition, structure and spatial distributions and its underlying mechanisms at species, community and ecosystem levels. The current research work was conducted during 2016-2020 to evaluate the plant resources and vegetation dynamics of the Murree Forest Division (MFD), ecologically. The main aim of the current study was to evaluate and confirm that climate change has considerable impacts on the vegetation cover and dynamics triggered by urbanization in the hilly areas of MFD over the past few decades. Overall findings of the current dissertation are broadly presented in three steps i.e., species and community level dynamics, digital elevation modelling, biotic interactions (climbers as indicators), vegetation cover dynamics over the last four decades and syntheses.

Phytosociological characteristics of the individual plant species were measured using the quadrats (498 in total) along the elevation transects (166 in total) via stratified random sampling design. Soil samples were taken and analyzed for their physiochemical properties. All the quantitative ecological data of plant species were analyzed for density, cover and Importance Value Index and then arranged according to the requirements of PCORD & CANOCO softwares. Multivariate statistical analyses were used to find the relationships between vegetation diversity, soil factors, topography and biotic factors. Preliminary findings confirmed 454 plant species distributed among 98 families and 176 genera recorded in the 494 quadrats. Taxonomically, Poaceae was the most abundant family followed by Asteraceae, Papilionaceae, Lamiaceae and Rosaceae. The dominant life forms were the Therophytes and Nanophanerophytes. Therophytes is one of the life forms that is having the ability to cope with adverse environmental circumstances via producing seeds for the harsher period of its life cycle. Nanophyll and Microphylls were the dominant leaf forms in the MFD. Various environmental variables that is the elevation, slope, soil texture, pH, organic matter, canopy, nitrogen and grazing pressure significantly affect the species distribution, composition and community classification (P-value $\leq$ 0.05). The application of classification and ordination techniques (multivariate analyses) broadly divided the Murree forest vegetation into five major plant communities/associations viz., 1) *Picea smithiana, Spiraea canescens, Trifolium* spp, 2) *Quercus robur, Rubus fruticosus, Cyperus rotundus,* 3)

Salix babylonica, Buddleja crispa, Potentilla reptans, 4) *Pyrus bourgaeana, Reinwardtia indica, Gentiana olivieri* and 5) *Lannea coromandelica, Buxus papillosa, Phyla nodiflora* community.

Knowledge about climber species in the forests is relatively inadequate and the current study provides the first report on the climber species of MFD Pakistan. Climbers were focused specifically, in relation to their host as a baseline reference for possible future dynamics. Overall 3400 individuals of climbers belong to 23 species, 19 genera and 13 families were identified. Climber species are classified into four classes based on their habit. The dominant class was represented by twining climbing mode followed by woody and hook mode. The abundance and distribution of climber plants were affected by parameters like biotic factors (grazing pressure and number of hosts) and abiotic factors (topographic and edaphic). Canonical Corresponding Analysis indicated that grazing and collection pressures along with elevation were the most important factors influencing the distribution and abundances of climbers.

Mapping of vegetation via ArcGIS was done to know the overall vegetation dynamics in the MFD over the last 4 decades. The whole MFD was then divided into five elevation classes namely, uppermost class (1901–2258 m), upper class (1601–1900 m), medium elevation class (1301m–1600m), lower class (1001–1300 m) lowest class ranges (519–1000 m) and showed via the Digital Elevation Models (DEM) maps. The effect of climate change (designated in terms of rainfall and temperature) on vegetation (designated in terms of Normalized Difference Vegetation Index; NDVI) and forest cover in the MFD were also assessed. Rainfall and Temperature data of nearest weather stations; vegetation and forest cover (consequent using 1988, 1998, 2008, 2018 years' data from Landsat imageries series i.e. 5 TM, 7 ETM, 8 OLI by using ArcGIS and ERDAS Imagine) were used in the investigation for both the pre-monsoon and post-monsoon seasons. The simple regression method was used to assess the relationship of climate change factors with NDVI and forest cover in this study. During the pre- monsoon season, forest cover and temperature analysis indicated high regression coefficient rate and vegetation (NDVI) and temperature analysis showed regression coefficient moderate rate. Furthermore in the post-monsoon season investigation forest cover and rainfall showed regression coefficient rate of 0.4959 and vegetation index (NDVI) and temperature displayed regression coefficient rate of 0.7338. The study revealed that temperature was significantly correlated with forest cover and vegetation in pre-monsoon season however In post-monsoon season rainfall demonstrated positive response to forest cover, and temperature showed negative response to vegetation index in the Murree forests. The results demonstrated that vegetation is reducing in the MFD, Pakistan.

In summary the current study apart from answering numbers of ecological questions provides a baseline for future studies of vegetation dynamics and climate change studies. It provides a record for monitoring forest cover changes over space and time and evaluation of the climate changes and anthropogenic pressures for long term management at species, habitats, and ecosystem levels in at the western Himalayas.

Chapter 1 General introduction

1.1 Vegetation

In mountain ecosystems, vegetation serves the very first trophic level. Vegetation is the plant composition of any given area which possesses characteristic physiognomy including various taxonomic groups and present in a particular microclimatic space (Hussain et al. 1992; Hargreaves 2008). Plant communities are the characteristic assemblage of plant species which is determined by the interaction of vegetation with other biotic and abiotic components and can easily be differentiated from each other (Malik and Husain 2006; Malik and Husain 2008). A plant community is a group of plants that have collective relationships with each other and their immediate environment (Oommen and Shanker 2005). The climate, topography and soil affect the characteristics of each plant community. The course or form of the plant community or types of vegetation is also shaped by biotic factors, especially human influences (Grubb 1987b). It forms a reasonably uniform layer that is distinct from neighboring patches of various types of vegetation. The nature and development of plant communities represents the conditions in which they are developed (Malik et al. 1994). Various aspects of vegetation studies also contribute to the conservation and management of plant diversity. These studies also evaluate the ecological impact and uses of vegetation and analyses of potential future changes (Kent 2011).

The unique species aggregation of an area reflects the effects of environment on vegetation.Vegetation complex fluctuates in correspondence with the environmental fluctuations, which might be a seasonal or long term in nature (Mandal and Joshi 2014). Vegetation of a region strongly depend on climatic, soil and variation in disturbance levels that itself affects other factors as well (Hussain et al. 1997). Vegetation thus provides valuable information about the health of an ecosystem. The concept of vegetation can historically be demonstrated as a means of organizing plant assemblies at various spatial scales. The composition of plants has changed, mostly over time, and human activities have become increasingly concerned with the aesthetic and socio-economic values of natural resources (Mueller-Dombois and Ellenberg 1974; Gillison 2006). The information can be used to manage an ecosystem, habitat and productivity of the area. Different environmental variables have different effects on the vegetation but all the environmental variables have a cumulative dynamic effect on plant species composition of an area (Billings 1952). Phytogeographical and phytosociological research all over the globe try to classify vegetation into plant communities based on composition, development and co-occurrence of species (Ilyas et al. 2015) which is important in ecological research to explore areas for the first time (Zhao et al. 2010). It deals with the species composition of plant communities, their evolution and the relationships between the species present. Gradient analyses are complementary tools to understand functioning and description of vegetation (Lee and Shukla 2005; Ewald 2003).

1.2 Vegetation Dynamics

Vegetation dynamics represent the net effects of several variables, including climate, biotic interactions, abiotic environment and the level and history of disturbances on the plant community. There is an emerging trend in ecological research to know how these variables interact and influence the coexistence and productivity of species over time and space in an ecosystem. Vegetation Dynamics are complex phenomena in many ways and need to be accessed via varied angles. Such dynamics are functions of the disturbance regimes in a particular spatiotemporal range. The higher biological diversity of specific sort of vegetation over the other is sometimes supported by the natural disorders. Forest management strategies thus need the knowledge of natural disturbances within a given region (King et al. 2000).

Several studies have shown that natural resources in northern Pakistan, especially forest resources, are constantly decreasing because of growing human population, increase in demand of fuel and timber wood, and expansion of land for crops. Carelessness in the collection of medicinal plants, over grazing, and mismanagement are other causes of reduction in forests. Furthermore, the actual state of forest cover in the country is controversial and has been assessed some time ago (Siddiqui et al. 1999; Butt et al. 2015a; Jan et al. 2015; Shehzad et al. 1999; Siddiqui et al. 2013).

1.2.1 Himalayan perspective of the vegetation dynamics

Himalaya is derived from the Sanskrit word which means “abode of snow” comprising a wide-ranging consistent arch about 2600 kilometers along the northern border of the subcontinent from the Indus river of Pakistan (Krishnaswami et al.

1992). The Himalayas contain the highest mountains in the world with the highest ecological amplitude (Dobremez and Jest 1976). The Himalayas include the most inexperienced habitat on earth that cherish varying biodiversity of forest types due to critical climatic changes, topographical and soil composition from the foothills to alpine mountaintops. The Himalayan flora is diverse and varies in the southeast from tropical evergreen forest species to thorn steppe and alpine species in the northwestern regions (Behera and Kushwaha 2006). The lesser elevation range (901-1501m) of the Himalayas are occupied by subtropical broad leaved and mixed pine forests particularly of *Pinus roxburghii*, *Dodonea viscosa, Olea cuspidata*, *Pinus walichiana*, *Punica florida* and *Acacia nilotica* species (Shinwari and Gilani 2003). The moist temperate forests and cool moist temperate forests were prevailed above the lesser elevation range with *Abies pindrow*, *Pinus wallichiana*, *Cedrus deodara*, *Asculus indica* and *Quercus dilatata* (Beg 1975).

Pakistani Himalaya is gifted with richness of plant biodiversity. The north western Himalayan zone is one of the 18 hotspots of the biosphere. Enormous geological, geographical and climatic variations in altitude, topography, temperature, precipitation, soil condition bring subsequent diversity in forestry, horticulture and wildlife of the region. These mountain ranges consist of a series of chains that run roughly parallel to each other for long distances and cover areas including a chain of valleys, and glaciers. Few high altitudinal regions of the Himalayan forests are comparatively protected due to their remoteness and low population densities. The lower subtropical and moist temperate forests are the most severe victims of anthropogenic stress resulting in massive forest losses. Three-quarters of the western Himalayan forest cover is reported to have been disappeared in the last century (Joshi et al. 2001). (Prabhakar et al. 2006) projected 60% forest deterioration in the states of Garhwal and Uttarkhand in Indian Himalayan. A rapid forest cover decline from 57% to 23% was recorded in Nepal from 1950 to 1980 with all of Nepal's subtropical forests either severely degraded or completely lost (Myers 1986). Due to heavy deforestation in Pakistan merely 4.8% of land remains covered with forests with an enduring deforestation annual rate of more than 3% (Cronin and Pandya 2009). Large scale logging activities in Yunnan of Chinese Himalayan province caused 20% loss of forest cover from 1960s to 1990s (Li et al. 2008). Pakistan lost 25% of forest cover in only 15 years during 1990 and 2005 (Abbasi et al.

2002). Forest loss of a total of 23% in western Himalayas and 8 % in Eastern Himalaya has been assessed by using GIS and remote sensing methods in last three decades (Pandit et al. 2007). The condition in Bhutan is quite different due to strict implementation of forest conservation plans, where about 60% of the country area remains forest covered, even though restricted exploitation remains (Dhital 2002).

1.2.2 Vegetation and climate change

The dynamics of vegetation are considered as a significant indicator for the regulation of the terrestrial equilibrium of carbon and climate change. This challenge is significant for the climate change assessment. Even though correlations between vegetation dynamics, temperature and precipitation have been widely studied, the correlated issues are linked to the relations between vegetation dynamics and other climatic variables. Monitoring the long term change of vegetation growth and exploring its relations with climate change is relevant for the global change study (Mancino et al. 2014; Shao and Zhang 2016).

Vegetation dynamics are very vulnerable to climate change in particular (Zhang et al. 2017; Zhang et al. 2000; Shao et al. 2019). A prevalent research area has been the use of remotely sensed data to dynamically analyze the interannual variations of long-term sequence vegetation (Ernst-Brock et al. 2019; Teh et al. 2015). Several researchers have used various vegetation indices and models to analyze and assess trends in vegetation change (Cui et al. 2019; Elhakeem and Elshorbagy 2015; Antilla 2005).

1.3 Quantitative Ecological assessment of vegetation

Visual estimations have been used in vegetation assessment despite more recent development of reliable numerical measurement techniques for the quantification of vegetation attributes. The evaluation of data by counting, measuring or even other ways of direct measuring is more comparable to approximation by eye. According to several ecologists, this does not provide a systematic way of evaluating vegetation parameters. Various methods have been suggested for this purpose in order to optimize the data collection on fields, supported via mathematical and statistical procedures in order to bring an accurate representation of vegetation (Curtis and Mcintosh 1950).

The use of multivariate methodologies in the investigation of vegetation data has many advantages. Ecologists get support from computer based multivariate systematic statistic softwares to define structure in data sets and to assess effects on complete group of species. Nowadays computer technology is fast and cheap (Hjorth 1993). Various software has been designed for vegetation sciences and used to develop comprehensive models, interpretation and approaches of descriptive statistics of plant communities. Vegetation science approaches include sampling, classification of vegetation, gradient analysis and investigation of association between species distribution and their atmosphere.

Recently several ecologists have been working to determine the underlying mechanism of vegetation composition in the entire vegetation complexes. The use of multivariate statistical methods such as Canonical Correspondence Analysis (CCA), Detrended Correspondence Analysis (DCA), Cluster Analysis and other statistical techniques have advanced ecological techniques (Hill 1979b; Ter Braak and Smilauer 1998). Cluster analysis is a technique of classification used to characterize and combine ecological communities into associations or clusters. DCA utilizes an Eigen vector of indirect gradient method focusing on investigation of plants distribution (Dyakov 2014; Waqas Khan et al. 2015; Chahouki 2013). As only plant plants data are needed for DCA study, it presents the results without interference. CCA, on the other hand, is a direct gradient, analytical method in which environmental factors regulate the distribution of plants. CCA is being used to establish association between plants and environmental factors (Arifa et al. 2018; Urooj et al. 2016; Ahmad et al. 2013; Urooj et al. 2015). Regression analysis is combined with either reciprocal averaging or correspondence analysis by the CCA method (David 2017).

Vegetation assessment has provided a strong base for improvement of ecological science for several decades. Plants at an individual or at community levels in response to its environment can be measured by means of quantitative and qualitative ecology (phytosociology). Phytosociology can also be used to explore plant community services over both quantifiable and qualitative methods from plants to community level, as it offers an understanding of species diversity and significance values (Greig-Smith 1983; Tüxen and Whittaker 1973). It is a developed field that explains the diversity of the plant communities and relationship with the environment (Miyawaki and Fujiwara 1988). The distribution of individuals in a community of the same or dissimilar species is a function of micro environmental changes, biotic interactions, and time. Therefore, understanding of vegetation can be helpful in assessing plant assembly of species in a community in a specific manner (Mueller-Dombois and Ellenberg 1974; Rieley and Page 1990; Shujaul Mulk Khan et al. 2011). In ecology, natural resource management and ecosystem protection, knowledge of plant species is a crucial requirement. This understanding is essential for the evaluation of rare plant species and the development of management policies to protect and minimize habitat fragmentation (Ewald 2003; Bhadra and Dhal 2010).

The investigation of plant diversity is a key concern to ecologists as it offers the foundation for global conservations policy (Pahwa et al. 2006). Phytosociological procedures permit environmentalists to compute plant diversity, abundance and richness of plant species in ecosystems. These methods not only assist to comprehend almost conservation but moreover measure as indicators of specific habitat forms. In addition, important value indices (IVI) can be calculated from datasets that do not merely provide an understanding of the heterogeneity of floral phenomena, but can also be used to provide an indication of plant conservation needs (Phillips et al. 2005; Mucina 1997). Furthermore frequency, fidelity and constancy investigation helps to recognize threatened plants and those habitats requiring protection (Baillie et al. 2004; Zou et al. 2007).

The use of several indicators and indices for better understanding in relation to anthropological activities are recommended (Feola et al. 2011; Vačkář et al. 2012). A single indicator cannot specify all aspects of biodiversity. On the basis of broad vegetation explanation and statistical investigation, indicator plants were recognized. (Khan et al. 2014) recognized indicator species based on the Indicator Species Analysis (ISA) in western Himalayas. At least one significant indicator was nominated from each of herb, shrub and tree layers in every community. Further vegetation studies along ecological gradients in mountains ecosystem have just matched the indices of diversity amongst communities. All species were treated correspondingly without seeing their ecological location and their importance in those specific ecosystems (Ren et al. 2006; Dasti et al. 2010; Siddiqui et al. 2009). Plant species with greater fidelity rates were reflected to determine the supreme conservation significance. Those type of species having limited distribution and perhaps patchy habitats are at maximum danger (Zou et al. 2007; Pinke and Pal 2008; Haarmeyer et al. 2010).

1.4 Biotic interaction in vegetation

Biotic interaction in the vegetation is the most significant factor for many plants affecting their surrounding plant species in environment. In ecology one of the most important debates focuses on the issue of the mechanisms by which plants interact with one another. Interactions between plants vary from positive (facilitation) to negative (competition) an have an impact on neighboring plants (Lambers et al. 2008). Many plants which germinate on the floor of the forest are climbers. Climbers grow by winding around, anchoring or adhering to other plants to achieve great stature for at least part of their life, or when the forest closes up around them (Jongkind and Hawthorne 2005).

Climber plant species depend on other plant species for mechanical provision; the amount of supporting tissues in axes has decreased to offer higher hydraulic conductivity in their stems. In development of length, a climber invests resource while tree allocates resources to supportive tissue (Gillespie et al. 2000). Climbers make a substantial contribution to forests' floristic, structural and functional diversity, where they can compete with other vegetation (Duivenvoorden et al. 2005). Both below and above ground resources, climbers compete with trees, considerably reducing growth rates, slowing the regeneration of tree seedlings and saplings and limiting the number of trees destroyed and killed in tree falls (Pérez-Salicrup 2001; Schnitzer 2005; Grauel and Putz 2004). Climbers may also have a beneficial impact on trees, offering useful shelter and links between tree canopies used by arboreal animals as pathways. By adding to carbon budgets, which comprise up to 10 percent of fresh aboveground biomass, climbers can also play a significant role at the ecosystem level (Putz 1984; Emmons and Gentry 1983; Ødegaard 2000; Kainer et al. 2006).

1.5 Abiotic Interaction and vegetation

The analysis of plant species – abiotic environmental variables is considered as an important subject in the ecological and environmental sciences. This type of interrelationship between environmental variables and forests is essential to any assessment (Guisan and Zimmermann 2000; Zhang et al. 2012). Floristic composition and its relation to environmental variables has become a recent subject of research.

Multiple studies have also shown that environmental variables are mostly correlated with the vegetation patterns and distribution, comprising local topographic variables (elevation, slope, aspect), soil factors (physical and chemical properties) and anthropogenic factors (Enright et al. 2005; Jabeen and Ahmad 2009; Jones et al. 2006; Tavili et al. 2009; Zhang and Zhang 2011; Zhang et al. 2012). Among abiotic variables, soil factors are the most important features affecting plant diversity and abundance in an area (Hejcmanovā-Nežerková and Hejcman 2006). In general, soil factors comprising of total nitrogen, organic carbon, and clay etc. primarily regulate the distribution of vegetation patterns. The main factors affecting plant species abundance and growth are the soil nutrients and physic-chemical soil properties (Eilu et al. 2004; Heydari and Pourbabei 2010; Zhang and Zhang 2011; Nguyen et al. 2015). Each species needs a particular nutrient contents and chemical composition to develop. The composition of these variables defines the fundamental habitat of an organism, described as the variety of conditions and resources under which individuals of a species can survive. Physiological tolerances to abiotic variables decide the boundaries of a basic habitat. Thus, abiotic variables have been found to be the strong determining features of certain plant species' development. Therefore, the distribution of plants within their environment is determined by the combination of abiotic variables, some of which are more significant than the others. On a local scale, what particular abiotic variables determine the fundamental habitat of a species? And what variables lead to increased success in one area in some habitats, and not in others? (Hotra et al. 2003; Boulangeat et al. 2012). Various approaches are used to determine such a complex relationship.

1.6 Geo-informatics and vegetation evaluation

Data collection to produce logical information about the dynamics of an ecosystem is an expensive and time consuming process. Consequently, our knowledge of globally important ecosystems like Western Himalayas, especially those which are found in the developing countries like Pakistan have been insufficient. However, with the invention and applications of satellite remote sensing techniques, these areas are getting international attention with detailed studies towards monitoring of biodiversity and ecosystem conservation (Muzein 2006). There is a need for speedy and innovative technologies for ecosystem management, inventories and valuation of biodiversity, environmental monitoring and species habitat suitability investigation.

These technologies should be based on physical factors of the ecosystem and socio-economic situations. Habitat mapping provides knowledge about quality and quantity of vegetation cover, the physical set up and anthropological interactions. Technological development in the area of remote sensing and GIS holds the promise to collect and integrate different levels of information (Roy and Ravan 1994).

Remote sensing data provide evidence with respect to location and extent of available areas and its spatial dissemination for execution of several problems. In the recent time relations between ecology and remote sensing have been considerably increased because of developments in imaging spectroscopy (Roy 1993; Schaepman 2005). GIS is associated with a powerful reference base or geographical locations including maps of vegetation, topography, soil, bird migration, hydrology and distribution of other wildlife. Locating various features related with attributes could allow various data sets to be combined and compared. It may also be analyzed in a particular data-base to create new relationships between environmental properties and the diverse biota. GIS, therefore, is an effective and powerful tool to communicate a wide range of data within the shortest possible time scale (Salem 2003). GPS is a ground based satellite and radio navigation system that facilitates the user to fix the accurate positions on the surface of earth. Therefore GPS and remote sensing have given rise to the beginning of more accurate and geographically referenced data sets for improved analysis (Milla et al. 2005; Codjoe 2007).

Knowledge about the distribution and status of species is important for wildlife research and conservation policies. Remote sensing and GIS are progressively used in monitoring flora and fauna habitats. In order to discover potential habitats for species such as the hamadryas baboons (Papio hamadras) in Eritrea, for example knowledge about the distribution of the main habitat features such as food sources, water supply, sharp cliffs and elevation of the area were digitized from topographical maps and remote data sets. It is demonstrated that locations with a mixture of these features are likely to be potential habitat for the species concerned (Zinner 1996). Therefore, remote sensing and GIS are broadly used to discover potential habitats, digitize the information and then for mapping the appropriate habitats. There has been a rapid rise in the usage of remotely sensed evidence for biodiversity assessment, land management, wildlife ecology, aquatic ecology as well as observing the effects of greenhouse gases and additional environmental problems (Muzein 2006).

Satellite imagery is a valuable basis for land use land cover information and urban land cover has been recognized and diagramed by remote sensed data with a reasonable spatial resolution (Cai et al. 2019; Tapiador and Casanova 2003). In the current years there has been a growing understanding of the impacts of geographical features in ecosystems. In specific important factors like spatial and scale configurations have become progressively significant in a huge range of ecological studies (Agrawal et al. 2007). Remote Sensing currently provides ecologists and other scientists with regular information on the earth and its atmosphere at the regional to global scale. GIS provides resources to collect evaluate and visualize spatial data containing those resulting from remote sensing altogether with related innovations in computational specialist tools and facilities (Austin 2007; Osborne et al. 2007).

Spectral resolution of the Remote Sensing method has high potential for monitoring land use and cover behavior, natural resources environment and hazards of land degradation in forest areas in Pakistan. Remote sensing and GIS can subsidize as an approach for observing land use through more comprehensive and time consuming approaches. Remote sensing has regularly been used to provide evidence of land cover. Variations in land use and land cover are the main variables that affect environmental system. Land use land cover types fluctuate significantly in their bio-geochemical cycling and hence information of their distribution is imperative in many ecological modeling studies. Land cover changes have major effects on matters fluctuating from climate change to biodiversity management. Given that the remotely sensed response is principally a function of land cover type there has been substantial interest in utilizing remotely sensed data sets as a source of evidence on land use land cover (Shahid 2011). Roles for GIS and RS can have a significant impact of the evaluation of spatial and temporal forest and urban land use classes. (Zafar et al. 2011) assessed land use variations by using Remote sensing data-sets for zonation organization of Margalla Hills National Park, Islamabad Pakistan on the base of diverse environmental variables. (Wardlow et al. 2007) utilized time series remotely sensed data for judgment of crops and related land cover types. Wheat harvest was projected based on the analysis and interpretation of the images. (Ashraf et al. 2007) investigated datasets of satellite imagery of drought and post-drought (2001 to 2006) phases in order to evaluate variations in vegetation cover and land use over hybrid (digital and visual) explanation methods.

Progressively organizations involved in forest conservation and management are utilizing this expertise to capture and analyze spatial occurrences. In conservation biology the emphasis has currently moved from individual species to entire ecosystems. GIS and Remote sensing methods could be utilized for inventorying, assessing and monitoring terrestrial biodiversity at local landscape and community ecosystem ranks (Noss 1990). Gap examination is a GIS based technique to identify breaches in the safeguard network (Powell et al. 2000). In a gap investigation of Western Ghats, India, (Ramesh et al. 1997) established that numerous regions of high biodiversity were omitted from the highest stages of protection. Recent developments in GIS and Remote sensing technologies have made it promising to quantify forest biodiversity from satellite images.

1.7 Vegetation of Pakistan and Study area

The vegetation types of Pakistan can broadly be divided into; a) Tropical:- Tropical dry deciduous forests, Littoral and Swap forests, Tropical thorn forests, b) Sub-tropical:- Sub-tropical pine forests and Sub-tropical broad-leaved evergreen forests, c) Temperate:- Himalayan moist temperate forests and Dry temperate forests, and d) Alpine:- Alpine scrub and Sub-alpine forests (Champion et al. 1965).

Administratively the study area is divided into six parts; 4 sub-divisions (Sambli, Ghora Gali, Sehr Bagla, and Lower Topa) and 2 ranges (Ban and Municipal range) shown in Iable 1.1. Murree forest division is approximately 44 % of the Murree Tehsil which contains almost 19,135-20127 hectares of forested land (State owned).

Table 1.1: Study area classification (subdivisions/ ranges)

Subdivision/ Range	Area (ha)
Sambli Subdivision	5,369.98
Ghora gali Subdivision	4,606.61
Sehr Begla Subdivision	3,182.12
Lower Topa Subdivision	2,439.12

Ban Range	2,368.53
Municipal Range	2,160.99

Murree is the most famous hill station in Pakistan. Murree located at 33-34° north latitudes and 73.30° east longitudes and lies 50 kilometers northeast from Islamabad, Pakistani capital at an elevation range from 500 to 2300m in the Himalayan foothills.

Figure 1.1: Murree Brewery remnants in the mid of Numbal and Ghora Gali

Murree is a mountainous region founding portion of the outer Himalayas on the western side Pakistan. It comprises four progressively growing foothills (Fig 1.1). On the highest among these is the Murree city itself situated at an altitude of 2290-2300m. Other peaks contain Patriata, Gharial and Kuldana. It is delimited in the east by River Jhelum, Haripur and Abbottabad districts of Khyber Pakhtunkhwa (KPK) to the West and North, in southwest Islamabad Capital Territory and in the South Kotli Sattian town of Rawalpindi district. Murree municipality was built in line with the European municipalities with Churches in the center and main The Mall road running along with commercial areas and organizational offices around this. The Mall road was and is still the center of charm. Non-Europeans were not permited to enter via the Mall road until independence in 1947.

1.7.1 Murree Forest Division (MFD)

Murree Forest Division is part of the Ecoregion of Western Himalayas which is familiar as among the Ecoregions of the World (referred to as G200/ Global 200) based on biodiversity and ecological significance. Murree Forest Division is a famous hill station and a well known tourist hotspot in Western Himalaya of Pakistan. It is situated along Islamabad - Kohala highway, 30 kilometers northeast of Islamabad. Murree is one of the large tehsil of District Rawalpindi, Punjab. Geographically MFD lies and centered at 33°52′26.34″ north and 73°23′42.21″ east (Fig. 1.2). MFD is located in diverse ecological zones from Himalayan moist temperate to Broad-leaved deciduous forest at lower elevations (CI-IAGHTAI et al. 1978). İts elevation ranges 500- 2380masl (1700-7800ft). Murree hills came in to existance by the collision of Indian plate and Eurasian plate by a rapid raise in early Ecocene era (Zeitler 1985). The area gives secenic view and is important in having compact forest at higher elevations which typically includes Cedrus, blue and chir pine forests.

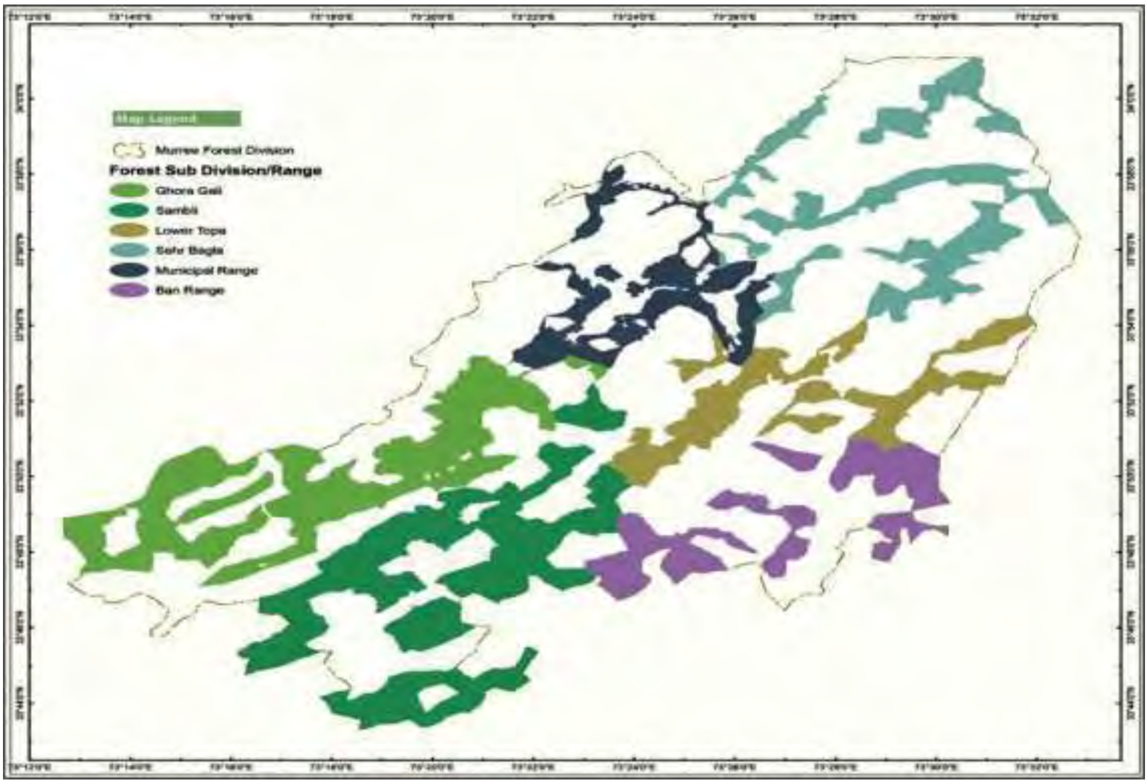

Figure 1.2: Administrative classification of MFD

1.7.2 Geology, Geography and Climate

The Himalayan range which is 2500 km long was formed during Eocene period by the collision of the Eurasian plate with Indian plate along a junction region about 20 million years ago leading to the construction of quickly elevating zones (Abbasi et al. 2002; Amir Nawaz Khan et al. 2011). Murree region comprises brittle rocks with hard gray reddish sandstones interbedded with soft red calcareous shales and alluvial deposits belongings to Shiwalik and Sirmar series of sub-Himalayas structure (Amir Nawaz Khan et al. 2011; Khan 1992; Farooq and Malik 1996; Saqib et al. 2014). This region fall in tertiary and quaternary sediments dominate the zone with extensive rock formation of Shiwalik nature (Gansser 1964; Ahmad 2011). Sedimentary rocks of the Murree area are highly mutilated due to active geological faults and tectonic pressures. These rocks have the uppermost affinity to landslide hazards (Ishfaq 1999; Amir Nawaz Khan et al. 2011). The Murree city is built in the European style that is the reason that has Church in middle and marketable regions along-side the main Mall road. At the time of foundation it comprised only five major regions but with the passage of time there have been several territorial variations in the Murree area. At present Murree is divided into fifteen union councils (UCs) and cantonment zones. Some of the UCs contain Murree are Angoori, Ghoragali, Charhan, Dewal, Phagwari, Mosyari, Potha Sharif, Nambal, Tret and Sehrbagla etc. Another geographic significance of the Murree is that it links the Punjab plains to the Kohala, Azad Kashmir, and Abbottabad, KPK province.

Climatically the Murree hills are divided into diverse regions from higher temperate zone to subtropical lowlands. Such a varied climate in a small geographical area to a diverse topography is triggered by the differences in elevation, depth of the snow accumulation amount of snowfall in winter and changing vegetation etc. The weather has four distinct seasons i.e. summer, autumn, winter, and spring. Usually the climate is cooler at higher elevation and warmer at lowlands with a short autumn and spring seasons. In the western Himalayas higher mountains located at the opening of the hills act as a block to the summer monsoon and bound its dissemination into the upper north western parts of the mountains (Syed et al. 2010; Clift et al. 2008). Winter normally start in the December and the area gets considerable snowfall. Murree and its neighboring parts are shielded with thick layer of snow in most of the winter and temperatures are often about freezing. Summer duration lasts from May to the end of August. The months of June and July are the topmost tourists' season in the Murree.

1.7.3 Temperature and Rainfall

The Murree region exhibits extensive differences in temperature due to substantial altitudinal and topographic variations. The mean lowest temperature was 4-9°C whereas highest temperature was 27-30°C respectively during the years 1988 – 2018 (Metrological Department Islamabad, Pakistan). The warmest month of the year was June, 2018 with an average maximum temperature of 30°C. Spring season in Murree area lasts from March to the middle of May. Maximum temperature in this period fluctuates between 12-20°C and minimum 4-9°C respectively. Monsoon winds are the leading source of rainfall. The Murree hills receives the highest quantity of precipitation in Pakistan with an average of 1,640mm- 1,904mm and nearly 89 mean rainy days per year (Farooq and Malik 1996; Archer and Fowler 2008; Association 2013). On the other hand several parts of the region receive fluctuating quantities of precipitation. The majority of the rainfall is received from July to August during the monsoon.

1.7.4 Murree Bio-physical Environment

Ecological research on habitat forms has not been performed comprehensively in some of the mountainous regions of Pakistan, particularly in the Himalayan regions. For the first time (Champion et al. 1965) designated the forest types of Pakistan using the wide-ranging groups: alpine scrub, subalpine forests, Himalayan dry temperate, Himalayan moist temperate, subtropical pine forests, tropical thorn forests, dry sub-tropical forests and marshlands. (Beg 1975) defined key habitat forms as; cold desert, alpine vegetation, dry temperate, subalpine forests, moist temperate forests, subtropical forests, subtropical semi evergreen forests, tropical dry deciduous forests, tropical thorn forests and tropical swamplands. All these vegetation forms excluding the swamplands are characterized in the northwestern parts of the Pakistan (Beg 1975; Champion et al. 1965). The Murree Mountains are placed on the foothills of the Western Himalaya, Pakistan and therefore forms a portion of the internationally acknowledged Western Himalayan floristic province (G200) of western Asiatic Irano-Turanian sub region. Its floristic, climatic, geological, geomorphological and geographical setting makes it a unique biodiversity hotspot.

This offers a particular phyto-geographical importance to the Murree hills and its flora.

1.7.5 Urban and Rural Division

Most of the urban populations live in the areas of two cantonments and Murree City (Fig 1.3). Permanent urban residents are few and most of the urban parts have private corporations, rest houses of government and summer resorts of elite class. Other important commercial institutes are the General Post Office, tailors and millinery and general merchants. Murree Brewery was established in 1860 at Ghora Gali to satisfy the drinking desires of the British in the area. About 88% of the rural population lives in small villages spread across the top of the Murree hills. The village residents have easy convenience to the local primary and secondary schools, clinics and bazaars. But water supply to the families of villages has constantly been a problem. People are migrating mostly for new job opportunities, the lack of other supplies like tap water, gas, roads and to meet the higher education needs of their children. Major portion of these people migrate near the low rental settlements of Rawalpindi and Islamabad.

Figure 1.3 Urbanization expansions in the Murree City

1.7.6 Education and Literacy

As per 1998 census Murree was reported with 69% literacy rate in the age of ten. Murree region is amongst the most well-educated parts of Pakistan and simply exceeds main cities in this respect. Ausia area having education rate of 82.7% in the populations of just 4450 residents is amongst the maximum literate areas in the country. There is undoubtedly no other rural village in Pakistan which has such an extraordinary literacy rate. In the beginning primary schools were established in the Ausia, Murree, Karor and Tret. There has been one degree college (for girls and boys each) at present in the Murree area. At Phagwari region, one additional girl's college was established. Moreover there are 112 boys and 109 girls primary schools, two boys higher secondary schools at Tanda and Ausia, 16 boys secondary and 6 girls high schools whereas 12 boys middle and fifteen girls middle schools.

Murree too is renowned for its elite academic institutions that have attracted students from all over the region. Lawrence College was founded as Memorial Asylum (Lawrence) around 1860 at Ghora Gali for children of retired or serving British armed forces far from tropical environment of subcontinent. It was portion of four such schools chain which established through British India. Lawrence College covers a space of more than 150 acres at an elevation of 1950m and provides education from grade 1 to O and A level and is famous among elite classes in Pakistan (Figure 1.4).

Other colleges established for the children of British colonialists but nowadays serving the Pakistani aristocracy includes Convent of Jesus and Marry and Saint Dynes (Figure 1.5). Saint Dynese has in recent times closed its boarding facilities in order to accommodate the necessities of the native population. After independence further schools have been established including: Army Public School, Cadet College Murree at Pindi Point and Cadet College Lower Topa. It would be discriminating not to discuss Murree Christian School which was unfortunately exposed to terrorist attack during 2002. Murree Christian School situated at Garial near Jika Gali assist educational necessities of children of missionaries who serve in Pakistan. It receives admission from grade 4 - 12 and is open for young people from Christian families even if they work in other occupations. It is the head office of the Murree-Town (sub-division) of Rawalpindi district, Punjab of Pakistani.

Figure 1.4 Lawrence College, Ghora Gali, Murree

Figure 1.5 Front elevation of Convent of Jesus and Marry building

1.7.7 Livelihood

Livelihood in most of the remote areas in the Murree Mountains is one of the challenges for survival. Typically, people have more than one kind of profession in order to keep sustainable livelihoods. Commonly each family keeps livestock grazing to meet their dairy and poultry requirements and to earn a living. The quantities and types of livestock differ from a few to hundreds. The majority of the households keep animals such as cows, buffalos and goats. The live stock provide the livelihoods to the indigenous people for the reason that the rangelands of the Murree region are full of palatable and nutritious grass species (Shaheen et al. 2011; Shaheen et al. 2014). Grasses are harvested and stored which are supposed to be used as dry-fodder which is fed to cattle during the winter seasons. Now the majority of the people are switching towards the adjacent cities of Islamabad and Rawalpindi for other professions.

As Murree area is mostly rain fed and hence the agricultural economy is contingent on rainfall and to a particular level on water providing by mountains springs and streams. The area in Murree region is cultivated up to round 2000 m asl with fruits and cereals frequently on stepped slopes even though there are also large parts which are uncultivated and have thin soil with slight vegetation. In a few parts of the Murree old ways of agriculture are still experienced where the fields are ploughed with bullocks. The commonly grown crops in the Murree area are Wheat, Millet, maize, Barley, Mustard, Sunflower, Turnip, Pulses, Tomato, Pumpkins, Radish, Cucumber, Lady finger and Potato etc. Fruits trees like Apple, Pear, Citrus, Plum, Guava, Apricot, Walnut and Peach are grown in the area (Ullah 2009).

Murree's livelihood also depends greatly on tourism during January to mid-October. Monthly from 20,000 to 25,500 tourists visits these foothills ranges. Similarly each year more than one million tourists visits the Murree area and the number is rising by 5% each year throughout the times of political calmness (Amir Nawaz Khan et al. 2011). Domestic tourism contributed Rs. 89 billion in 2018, contributed up to 30% of the total domestic travels and tourism expenditures.

1.8 Importance/ justification of the present study

The foothills of Western Himalayas have been rarely studied for ecological evaluation and vegetation dynamics. Vegetation diversity in these mountains is under huge anthropogenic pressures in the form of over grazing, poor collection approaches, flawed storing of medicinal plants, uneducated people and unmaintainable Government policies (Hamayun et al. 2003). The consistent abandoned harvesting of essential medicinal plants along with augmented habitat degradation and human interventions in their distribution zones has an overwhelming effect on populations. Numerous essential plants having small ecological place are being constantly exploited are vulnerable to their presence (Shinwari and Gilani 2003). In this situation basic phytosociological knowledge about vegetation dynamics and distribution is instantly mandatory to develop and launch a conservation plan.

Phytosociological studies disclose that many of the struggles in such disciplines performed individually; focusing on only one approach. The struggles are not restricted to ecological either quantitative vegetation characteristics such as frequency, density, and cover or only floristic inventories of the vegetation but also utilized geo-informatics (GIS & RS) tools. Therefore in the current research an integrated approach was made to study, investigate and analyse both important sides of vegetation i.e. Ecological multivariate analysis and their association with environmental and anthropogenic variables and GIS & Remote sensing tools for long term historical forest dynamics assessment by land use land cover. This research work was planned to collect baseline information about phytosociology; species composition and distribution pattern, stand population structure, frequency, density, abundance and other essential species as well as community physiognomies in the western Himalayan region.

In the present study, an attempt has been made to examine and evaluate association of vegetation in relation to important environmental factors using multivariate analyses procedures. Limited quantitative studies have been conducted so far in forests regions of western Himalaya of Pakistan to explain different population structure and forest types. Similarly few studies have been carried out using GIS and Remote sensing tools. Therefore this research was intended to describe quantitative description and population structure of diverse Himalayan forests in Murree Mountains, Pakistan. Another important aspect was to analyze the individual characteristics and mapping the forest vegetation into diverse forest types. Data acquired over a combination of these methods make available basic information for conservation planners and biodiversity managers to assess ecosystem services delivered by mountain ecosystem and to articulate sustainable management policies.

1.9 Research Hypotheses, aims and Objectives

The main aim of this PhD research project is the evaluation of vegetation dynamics of the Murree forests with special focus on integrating of Ecological and Geo-informatics tools for Present day picture of plant biodiversity, to assess impacts of climate change and loss of vegetation due to expansion in infrastructure to evaluate the anthropogenic pressures; a step towards sustainable conservation of flora.

In order to meet the stated aims, all the objectives were successively met. In the first year, the objective was to complete floristic inventories of the overall vegetation diversity by using ecological approaches along with the diversity and abundance of climber plant species was carried out using multivariate approaches. In the second and third years, these data sets were incorporated to classify different plant communities on the basis of indicator species in different habitat types and also to evaluate the microclimatic conditions of species-environment relationships by using multivariate methods such as canonical correspondence analyses, data attribute plots and indicator species analyses (ISA). In the third and fourth years, research was conducted to understand the land use land cover classes and climate change impacts in the Murree forests was analyzed through GIS & Remote Sensing tools. The objectives were explored by investigating the following hypothesis:-

1.9.1 Hypothesis 1

Present day vegetation structure and community assemblies are an expression of the abiotic factors and biotic relationships and it is of crucial importance for future conservation strategies.

1.9.1.1 Objective i:

To quantify vegetation dynamics and features like floristic inventory cover, density, frequency, IVI, leaf spectra and life form from Murree.

1.9.1.2 Objective ii:

To quantify the present day vegetation and to categorize different plant communities on the basis of indicator plant species in different habitat types by combining multivariate classification and ordination practices.

1.9.2 Hypothesis 2

Climber plant biodiversity has a strong correlation with hosts (trees and shrubs) and is affected by abiotic factors as well

1.9.2.1 Objective iii:

To assess the diversity and abundance of climber plant species by using multivariate techniques

1.9.3 Hypothesis 3

Climate change has considerable impacts on the cover of vegetation that is triggered by urbanization in the hilly areas over the past few decades.

1.9.3.1 Objective iv:

To analyze various data sets related to climate change and land use land cover classes for estimation of vegetation dynamics in MFD and loss of vegetation due to expansion in infrastructure through GIS & Remote Sensing tools.

1.10 Thesis structure

Keeping in mind the overall Hypotheses and objectives of the current research, I have written the thesis in the following way. Chapter 1 comprises a general introduction that provides an overview of quantitative ecological evaluation, biotic and abiotic interactions of vegetation, geo-informatics evaluation of vegetation dynamics, importance of the study area, aims and objectives and thesis structure. Chapters 2-4 have been written in the journal articles design; each one having introduction, methods, data collection, analysis, results and discussions. Chapter 2 covers quantitative ecological evaluation and vegetation dynamics (vegetation structure and community assemblies). Chapter 3 describes the diversity and abundance of climber plant species. The 4th chapter is about climate change and land use land covers classes for estimation of vegetation dynamics in MFD and loss of vegetation due to expansion in infrastructure via geo-informatics tools. Chapter 5 discusses and synthesizes the main findings and conclusions with respect to their significance for the MFD of the Western Himalayas. It is comparatively unexplored floristically in terms of biodiversity conservation and hence provides recommendations for biodiversity conservation plan that prioritize plant species and habitats for sustainable future.

Chapter 2 QUANTITATIVE ECOLOGICAL EVALUATION AND VEGETATION DYNAMICS ALONG THE ELEVATION IN THE MURREE FOREST DIVISION (MFD)

2.1 Introduction

The Himalayan region is one of the earth's rich montane ecosystems in terms of of biodiversity and vegetation. It is one of the significant biodiversity hotspots and hence possesses vast diversity in flora and fauna (Chawla et al. 2008; Singh 2001; Khan et al. 2013b). A wide range of elevation, climate, rainfall, geological conditions, topography and river systems have given rise to diverse flora and fauna in the region. Flora is the reflection of physiognomy, biotic and abiotic influences. Floristic inventory is the baseline study for the exploration, sustainable use, conservation and management of the biodiversity components and monitor fluctuations over time (Heywood and Watson 1995). The floristic diversity demonstrated by a particular region's flora depends upon the related environmental and climatic conditions (Khan et al. 2018). The distribution of vegetation is the reflection of micro-and macro-environmental factors. Understanding these associations concerning species diversity and abundance and biotic and abiotic environmental components is a critical field of ecological research (Vetaas and Grytnes 2002; Tavili et al. 2009). For example, aspect and altitude significantly affect plant species composition and distribution pattern in the mountainous region (Chawla et al. 2008; Waqas Khan et al. 2015).

On the other hand, (Raunkiaer 1934) proposed the concept of biological spectrum classification. It is the percentage distribution of various life form classes of a particular flora. It is used as a catalog for comparing geographically distributed plant communities with a defined stratification pattern and layering of a community, the nature of phyto-climate and its ambient stress elements (Moro et al. 2015). The existence of a similar biological spectrum in diverse areas specifies a similar environmental situation and acts as an indicator of the micro and macro climate of an area (Abedi and Abedi 2015). Plants are classified into various life forms based on similarities in function, structure and environmental conditions, including adaptation responses to the leading climatic circumstances (Sher et al. 2014). The life form classification is an essential physiognomic characteristic that articulates the synchronization between plants and their surroundings. It is used in floristic studies standing next to vegetation composition (Shimwell 1971). Leaf size spectra are a reflection of the vegetation adaptation and are convenient for discovering plant associations concerning the predominant climatic features (Rashid et al. 2011). According to (Raunkiaer 1934) system of classification, all types of plant species are categorized into five fundamental life form classes i.e., Chamaephytes, Cryptophytes, Hemicryptophytes, Phanerophytes and Therophytes (Ullah et al. 2015).

The leaf spectra, life form and other phenotypic characters reflect the prevailing environmental and evolutionary operating conditions (Badshah et al. 2013; Hussain et al. 2015). It s used as a robust indicator for evaluating the ecological healthiness of a specific area. For example, the dominant life form characterizes how plants have evolved in that area (Zarezadeh et al. 2007). Similarly, the leaf size indicates the day and night temperature, rainfall and solar exposure of the region (Wright et al. 2017). Life form spectra and leaf size are important physiognomic features that indicate an area's micro and macroclimate (Shimwell 1971; Khan et al. 2018). Unraveling the patterns of these ecological characters can significantly advance our understanding of the functional features of vegetation of a particular area (Cadotte et al. 2011).

Furthermore, ecologists use multivariate statistical techniques for the classification and ordination analysis to understand the complicated relationship of flora in different environmental gradients. These help to determine structure in vegetation data and the number of significant plant communities. It also evaluates the effects of environmental factors on whole groups of species more effectively (Jongman and Jongman 1995). Statistical analysis simplifies data by summarizing it into well-presented format.(Dufrêne and Legendre 1997; McCune and Mefford 1999; Shujaul Mulk Khan et al. 2011; Haq et al. 2015a). These multivariate approaches can be divided into indirect and direct gradient analysis. The groups of species can be identified using detrended correspondence analysis (DCA) and Hierarchical clustering (Jongman and Jongman 1995; Ahmad et al. 2010). (Hill 1979a) created DCA, which can be used to classify species groups based on their compositional variance with standard deviation (SD) of species axes (Hill and Gauch 1980). Similarly, canonical correspondence analysis (CCA) generated by (Ter Braak 1987) and used to measure the pattern of species-environment relationship comprising permutation test which can be used to assess the overall significance as well as for individual CCA axes and descriptive variables (Legendre and Legendre 1998). Such methods have still rarely been used for vegetation in Pakistan (Malik et al. 2007; Saima et al. 2009; Malik and Husain 2008; Wazir et al. 2008). Indicator Species Analysis (ISA) is a significant focus in plant ecology (Kremen et al. 1993; Carignan and Villard 2002; Dauber et al. 2003; Abbas et al. 2016; Iqbal et al. 2018). Typically, one or more indicator species are assigned within each particular habitat. Indicator species are amongst the most crucial habitat species that serve as a reference for ecosystem monitoring. Also, the identification of indicator species makes it much simpler to manage different sampled ecological communities. Such grouping may be stenotopic and eurytopic (Noss 1990; Kremen et al. 1993; Shah et al. 2015). Various environmental factors, such as climate, soil conditions and other prevailing practices, also influence the recognition, distribution and classification of indicator species (Khan et al. 2013a; Iqbal et al. 2018).

The Himalayan range is one of the most resourceful ecosystems with changing climate, remarkable seasonality, and various plant species and groups. But due to inaccessibility, extremes of climate, uncertain geopolitical situation and rough landscape, most of the regions are still ecologically unexplored (Khan et al. 2013a; Oommen and Shanker 2005). Forests are the most valued and precious natural resources are in need of repeated monitoring, implementation, developmental activities, and conservation plans to save diversity. An area's biodiversity status is indicated by ecological studies associated with planting species dynamics and their relationship with the environment (ARSHAD MAHMOOD Khan et al. 2015). The majority of the botanical research published from the Pakistani Himalayas/this region included floristic records for writing ethnobotanical or floras studies (Waqas Khan et al. 2015; Ralph Randles Stewart et al. 1972; Dickoré and Nüsser 2000; dan Prospek et al. 2013; Khan et al. 2018). Limited measurable studies piloted to report the plant communities and their related environmental variables for local vegetation and plant diversity structures have been undertaken using a modern statistical approach (Khan et al. 2013a; Wazir et al. 2008; Saima et al. 2009; Shujaul Mulk Khan et al. 2011; Shaheen et al. 2011; Shaheen et al. 2012). Therefore in the first part, we considered the floristic composition and biological spectrum of the Murree hills' ecological features as a preliminary step towards finding prospect of its expansion and exploration for the betterment of the indigenous people.

This study's findings will serve as the first detailed baseline document to identify and document plant biodiversity. It's hypothesized that the prevailing environment factor strongly influences the vegetation of the study area. The second part of the study aims to attain an empirical model of forest vegetation using plant species associations to describe different vegetation types (Weber et al. 2000). The primary objectives of this study were: (i) To measure the floristic composition (abundance & rarity) of vegetation, (ii) To evaluate the microclimatic conditions of the species-environment relationship, and the significance of the different variables by using multivariate methods such as canonical correspondence analyses, data attribute plots and indicator species analyses for developing vegetation framework to understand better indicator groups (iii) To identify indicator plant species in different habitat types and categorize different plant communities and (iv) To classify and map the study area into various elevation classes.

2.2 Materials and Methods

2.2.1 Field Survey

Frequent floristic surveys ranging from subtropical to temperate zones were conducted to evaluate the floral diversity and structure in the Murree Forest Division (MFD) during the years of 2016 to 2018 (Figure 2.1). The quantitative quadrat method was assessed for the vegetation sampling (Cox 1996; Everson and Clarke 1987; Moore 1986; Khan et al. 2013b). First, the entire MFD was divided into 40 sampling localities/stations (villages). At each station, transects and quadrats of different sizes such as $1m^2$, $5m^2$ and $10m^2$ were taken for herbs, shrubs and tree species, respectively. Phytosociological attributes (cover, frequency, density, relative values, and importance value index) for each plant species were measured in each quadrat (Kharkwal et al. 2005; Ali et al. 2006; Khan et al. 2014; Tanvir et al. 2014). The recorded plant specimens were pressed, dried, and mounted on standard herbarium sheets using standard taxonomic techniques. These specimens were identified by comparing with authorized herbarium specimens at the Department of Plant Sciences, Quaid-i-Azam University Islamabad and with the help of taxonomic keys of Flora of Pakistan (Ali 2008; Magill et al. 2019; Ali and Qaiser 2008; Garden 2011; JCh 2007; Qaiser and Abid 2003; Nasir et al. 1972; RR Stewart et al. 1972) in addition to Efloras and Tropicos, (2018). Various available online taxonomic literature and databases (Efloras, The Plantlist, Global Names Index, Jstor, Grin/NPGS, MMPND, ITIS, GBIF, Tropicos, PFAF, Springer Reference and Plantsystematics.org) were accessed to describe the up-to-date taxonomic naming rank of all the plant specimens (Arshad Mahmood Khan et al. 2016). All the specimens were deposited in the Plant Ecology and Conservation Lab., Department of Plant Sciences, Quaid-i-Azam University Islamabad, Pakistan, for record and future references.

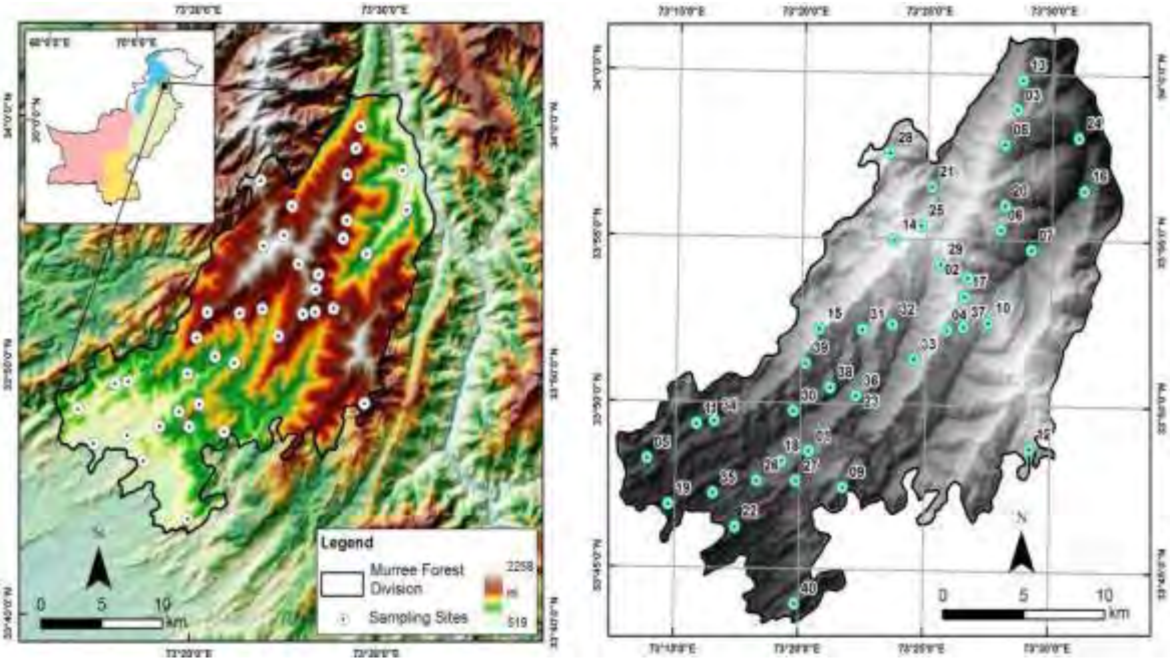

Figure 2.1: Map showing the vegetation sampling locations in the study area

2.2.2. Recognition of Abundant and rare species

The abundance and rare vegetation measurements were assessed based on the Importance Value Index (IVI). It was calculated by adding Density, Frequency, and cover's relative values and dividing by three (Khan et al. 2017). The plant species with an IVI value of more than one thousand were considered the forests' dominant species. On the other hand, rare plant species were considered to have an IVI less than 30.

2.2.3. Assessment of biological spectrum

The biological spectrum of the recorded plant species was measured using (Raunkiaer 1934) classification.

2.2.4. Estimation of environmental, edaphic and topographic variables

Geo-coordinates and altitude were recorded using GPS (Garmin Etrex 30 GPS) of each sampling station. The slope angle of each station was determined using a clinometer (Haq et al. 2015a). The digital elevation model (DEM) of the study area was designed by ArcGIS (10.3 version) for mapping plant communities (Gergely et al. 2016).

Soil samples (1000 g) were collected up to 15 cm depth from each quadrat/station and labeled appropriately. The soil samples were mixed in a 1:5 ratio by volume with distilled water, shaken for 5-10 minutes and kept for 30min in normal conditions. The soil pH and electrical conductivity were measured using pH and electrical conductivity meters (Schofield and Taylor 1955; Jackson 2005). The hydrometer method was assessed to determine soil texture (Beretta et al. 2014). The calcium ions were removed and determined from the solution by complexion with oxalate anions by adding soil (0.5 gram) to 20mL dilute HCL to completely dissolve. Neutalized the solution and transfered it to volumetric flask (100 ml). Titration method was used to determine calcium ions (Kroetsch and Wang 2008; Monteith et al. 2014). Walkley and Black's titration method was used to determining the soil organic matter (OM) (Hussain 2009; Schulte and Hoskins 1995). Sodium bicarbonate solution as an extracting agent was used to calculate the available phosphorus (ppm) and available potassium (ppm) using the ammonium acetate and potassium chloride as standardized solutions (Kitayama and Aiba 2002; Olsen 1954). Regeneration on a scale (of 1–4: None, Poor, Fair and Good) was calculated by comparing sapling and seedings density to that of mature plant species; and forest Canopy on a scale (of 1–3: Open, Moderate and Close) were measured. Anthropogenic disturbance variables on a scale (of 1–3: Least (< 10%), Moderately (10-50%) and highly disturbed (> 60%)) focusing deforestation or wood extraction pressure at each quadrat were measured (Shaheen et al. 2015). Grazing pressure (low to very high) was measured on a scale (of 1–4: Low/ none, Moderate, High and Very High) by counting the livestock dungs (0-4) and also by observing the new signs, trampling effects (0-4) and intensity of grazing cattle (1-4 or >4) (Bahamonde et al. 2017).

2.2.5. Data analyses

All the collected data of 454 plant species and measured environmental variables were put in MS Excel and prepared according to software requirements. Species presence and absence data were prepared for Cluster and Two-way Cluster Analysis using PCORD version 5. These analyses provided information about significant plant communities based on similar floristic composition (Greig-Smith 1983).

2.2.6. Drawing Species Area Curves (SACs)

SACs are commonly used to estimate the required sample size, to understand biodiversity in plant ecology and environmental influences. Species area curves and compositional curves were constructed for 166 stations to evaluate whether the sampled size was sufficient to achieve the plant species composition concerning the number of sampled sizes (McCune and Mefford 1999; Turner and Tjørve 2005; Grandin 2006).

2.2.7. Mantel test

The Mantel test was conducted for the examination of significance of correlation among the plant species and environmental data using PCORD software via the permutation method. The Z statistics calculated after each permutation and the following values are used for the significance test. To measure the correlations between the environmental and floristic distance matrices, the Mantel test was run. Both primary and second matrices with a similar number of rows were needed to run a Mantel test. The extent of correlation of quantitative features of vegetation under the effect of environmental factors by using the Mantel statistic value (vary from −1 to +l) at various locations (Mantel 1967; Khan 2012). The vegetation data matrix was examined concerning only one environmental variable to avoid the third standard variable for two correlated variables as no ecological significance can observed.

2.2.8. Identification of indicator species (ISA)

ISA was carried out to identify the indicator plant species of each plant community using PCORD software. The indicator values for each plant species found out using the Monte Carlo Test of significance (Dufrêne and Legendre 1997; Shujaul Mulk Khan et al. 2011). A threshold level of 95% significance ($p \leq 0.05$) was kept to identify indicator plants (Ter Braak and Prentice 1988; Dufrêne and Legendre 1997).

2.2.9. Species-environment relationship by using correspondence analyses and data attribute plots

Ordination analyses i.e., Canonical Correspondence Analysis (CCA) and Detrended correspondence analysis were carried out to examine the plant species composition in relation to environmental factors. The ordination procedures i.e., direct environmental gradient and indirect analyses, were done using CANOCO ver. 4.5 (Ter Braak 1987, 1986; Ter Braak and Barendregt 1986; Ter Braak and Prentice 1988; Ter Braak and Smilauer 1998). Complete data sets were used in the gradient investigation. We used indirect methods i.e., Detrended Correspondence Analysis (DCA) and direct method Canonical Correspondence Analyses (CCA). The vegetation data were used without the environmental data input to evaluate the faithfulness of numerous assemblies of species and stations. Detrended Correspondence Analysis provided more strong and understandable outcomes than Canonical Correspondence Analyses and therefore was used as a tool for more indirect gradients exploration.

2.2.10. Elevation classes and vegetation of MFD

Elevation classes of the Murree Mountains were classified based on the altitudinal values by using DEM of a geographic information system working with maps (ArcGIS) (Gergely et al. 2016).

2.3 Results

2.3.1. Adequacy of sampling

Species area curves were measured using PCORD in order to ensure an adequate sample size used for vegetation study. Our data set's average number of species ranged from 30-35 at 1st station with (average distance 0.7850 km) to 454 in station 166 with an average distance of 0.0058. The average Sorensen distance was reduced to around 10% after about 13 stations had been sampled, demonstrating that a stable plant community composition had been estimated (Figure 2.2).

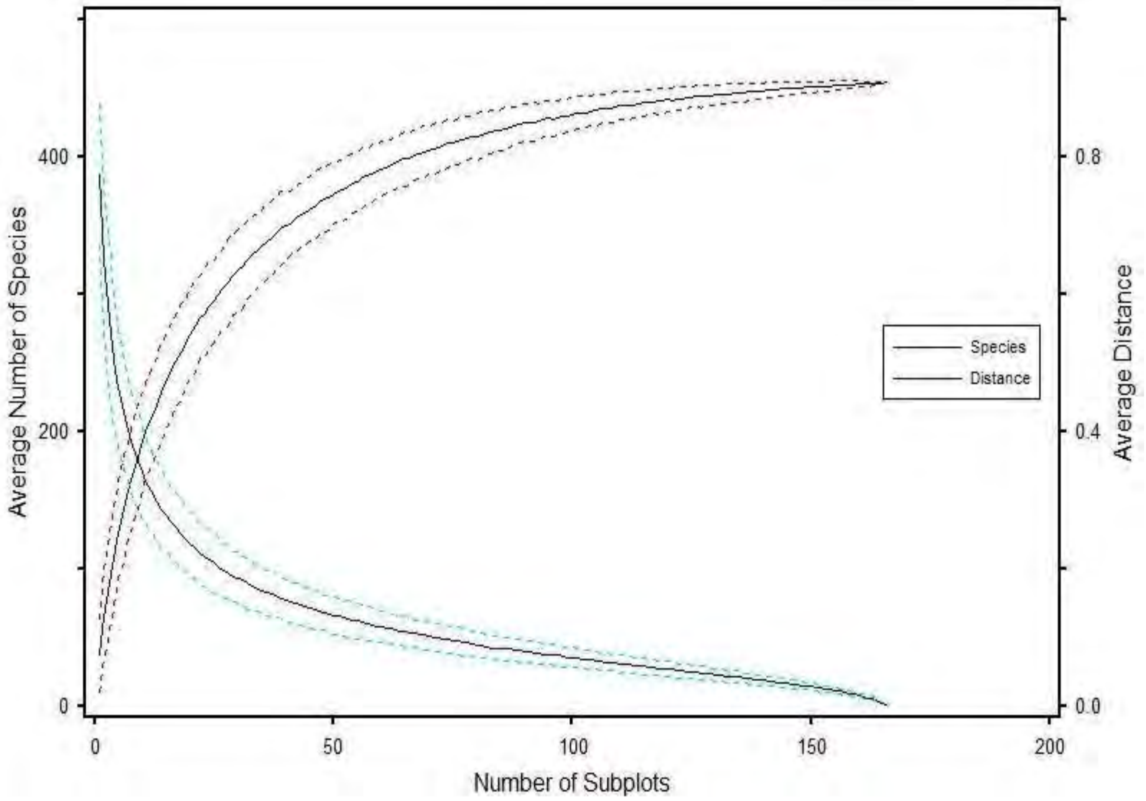

Figure 2.2: Species area compositional curves based on IVI data for all 454 plant species and 166 stations.

2.3.2. Floristic composition

A total of 454 different plant species (belongs to 98 different families) were recorded from 166 stations consisting of 498 quadrats. Habit wise they consisted of 70 trees (15.41%), 85 shrubs (18.72%) and 299 herb (65.85%) species (Figure 2.3). All the reported plant species belonged to 294 genera. Genus wise leading genera were *Galium*, *Geranium*, *Rosa* and *Swertia* (6 spp. each) followed by *Carex*, *Clematis*, *Dryopteris*, *Quercus* and *Ranunculus* (5 spp. each) each, *Adiantum*, *Albizia*, *Euphorbia*, *Indigofera*, *Medicago*, *Plantago*, *Poa* (4 spp. each), *Acacia*, *Agrostis*, *Asparagus*, *Bergenia*, *Bromus*, *Cymbopogon*, *Erigeron*, *Ficus*, *Gentiana*, *Hypericum*, *Impatiens*, *Jasminum*, *Lolium*, *Persicaria*, *Pyrus*, *Rhus*, *Rubus*, *Rumex*, *Salix*, *Solanum*, *Sonchus*, *Veronica* and *Ziziphus* genera were represented by 3 species each while the remaining 255 genera possessed either two (2) or one (1) species in each genus (Figure 2.4).

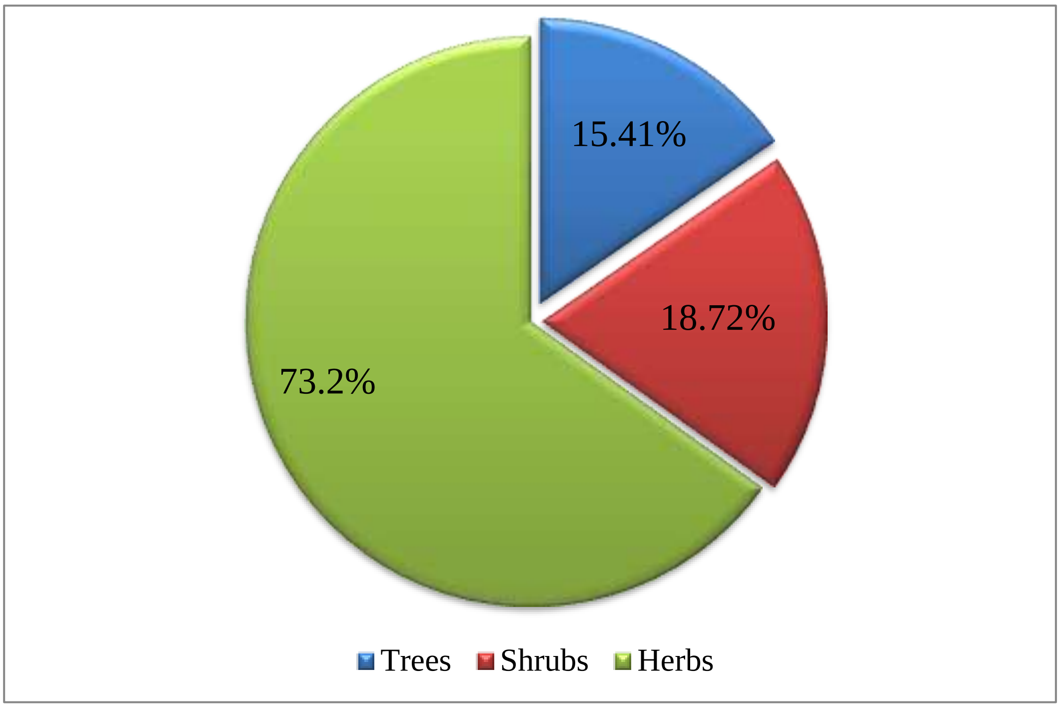

Figure 2.3: Histogram showing habit wise percentages of plant species present in Murree Forest Division

2.3.3. Taxonomic categorization

Dicotyledonae and Monocotyledonae subdivisions of Angiosperms division consisted of 91 families, whereas Gymnospermae contained 4 (Cupressaceae, Ephedraceae, Pinaceae and Taxaceae) families and Pteridophytae comprised 3 (Dryopteridaceae, Equisetaceae and Pteridaceae) families (Table 2.1).

Table 2.1: Taxonomic detail of reported plant species of the Murree Forest Division

Taxonomic category	No. of Families	No. of Species
Dicot	81	352
Monocot	10	80
Subtotal of Angiosperms	**91**	**432**
Gymnosperms	4	9
Subtotal of Spermatophyta		
Pteridophytes	3	13
Total No. of Families & Species	**98**	**454**

Family wise, Poaceae was the most abundant plant family with 53 species and comprising 54% of the total population of species, followed by: other families such as Asteraceae with 37 species and a 38% share; Papilionaceae, Lamiaceae, Rosaceae with 21 species and 21% share; and Apocynaceae, Cyperaceae, Ranunculaceae with 12 species and 12% share; and Rubiaceae with 11 species and 11% share. The above mention 9 families contributed 44% of the entire species. The other remaining 89 families possessed below 10 or fewer species having 56% (Table 2.2).

Table 2.2: List of all families with species number and their group

Family Name	No of species	Percentage	Family Name	No of species	Percentage
Poaceae	53	54%	Saxifragaceae	3	3%
Asteraceae	37	38%	Thymelaeaceae	3	3%
Lamiaceae	21	21%	Urticaceae	3	3%
Papilionaceae	21	21%	Aceraceae	2	2%
Rosaceae	21	21%	Araliaceae	2	2%
Apocynaceae	12	12%	Arecaceae	2	2%
Cyperaceae	12	12%	Cannabaceae	2	2%
Ranunculaceae	12	12%	Chenopodiaceae	2	2%

Rubiaceae	11	11%	Colchicaceae	2	2%
Gentianaceae	9	9%	Cupressaceae	2	2%
Euphorbiaceae	8	8%	Cuscutaceae	2	2%
Mimosaceae	8	8%	Juncaceae	2	2%
Oleaceae	7	7%	Lythraceae	2	2%
Plantaginaceae	7	7%	Meliaceae	2	2%
Polygonaceae	7	7%	Menispermaceae	2	2%
Rhamnaceae	7	7%	Orchidaceae	2	2%
Salicaceae	7	7%	Polygalaceae	2	2%
Anacardiaceae	6	6%	Primulaceae	2	2%
Geraniaceae	6	6%	Rutaceae	2	2%
Moraceae	6	6%	Scrophulariaceae	2	2%
Pteridaceae	6	6%	Smilacaceae	2	2%
Acanthaceae	5	5%	Tiliaceae	2	2%
Apiaceae	5	5%	Umbelliferae	2	2%
Asparagaceae	5	5%	Violaceae	2	2%
Convolvulaceae	5	5%	Vitaceae	2	2%
Fagaceae	5	5%	Equisetaceae	2	2%
Pinaceae	5	5%	Aquifoliaceae	1	1%
Solanaceae	5	5%	Aristolochiaceae	1	1%
Verbenaceae	5	5%	Betulaceae	1	1%
Dryopteridaceae	5	5%	Coriariaceae	1	1%
Boraginaceae	4	4%	Cornaceae	1	1%
Caprifoliaceae	4	4%	Dioscoreaceae	1	1%
Amaranthaceae	3	3%	Ebenaceae	1	1%
Balsaminaceae	3	3%	Elaeagnaceae	1	1%
Berberidaceae	3	3%	Ephedraceae	1	1%
Brassicaceae	3	3%	Grossulariaceae	1	1%
Buxaceae	3	3%	Hippocastanaceae	1	1%
Caesalpiniaceae	3	3%	Hydrangeaceae	1	1%
Celastraceae	3	3%	Juglandaceae	1	1%
Hypericaceae	3	3%	Lauraceae	1	1%

Malvaceae	3	3%	Linaceae	1	1%
Papaveraceae	3	3%	Malpighiaceae	1	1%
Sapindaceae	3	3%	Myrsinaceae	1	1%

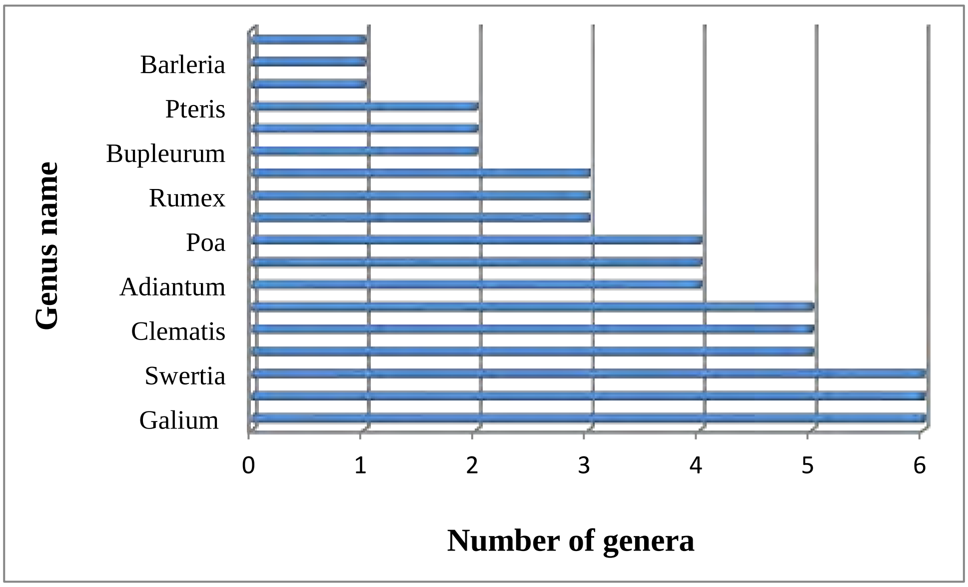

Figure 2.4: Dominant Genera in the Murree forests

2.3.4. Species Distribution and abundance in MFD

Two-way Cluster Analysis elucidated with the help of absence and presence of the plant species. It showed the distribution of plant species at each station. The black dots in the given dendrogram showed the presence of plant species, whereas white dots showed the absence of plants (Figure 2.5).

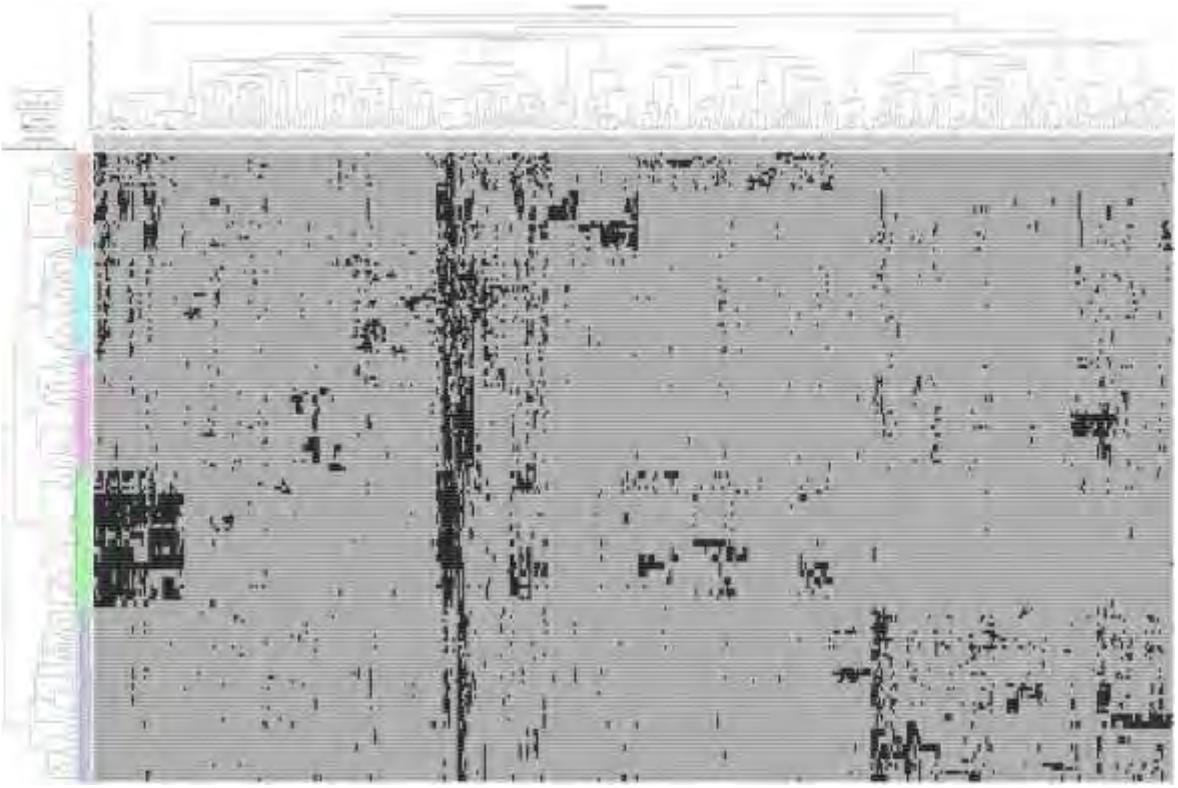

Figure 2.5: Two Way Cluster Analysis showing the distribution of 454 plants in 5 plant communities.

2.3.5 Species Distribution along along the samples size

Indirect ordination analyses, including Correspondence Analysis (CA) and Detrended Correspondence Analysis (DCA), were initially used to explain the environmental gradients of the plant species matrix. DCA was the most important among the indirect ordination techniques due to the most extended gradient length of the 1st axis with 4,286 Average Standard (SD) deviation of species turnover (Table 2.3). The first two axes of DCA designate 9% of the variance of the plant species. The plant species ordination figures further back up these gradients' impacts on plant's composition, diversity and community structure (Figure 2.6).

Table 2.3: Explanation of the DCA's four axes for data on vegetation

Summary of the all four axes of DCA for 454 species and 166 samples					
Axes	1	2	3	4	Total inertia
Eigen values	0.644	0.348	0.246	0.208	10.112
Lengths of gradient	4.286	3.179	3.055	2.733	
Cumulative % variance of plant species data	6.4	9.8	12.2	14.3	

The DCA 1st axis separated the higher altitudes habitats from those lower altitudes. Communities 1st and 2nd occupied the left side, 5th community is found on the right side of the DCA. This also reveals the latitudinal and altitudinal gradient composite of the study area i.e., stations/ samples at the lower latitudes of the Murree are determined on the left of the diagram and the higher latitudes stations are clustered mostly towards the right side of the Figure. The 2nd axis ordination of the DCA segregates the vegetation according to the aspect by assembling the communities. As a whole, the 2nd axis of DCA discloses a physiographic and geomorphologic gradients complex from habitats (Figure 2.6).

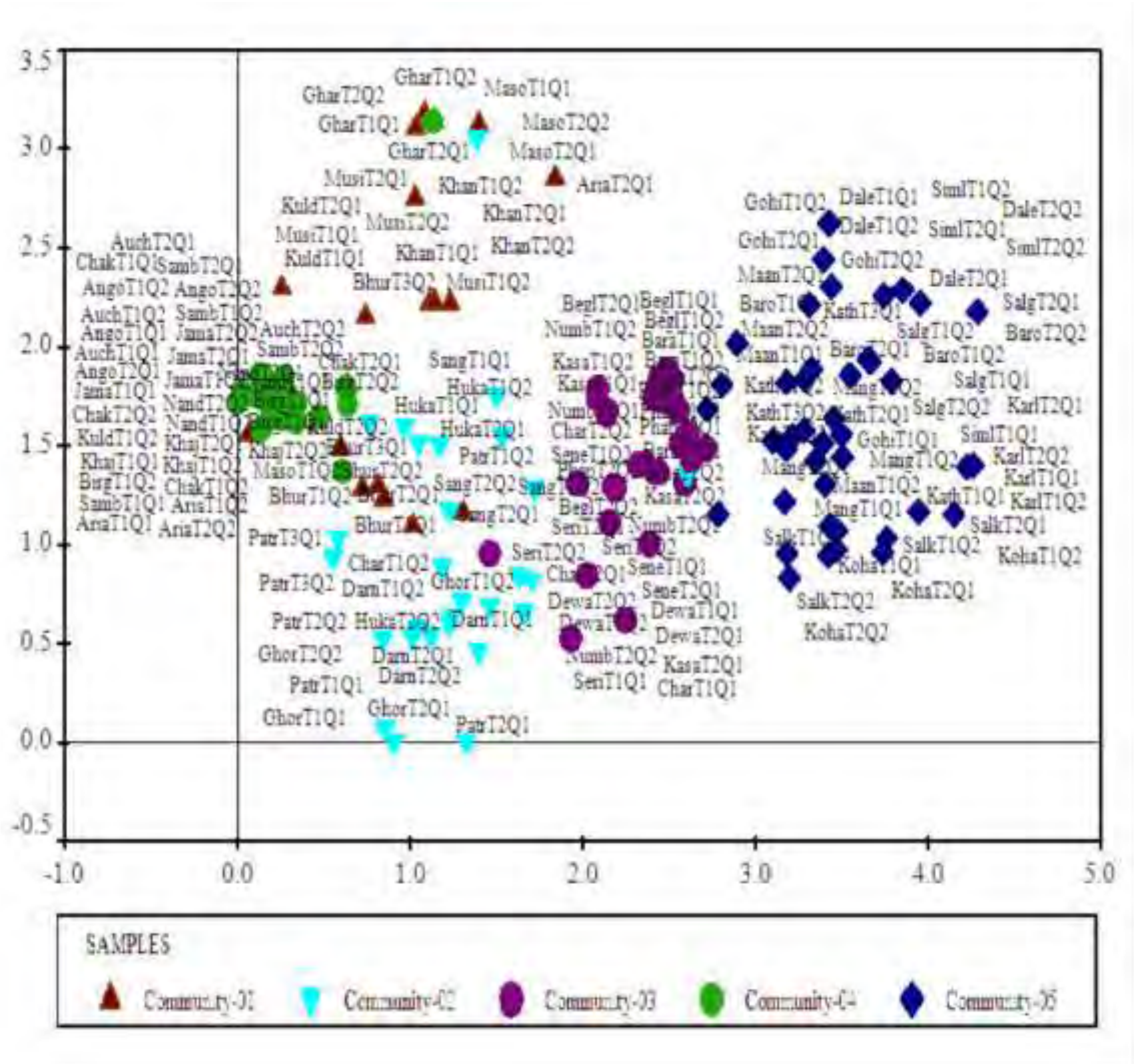

Figure 2.6: DCA diagram displaying distribution of five plant communities and habitat types among 166 sampling stations.

2.3.5.1 Dominant and rare trees of the area

The trees with an IVI value of more than one thousand were considered as the dominant trees of the forests. *Pinus roxburghii* with 6427 IVI was the most dominant tree species followed by *Pinus wallichiana* with 3777 IVI, *Cedrus deodara* 1679, *Olea paniculata* 1526.5 IVI and *Acacia modesta* with 1059.7 IVI in the region (Figure 2.7).

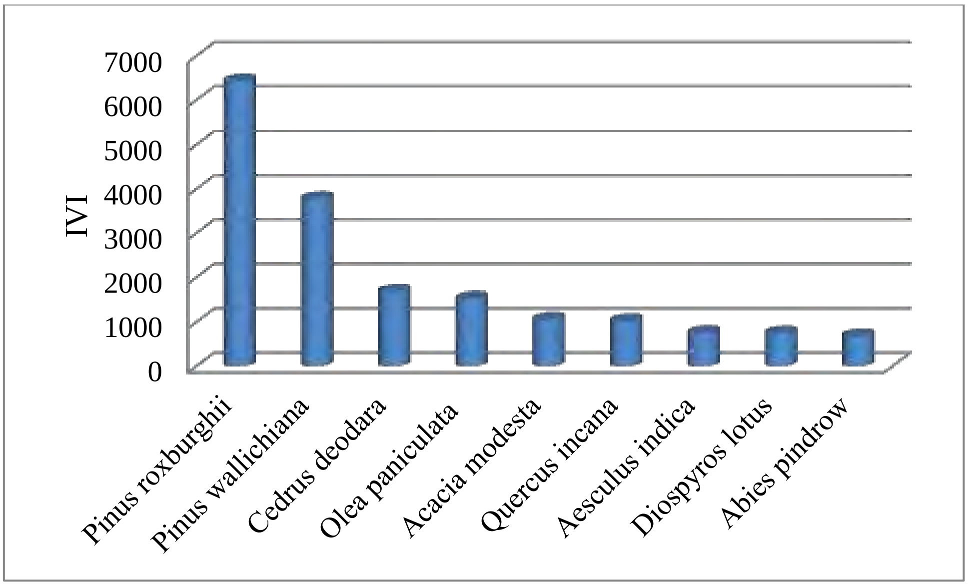

Figure 2.7: Dominant Tree species of Murree forests based on IVI.

The trees with an IVI value of less than 30 were considered as criteria for rare trees. *Morus alba* was recorded with least IVI value i.e., 13.69 as the rarest tree species in the region. Pru arme (15.88), *Ilex dipyrena* (18.64), *Salix babylonica* (21.76) and *Prunus cornuta* (24.57) IVI were the rare tree species (Figure 2.8).

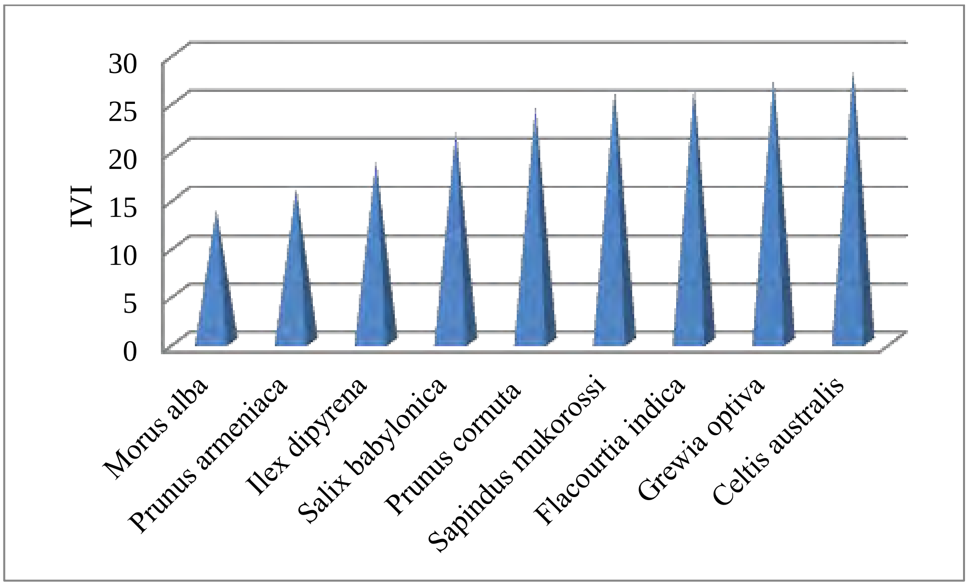

Figure 2.8: Rare tree species of the Murree forests

2.3.5.2 Dominant and rare shrubs

Among the total 85 described shrub species, seven were considered as dominant basis on an IVI of greater than one thousand. These species included *Myrsine africana* with an IVI of 3766, followed by *Carissa spinarum* with an IVI value 3431, *Berberis calliobotrys* with an IVI value of 1658, *Rubus ellipticus* with an IVI value 1309, *Sarcococca saligna* with an IVI value 1282, *Dodonaea viscosa* with an IVI value 1235 and *Viburnum grandiflorum* with an IVI value 1071.61 (Figure 2.9).

On the other hand rare shrub species was calculated having an IVI value of less than 30. These species include *Ziziphus jujuba* with the lowest IVI value of 5.89, other species are Cot numm with IVI value of 7.24, *Syringa emodi* with IVI value 10.84 and *Buxus wallichiana* with IVI value 12.44 and *Betula utilis* with IVI value 16.47 (Figure 2.10).

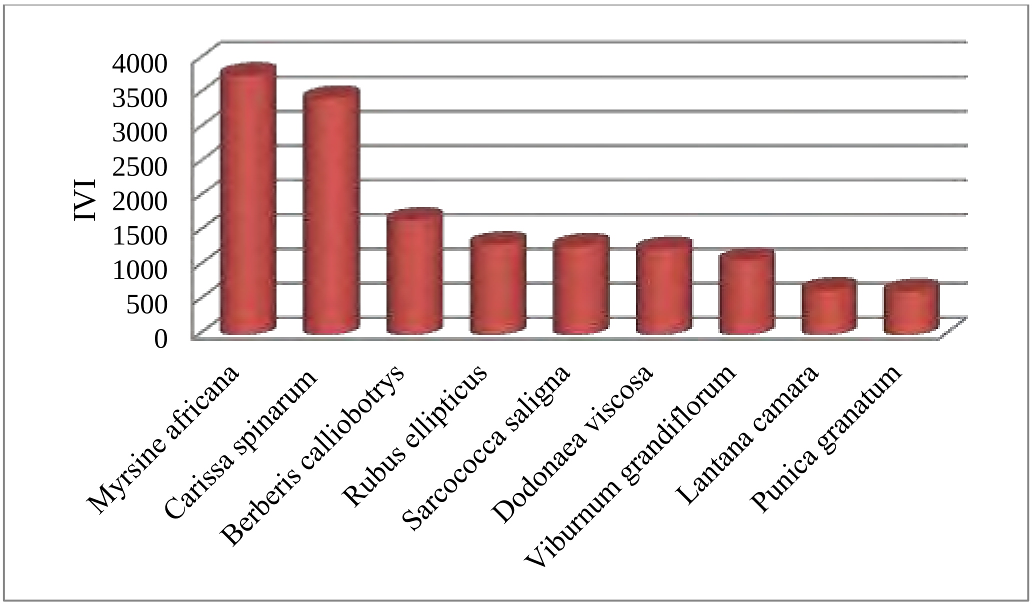

Figure 2.9: Dominant Shrubs of the Murree

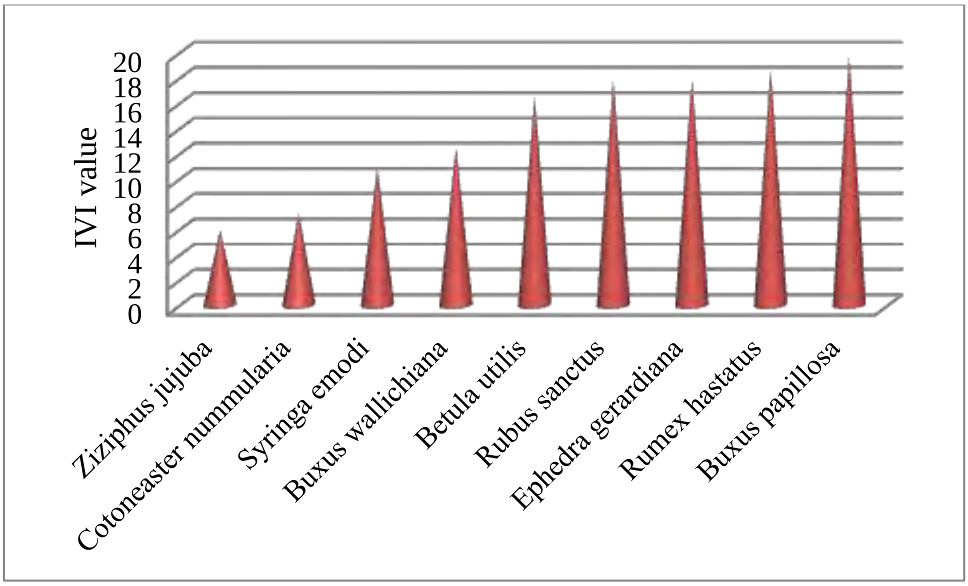

Figure 2.10: Rare shrubs species of Murree

2.3.5.3 Dominant and rare herbs

Herbaceous plants contribute major part of 73.2% of the whole vegetation recorded in the Murree forests division. The criteria for the herbs abundance were the same as that of trees and shrubs. It include *Themeda anathera* as the most dominant herb species with an IVI of 2442, followed by *Oxalis corniculata* (851), *Fragaria nubicola* (801), *Cynodon dactylon* (790.32) and *Micromeria biflora* with an IVI value of 696.22 (Figure 2.11).

Whereas rare herb species include *Swertia angustifolia* with the minimum IVI value i.e., 2.41. Other rare species were *Gloriosa superba* with an IVI of 2.57, *Bergenia ciliata* and *Clematis montana* were recorded with the same IVI value of 2.81 and *Ocimum basilicum* with an IVI value of 3.42 (Figure 2.12).

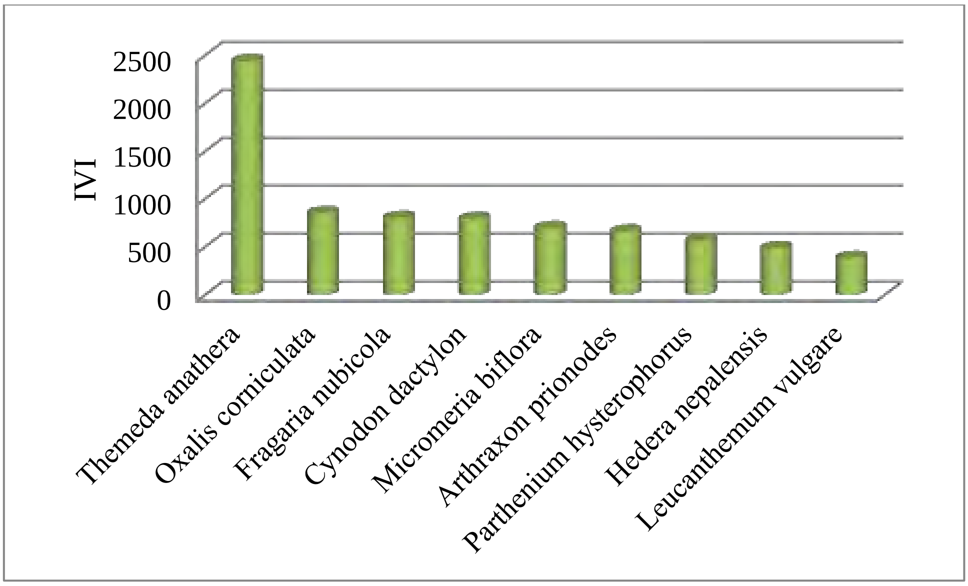

Figure 2.11: Dominant herb species of the Murree forests

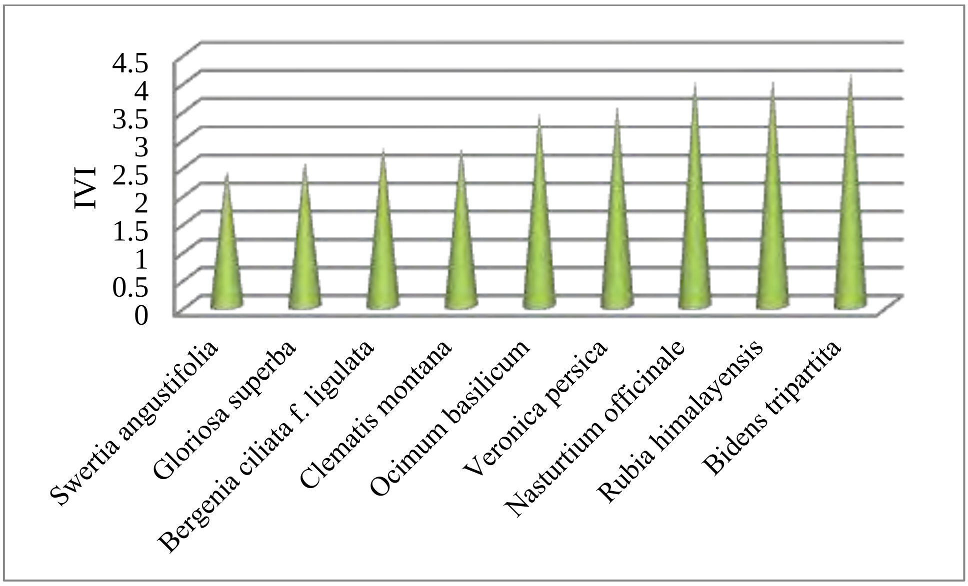

Figure 2.12: Rare Herb species of the Murree forests

2.3.6. Life and Leaf form classification

The Phanerophytes was the dominant life class with a 40.30% total share. It was further subdivided into subclasses in which Nanophanerophytes were dominant with 95 species followed by Megaphanerophytes with 38 species, Mesophanerophytes and Microphanerophytes with 25 species each. Therophytes followed phanerophytes with 126 species (27.75% share), Hemicryptophytes with 78 species (17.18%) share, Geophytes with 41 species (9.03%) share and Chamaephytes with 26 species (5.72%) share (Table 2.4).

Table 2.4: Life form classes of the Murree forests

Life-form classes	**Species number**	**%age**
Megaphanerophyte	38	8.37004
Microphanerophyte	25	5.50661
Mesophanerophyte	25	5.50661
Nanophanerophyte	95	20.9251
Therophyte	126	27.7533
Hemicryptophyte	78	17.1806
Geophyte	41	9.03084
Chamaephyte	26	5.72687
Total	**454**	**100%**

The Nanophyll was the dominant leaf form spectra with a total of 175 species (38.54% share), followed by Microphylls with 121 species (26.65%), Mesophyll with 81 species (17.84% share), Leptophylls with 53 species (11.67% share), Macrophylls with 20 species (4.40 % share) and Aphyllous with 4 species (0.88% share) (Table 2.5 & Appendix 1).

Table 2.5: Leaf form classification of the Murre hills

Leaf form classes	**Species number**	**%age**
Macrophyll	20	4.40528
Mesophyll	81	17.8414
Microphyll	121	26.652
Nanophyll	175	38.5463
Leptophyll	53	11.6740
Aphyllous	4	0.88106
Total	**454**	**100%**

2.4 Classifying plants of MFD into various Communities

Cluster analyses of PCORD version 5 classifies all the plant species (454) and stations (166) into five plant communities based on Sorenson Distance Measurements (Figure 2.13).

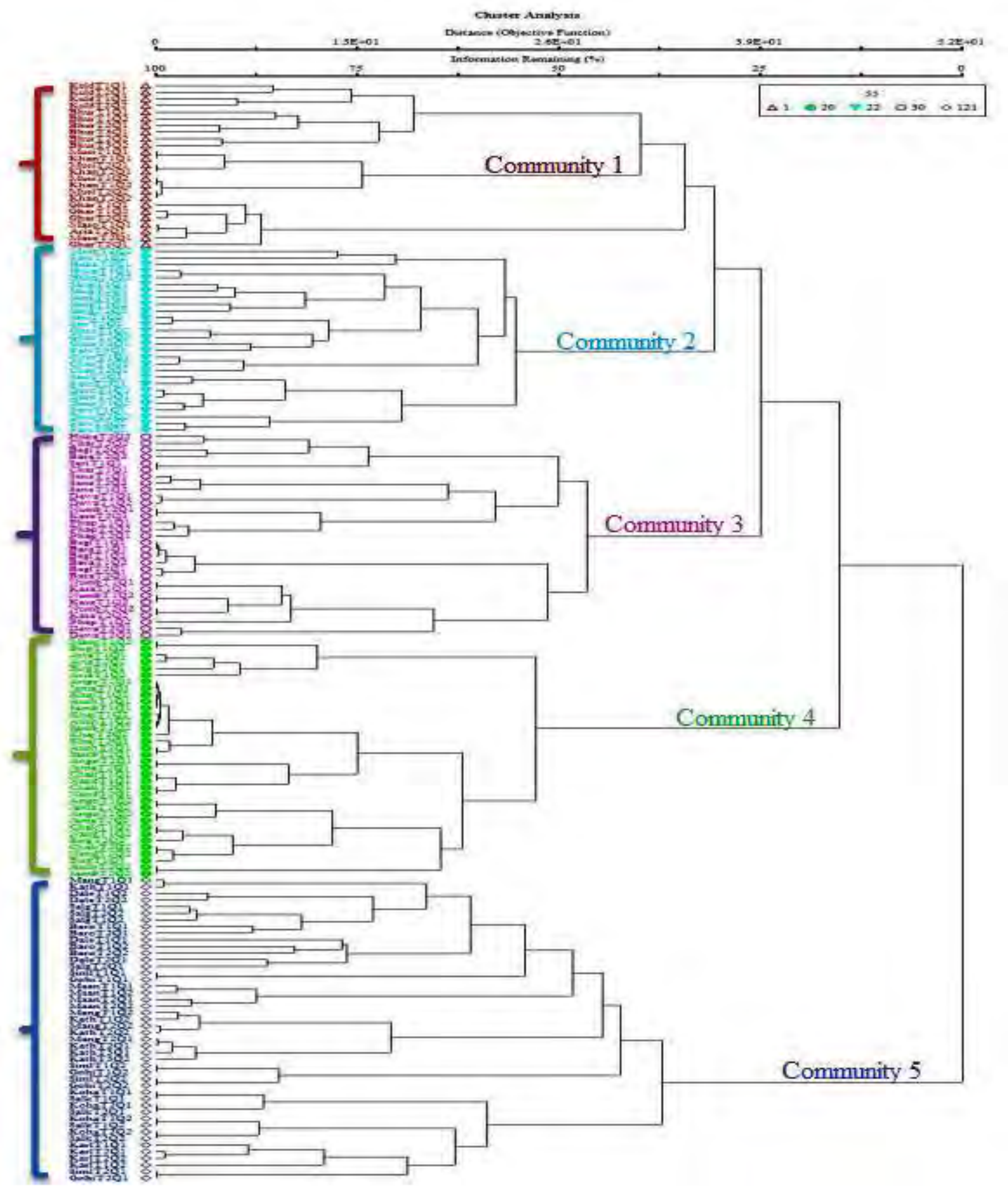

Figure 2.13: Cluster dendrogram of 166 stations based on Sorensen measures; classifying all stations into five plant communities.

2.5 Vegetation dynamics along the environmental gradient

CANOCO offers ecologists a choice by ordination studies to indirectly discover environmental gradient by using only species matrix or directly by using both plant species and environmental data sets.

2.5.1. Species distribution and underlying ecological drivers

To investigate both plant species and environmental matrices together, direct gradient methods were carried out. Direct gradient techniques such as CCA were tested on the available species and environmental data in order to test whether the plant association was aligned with the measured environmental variables. Plant species data and environmental data were put together in CANOCO software (Version 4.5) to compare and measure the effects of various environmental factors on plant species dynamics. The environment's abiotic and biotic components indicated significant relation and effect on the plant species composition, distribution pattern, and abundance having a p-value ≤ 0.05 (Table 2.7 and 2.8). The treated environmental factors were Soil factors; referred to as chemical (pH, electrical conductivity (EC), organic matter (OM), nitrogen (N), phosphorous (P), potassium (K), chlorine (Cl), calcium (Ca), Total Soluble Solute (TSS), calcium carbonate ($CaCO_3$) and physical (Sand, Silt and Clay) features of the lithospheric forest ecosystem. Other factors included were anthropogenic pressure, grazing pressure, slope, elevation, aspect and canopy influencing the distribution patterns of trees, shrubs and herbs.

2.5.5.1 CCA bi-plot for trees

This CCA bi-plot consisted of tree plant species whose relationship with various chemical and physical gradients was shown (Fig. 2.14 and Table 2.6). The first quadrant showed that most of the plant species *Platanus orientalis*, *Cupressus sempervirens*, *Broussonetia papyrifera*, *Thuja orientalis*, *Celtis australis* and *Rhamnus purpurea* etc were under the effect of sand and low pH. These plants were. Whereas moving to the third quadrant some of the tree species were significantly affected by silt and $CaCO_3$ variables. These factors have an influence on *Salix babylonica*, *Prunus armeniaca*, *Machilus duthiei*, *Salix tetrasperma*, *Quercus baloot* and *Pinus roxburghii* etc. Similarly, the second quadrant was affected by the gradients like elevation, slope and canopy. The plant species influenced by these factors were *Picea smithiana, Quercus robur, Taxus wallichiana, Diospyros lotus, Pinus wallichiana* and *Quercus glauca* etc. The fourth quadrant was influenced by gradients corresponding to anthropogenic pressure and soil texture like clay and potassium. The plant species affected by above stated ecological factors *Chamaerops humilis, Pistacia chinensis, Toona ciliata, Olea paniculata* and *Xylosma longifolium*.

Table 2.6: Summary of the four axes of CCA bi-plots for the Trees

Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigenvalues	0.543	0.231	0.192	0.157	9.237
Species-environment correlations	0.849	0.684	0.723	0.673	
Cumulative percentage					
Variance of species data	5.9	8.4	10.5	19.9	
Species-environment relation	29.6	42.2	52.7	61.2	
Sum of all eigenvalues					9.237
Sum of all canonical eigenvalues					1.834
Summary of Monte Carlo test (499 permutations under reduced model)					
Test of significance of 1st canonical axis		Test of significance of all canonical axes			
Eigen value	0.543	**Trace**			1.834
F-ratio	9.065	**F-ratio**			1.797
P-value	0.0020	**P-value**			0.0020

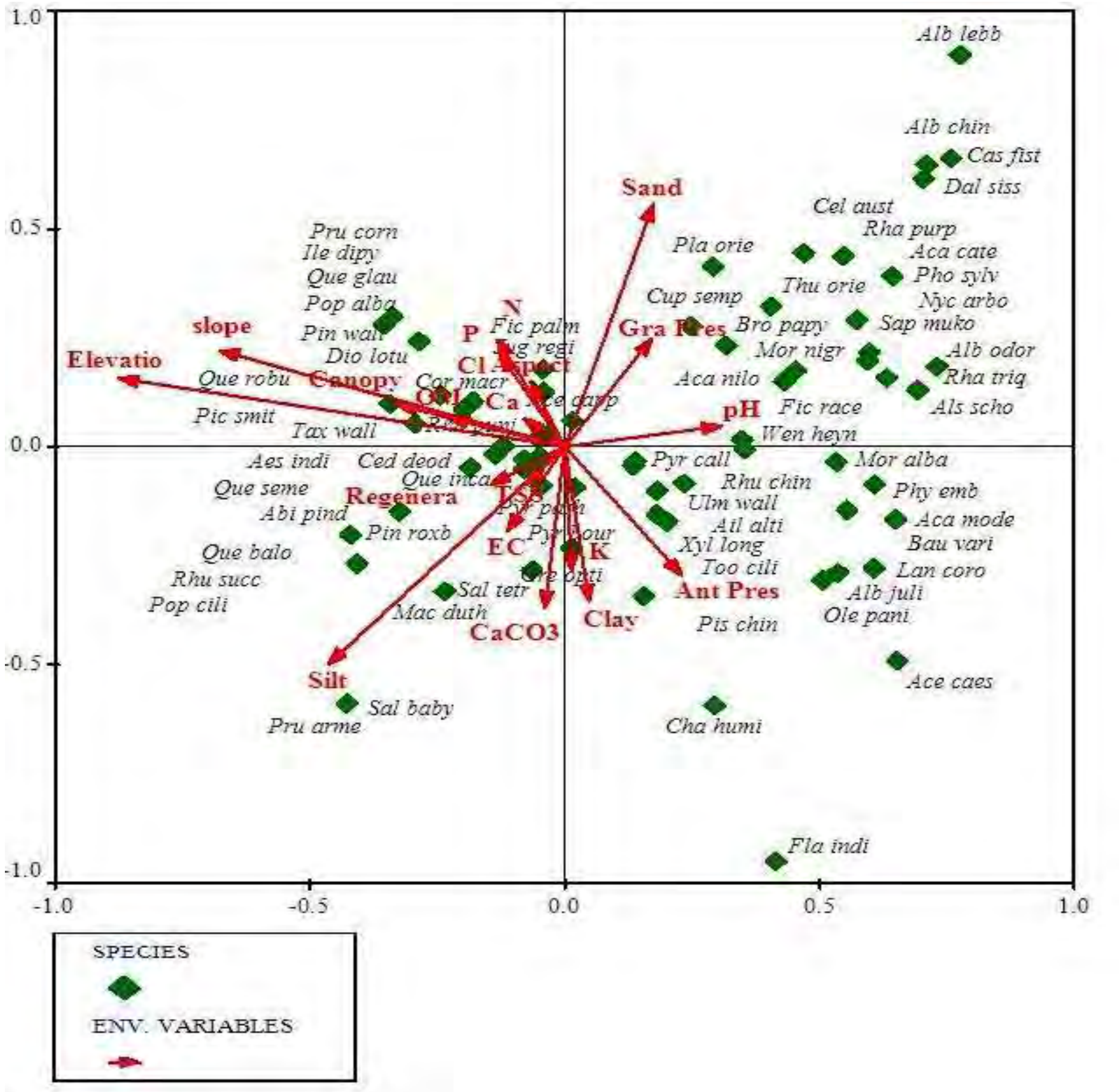

Figure 2.14: CCA data attribute plot showing tree species correlation with environmental variables

where P= Phosphorous, K= Potassium, EC= Electric Conductivity, Fru Tree= Fruit giving trees, Soil con= Soil condition, Na= Sodium, Fodd Col= Fodder Collection, Graz Pre= Grazing pressure, OM= Organic matter and Soil tex= Soil texture

2.5.5.2 CCA bi-plot for shrubs

The first quadrant of CCA biplot revealed that most plant species were under the impact of a slope and $CaCO_3$. This quadrant also revealed Cl, OM, N, P, TSS, and

K and canopy and regeneration variables. The shrub species under the impact of aformentioned factors (slope and $CaCO_3$) were *Cotoneaster nummularia, Indigofera himalayensis, Indigofera linifolia*, and *Indigofera hebepetala, Punica granatum, Viburnum grandiflorum*, *Andrachne cordifolia* and *Daphne papyracea* species. At the same time, third quadrant majority of the shrub species were under the influence of clay and anthropogenic pressure. *Betula utilis, Ziziphus jujuba, Berberis aristata, Jasminum mesnyi*, *Lespedeza juncea* and *Ephedra gerardiana* etc. The second quadrant showed that the soil pH, texture (sand), and grazing pressure significantly affect Ziziphus oxyphylla, Carissa spinarum, Woodfordia fruticosa, and *Dodonaea viscosa, Rosa moschata, Rhamnus* pentapomica, *Nerium oleander* and *Deutzia staminea* etc. The fourth quadrant of CCA biplot clustered *Rubus sanctus, Debregeasia saeneb, Syringa emodi, Cotinus coggygria, Rubus ellipticus, Myrsine africana, Ziziphus nummularia*, *Lonicera* species, *Rumex hastatus* etc under the impact of silt, aspect, Ca, Canopy and elevation (Figure 2.15 and Table 2.7).

Table 2.7: Detail summary of CCA analysis of all the shrub species with measured environmental factors

Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigenvalues	0.556	0.250	0.157	0.108	6.953
Species-environment correlations	0.906	0.723	0.700	0.673	
Cumulative percentage					
Variance of species data	8.0	11.6	13.8	19.9	
Species-environment relation	33.8	49.0	58.5	65.1	
Sum of all eigenvalues					6.953
Sum of all canonical eigenvalues					1.646
Summary of Monte Carlo test (499 permutations under reduced model)					
Test of significance of 1st canonical axis		Test of significance of all canonical axes			
Eigen value	0.556	**Trace**			1.646
F-ratio	12.602	**F-ratio**			2.249
P-value	0.0020	**P-value**			0.0020

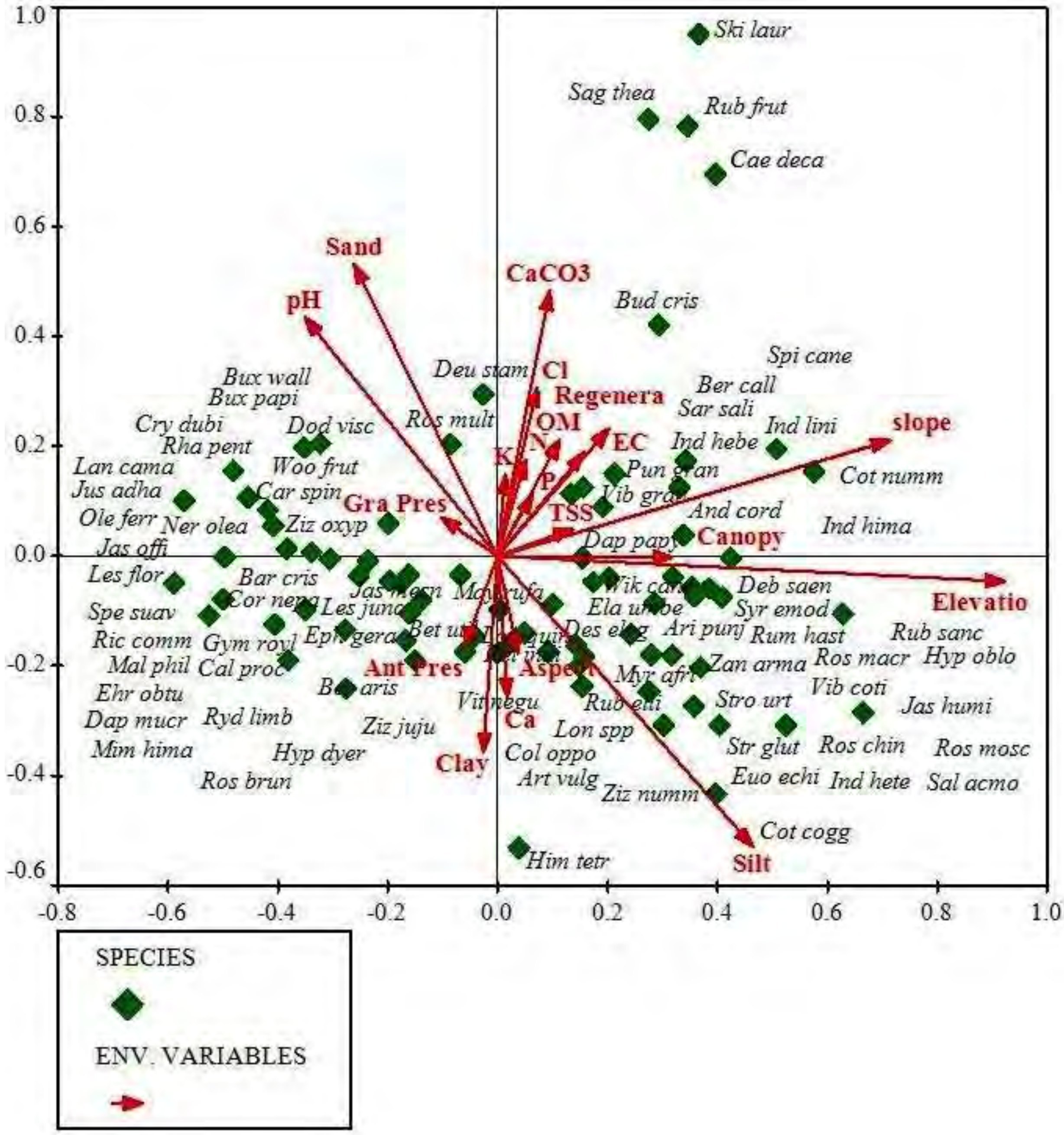

Figure 2.15: CCA data attribute plot show shrub species correlation with environmental variables

2.5.5.3 CCA bi-plot for herbs

The first quadrant of CCA bi-plot comprehended the impact of grazing pressure, soil pH, sand and chloride on herb species. These plant species were *Chenopodium ambrosioides, Bupleurum lanceolatum, Dichanthium foveolatum, Silybum marianum, Erigeron bonariensis* and *Agrostis gigantea* etc (Figure 2.16). In comparison, the third revealed slope, silt and chemical gradients like Nitrogen (N) and organic matter (OM) significantly affect herb species. These species were *Cymbopogon distans, Gentiana kurroo, Cyperus rotundus, Paeonia emodi, Galium asperifolium var. obovatum, Impatiens brachycentra, Phalaris minor* etc.

In the second quadrant, the herb plants were affected by the gradients like elevation, canopy, $CaCO_3$, K and P. The herb species which were influenced by these factors were *Teucrium royleanum, Plantago amplexicaulis, Apluda mutica, Aristida mutabilis, Apluda mutica, Gerbera gossypina, Bergenia stracheyi* and *Galium aparine* etc. In the fourth quadrant, herbaceous species were influenced by aspect and Ca ions. The plant species affected by these influencing gradients were the herbs like *Themeda anathera, Ipomoea nil, Potentilla supina, Ranunculus laetus, Colchicum luteum, Ajuga parviflora* etc.

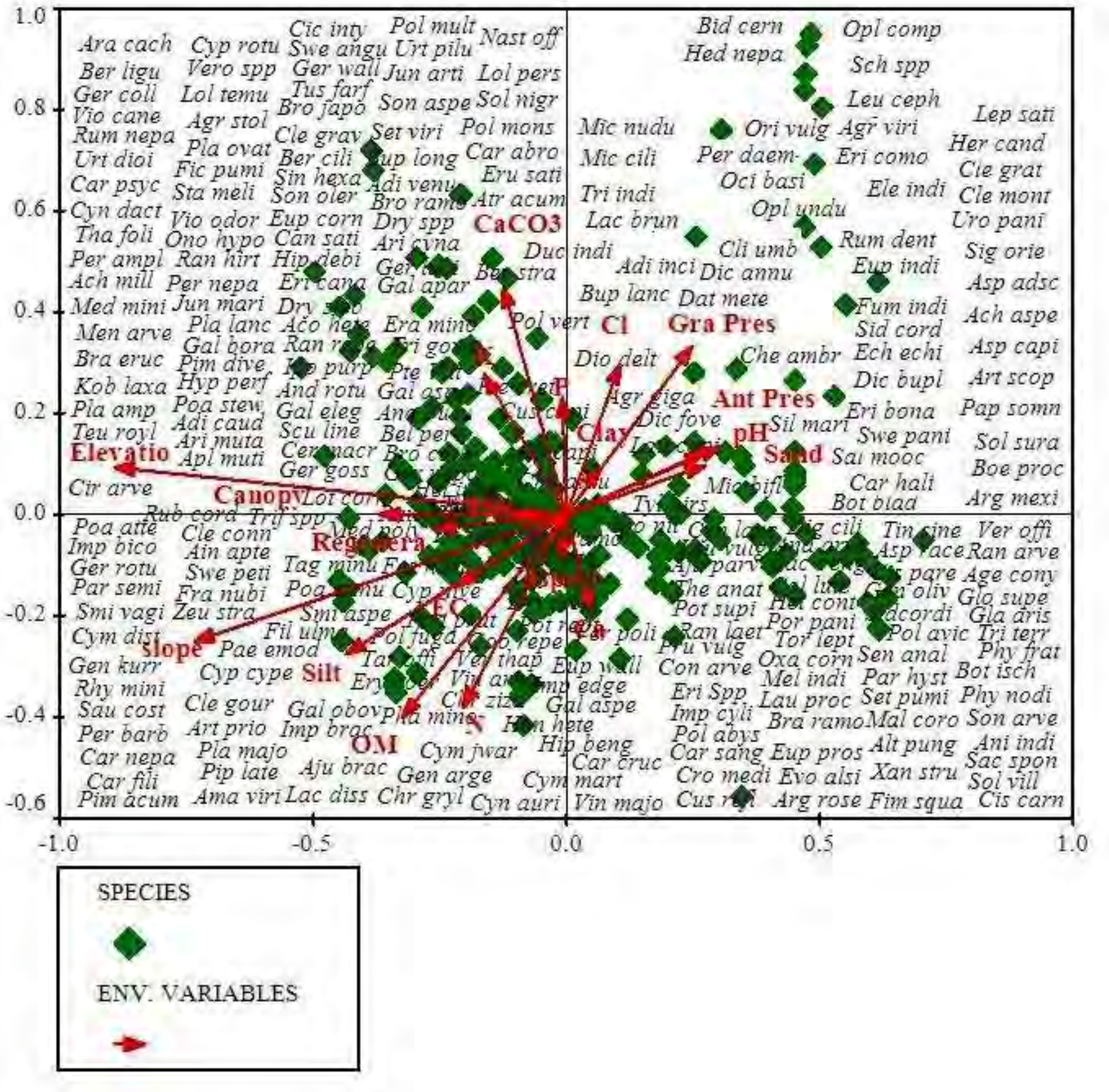

Figure 2.16: CCA data attribute plot showing herb species correlation environmental variables

2.5.5.4 CCA bi-plot for stations

The CCA bi-plot for 166 stations was made to know the different environmental factors at the stations level. The first quadrant of the CCA bi-plot indicated that the sand, pH, Cl, grazing pressure, anthropogenic pressure influenced the stations. Less impact of anthropogenic pressure was observed, whereas significant sand, pH, and grazing pressure gradients were revealed. MaanT2Q1, JamaT1Q2, JamaT2Q2, MangT1Q1, MaanT1Q1, KathT3Q2, Mang1Q2 stations were under the influence of sand, pH and grazing pressure. PhapT1Q1, NandT2Q1, JamaT1Q2, NandT2Q2 were under the effect of Cl and grazing pressure as well. JamaT1Q1, KhajT1Q2, BaraT2Q2, BaroT1Q2 and SalkT1Q1 etc. were under the impact of anthropogenic pressure.

However, most of the other sampling stations were affected by chemical ecological gradients like organic matter, nitrogen, soil texture like silt, moving to the third quadrant. Here the corresponding sampling stations were also affected by other ecological gradients like TSS, and by aspect as well. In the third quadrant the relatively lengthened arrows showed the high impact of gradients like organic matter, nitrogen, soil texture like silt and aspect and TSS have relatively low effect as indicated by short length of arrows. Here it is key to note that the lengthy arrows of gradients revealed the more dynamic influence in a particular quadrant as compared to other ecological gradients with shortest arrows length which means less impact either upon samples station or plant species. The second quadrant was under the thriving influence of $CaCo_3$, physical gradient like Canopy, K, regeneration and P. Sampling stations like AngoT2Q2, AngoT2Q1, PhapT1Q1, KhanT2Q1, AuchT2Q2, CharT2Q2, AriaT2Q2, SeriT1Q1 and other such stations of the same axis were influenced by the above indicated ecological gradients. Numerous of the sampling stations as illustrated in the fourth quadrant were under the influence of Ca ions and clay. The Summary of the CCA has obviously shown that there was significance in the relationship of sampling stations and chemical and physical ecological gradients. The CCA bi-plot is shown as follows (Fig 2.17 and table 2.8)

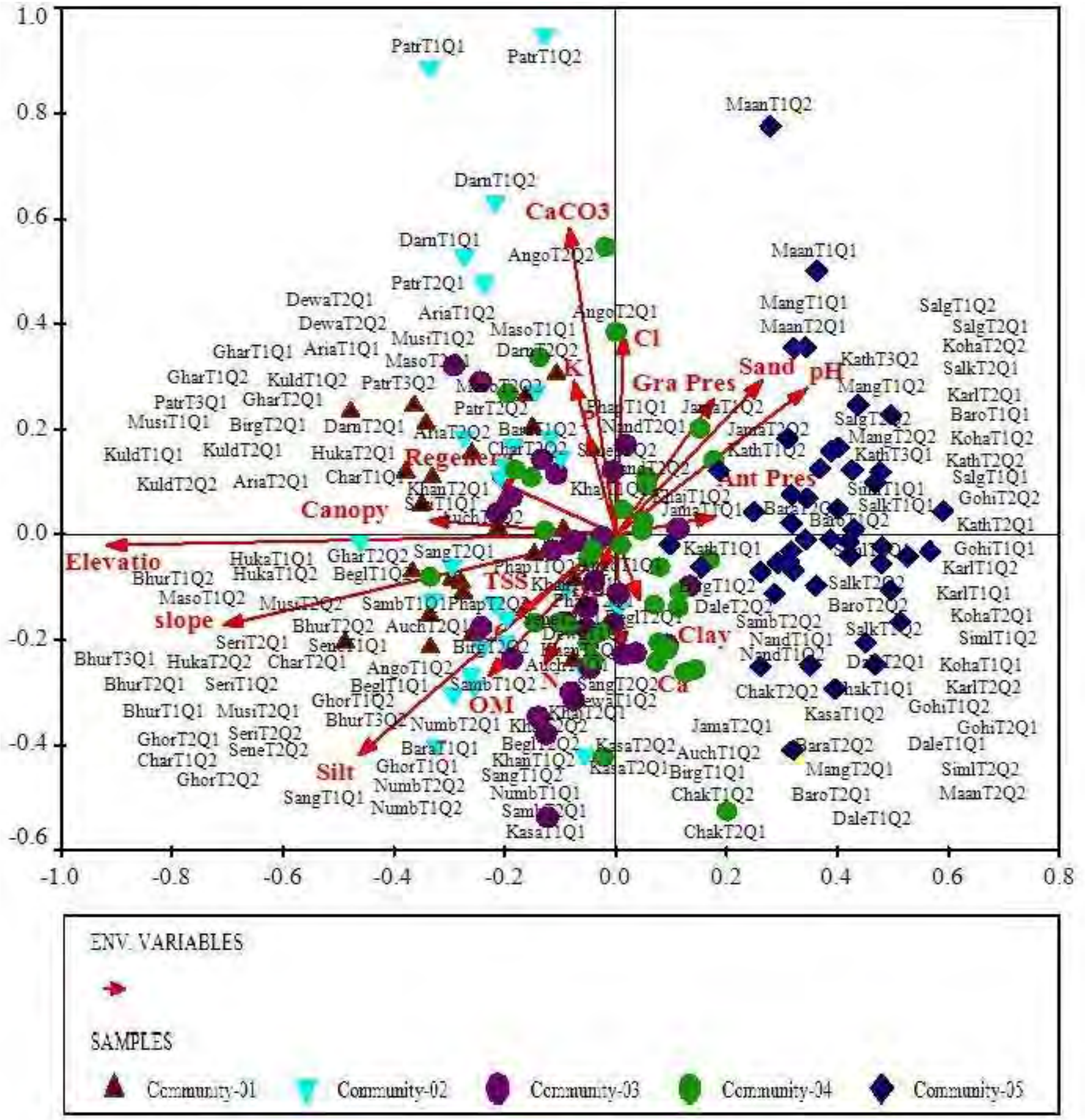

Figure 2.17: CCA data attribute plot show the distribution pattern of sample space with the correlation of environmental variables

Table 2.8: Summary of Monte Carlo test for stations of the studied area

Axes	1	2	3	4	Total inertia
Eigenvalues	0.404	0.262	0.220	0.194	11.201
Species-environment correlations	0.899	0.851	0.762	0.730	
Cumulative percentage					
Variance of species data	3.6	5.9	7.9	9.6	
Species-environment relation	17.2	28.3	37.7	46.0	
Sum of all eigenvalues					11.201
Sum of all canonical eigenvalues					2.349
Summary of Monte Carlo test (499 permutations under reduced model)					
Test of significance of 1st canonical axis		Test of significance of all canonical axes			
Eigen value	0.404	**Trace**			2.349
F-ratio	5.426	**F-ratio**			1.924
P-value	0.0020	**P-value**			0.0020

2.6 Plant communities based on indicator species Analysis

The application of multivariate analyses, i.e. Cluster and Two-way Cluster analysis divided the Murree forest vegetation into five major plant communities, which could be observed in the cluster dendrograms (Figure 2.5 and 2.13). The detailed description of each plant community is as follows:

2.6.1. Community- 01; *Picea smithiana, Spiraea canescens, Trifolium* species

This community was established at higher elevations of 1901 – 2258 meters above sea level (masl). It is represented by a total of 25 stations. The community name was based on topmost indicators/characteristic species at a threshold level of >20% and p-values ≤0.05). The topmost indicator species of this community were *Picea smithiana*, *Spiraea canescens* and *Trifolium* species. These indicators were under the influence of high elevation, north aspect, slope, regeneration (fair to good), high K, organic matter (OM), phosphorous (P) and nitrogen (N) (Table 2.9; Figures 2.18; 2.19; 2.20. and appendix 2). The detailed characteristics of the indicators plants of the 1st community were presented in table 2.10. The dominant tree species of this community were *Pinus wallichiana*, *Pinus roxburghii* and *Diospyros lotus*. The rare tree species were *Ilex dipyrena*, *Prunus cornuta* and *Toona ciliata*. The other dominated shrubs were *Myrsine africana* and *Strobilanthes urticifolia* while rare shrub species were *Rumex hastatus, Artemisia vulgaris* and *Desmodium elegans*. The herb layer was also dominated by other species like *Themeda anathera*, *Arthraxon prionodes*, *Fragaria nubicola* and *Dichanthium annulatum*. Rare herb species were *Sonchus oleraceous*, *Aconitum heterophyllum*, *Bergenia stracheyi*, *Hypericum perforatum* and *Equisetum ramosissimum*.

Table 2.9: The detailed characteristics of the 1st community along with indicator species

The total number of stations were 25				
S.No.	**Indicator species**	**Variables**	**Important value**	**P* value**
1	***Picea smithiana***	Canopy	9.2	0.0156
		Regeneration	13.5	0.01
		Sand	44.6	0.012
		TSS	45.9	0.0108
		P	27.9	0.0946
2	***Spiraea canescens***	EC	4.7	0.0552
		TSS	49.9	0.0008
		Ca	32.8	0.0898
		Cl	30.9	0.0734
3	***Trifolium* spp.**	Elevation	34.8	0.0242
		Regeneration	24.7	0.0572
		Canopy	6.9	0.0686

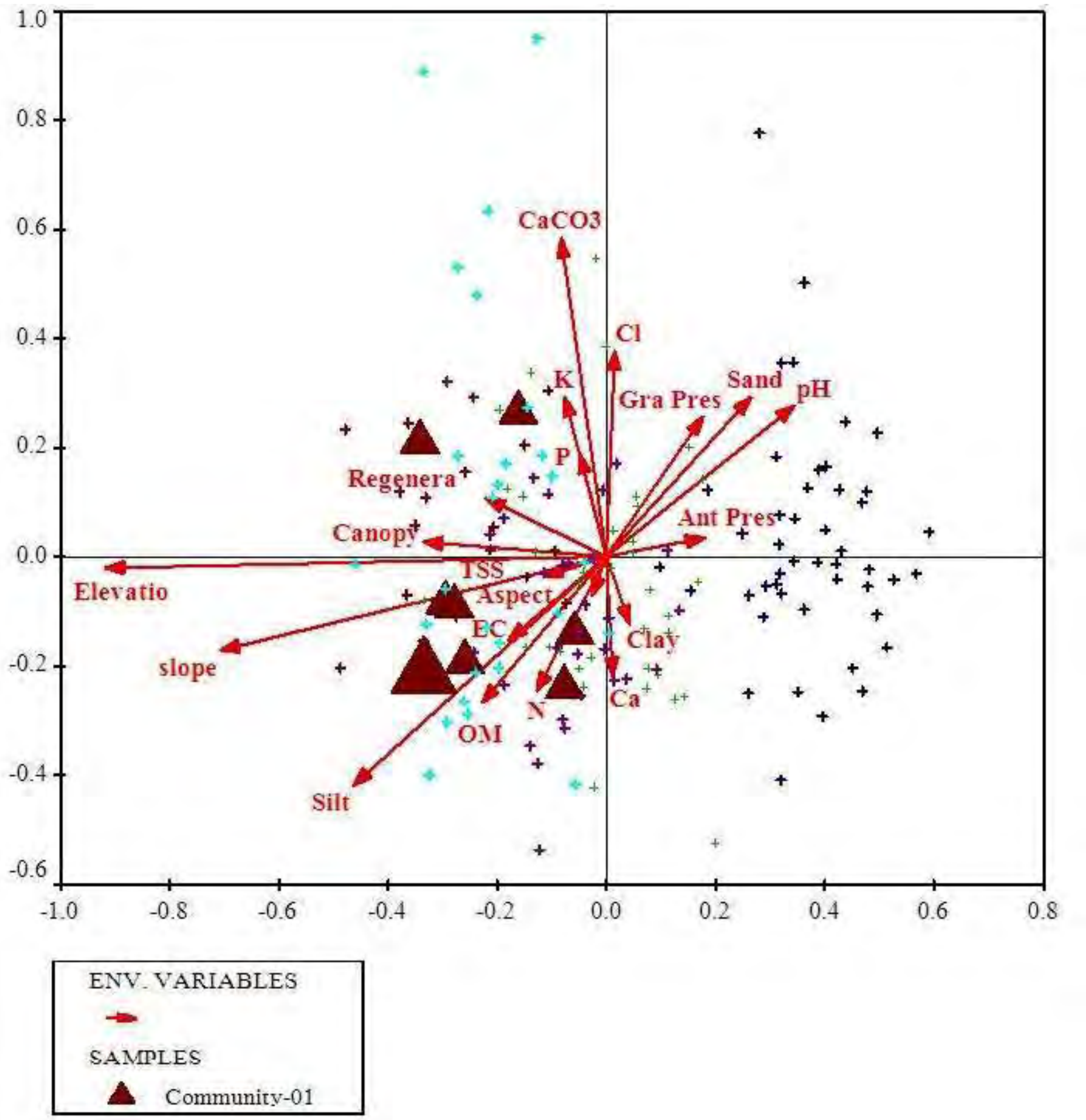

Figure 2.18: Data attribute plot of *Picea smithiana*; the first indicator of the 1st community

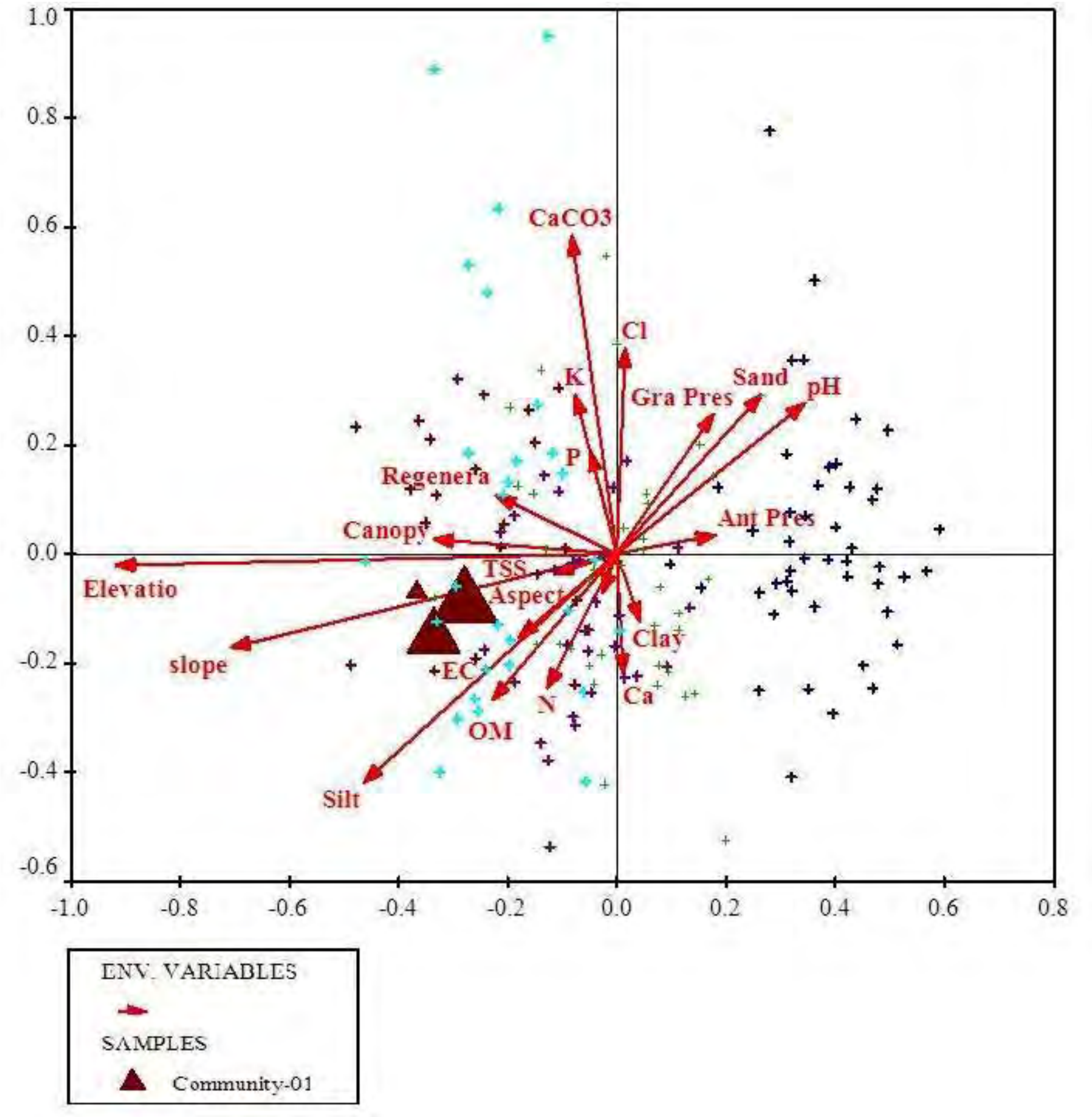

Figure 2.19: Data attribute plot of *Spiraea canescens*; the second indicator of the 1st community

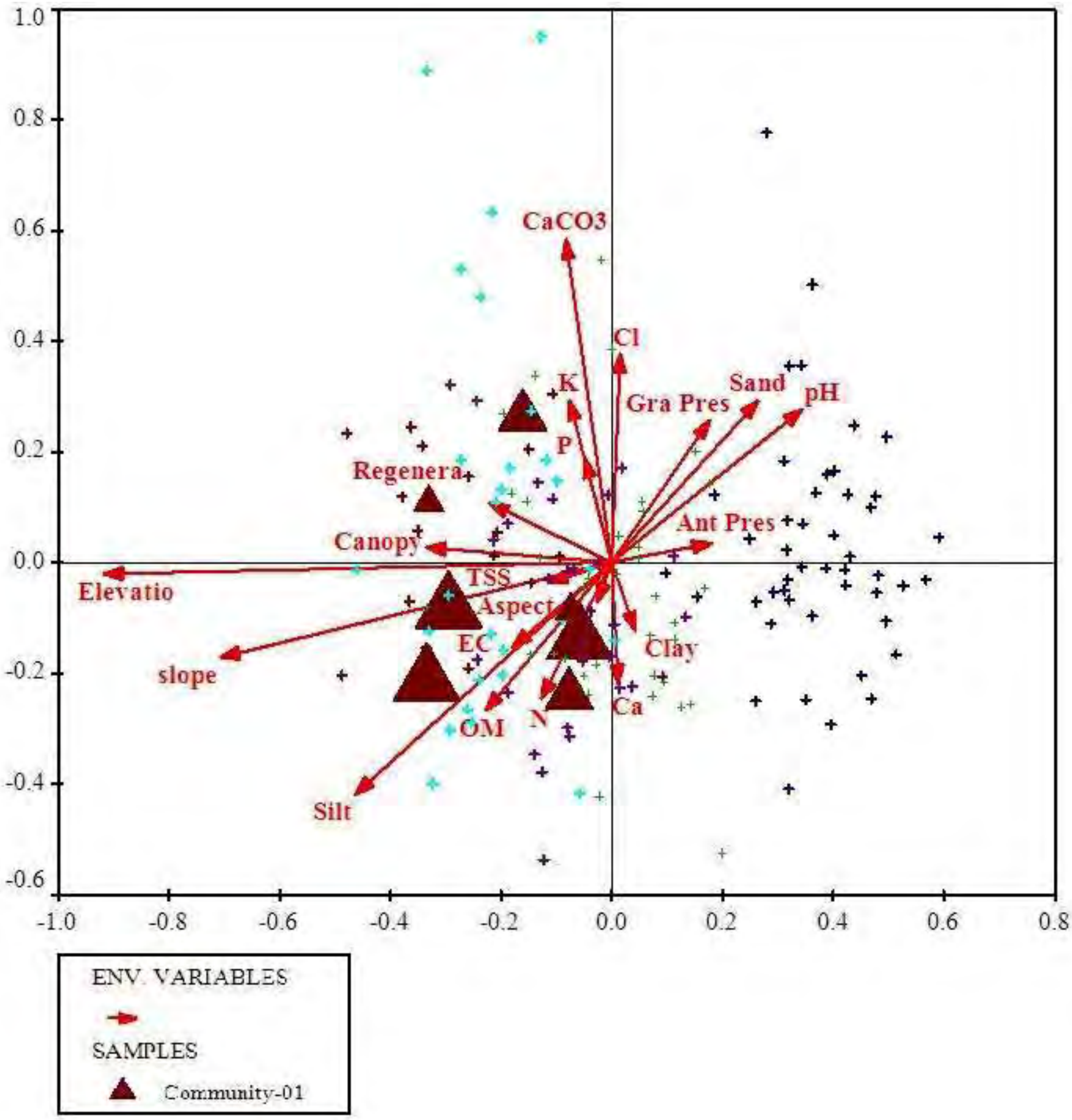

Figure 2.20: Data attribute plot of *Trifolium species*; the third indicator of the 1st community

2.6.2. Community- 02; *Quercus robur, Rubus fruticosus, Cyperus rotundus*

This community is situated at second higher elevations of 1601 –1900 (masl). This community represents a total of 28 stations. *Quercus robur* was the characterized indicator species of the tree layer, *Rubus fruticosus* shrub layer and

Cyperus rotundus was the characteristic indicator species of the herb layer in this community.

Data attribute plots of the indicator species of this community was mainly under the influence of high organic matter (OM), silt soil texture, aspect (south-southwest), high electrical conductivity (EC), phosphorous (P), K, nitrogen (N), higher elevation, slope (43), poor regeneration and high-level $CaCO_3$ while less influence of grazing pressure, anthropogenic pressure and sand (Table 2.10; Figures 2.21, 2.22, 2.23 and appendix 2). The dominant tree species of this community comprised *Pinus roxburghii* and *Pinus wallichiana*. The rare trees in the community included *Populus ciliata*, *Grewia optiva* and *Salix tetrasperma*. Other co-dominant shrub species in the community included *Berberis calliobotrys* and *Myrsine africana*. The rare shrubs in the community comprised *Andrachne cordifolia*, *Indigofera hebepetala* and *Wikstroemia canescens*. Other co-dominant herbs included *Cynodon dactylon*, *Carex filicina*, *Fragaria nubicola* and *Hedera nepalensis*. Rare herb species were *Persicaria nepalensis, Agrostis viridis, Dioscorea deltoidea*, *Gentiana argentea* and *Dryopteris ramosa*.

Table 2.10: The detailed information of the 2nd association along with characteristic variables

Total number of stations in association was 28				
S.No.	**Indicator species**	**Variable**	**Important value**	**P* value**
1	***Quercus robur***	Anthropogenic pressure	12.1	0.0232
		EC	18.3	0.0032
		N	19	0.0046
		OM	24.2	0.0036
		TSS	71.2	0.0002
		Slope	46.5	0.0014
		Sand	38.5	0.024
		Regeneration	12.8	0.0516
		K	24.2	0.0742
		Elevation	25.4	0.0496

2	***Rubus fruticosus***	Ca	72.9	0.0074
		Cl	72.4	0.0048
		$CaCo_3$	44	0.014
		EC	12.8	0.0196
		Elevation	24.4	0.0934
		Sand	30.6	0.0452
		Silt	27.6	0.0558
		Slope	20.9	0.0784
3	***Epilobium hirsutum***	Ca	99.5	0.0004
		Cl	99.5	0.0002
		$CaCo_3$	73.7	0.001
		Elevation	38.7	0.0334
		OM	6.6	0.0632

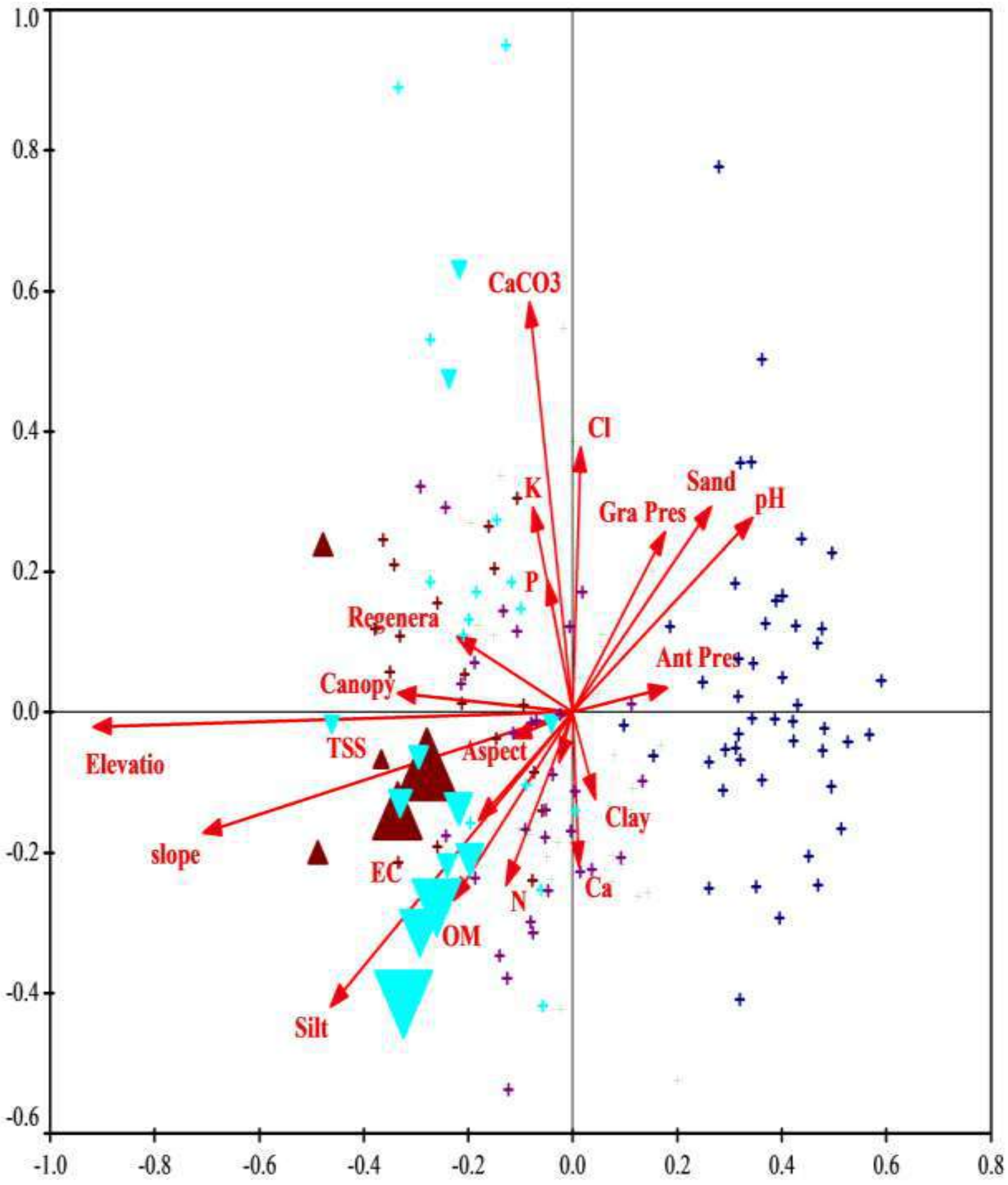

Figure 2.21: Data attribute plots of *Quercus robur*; the first indicator of the 2nd community

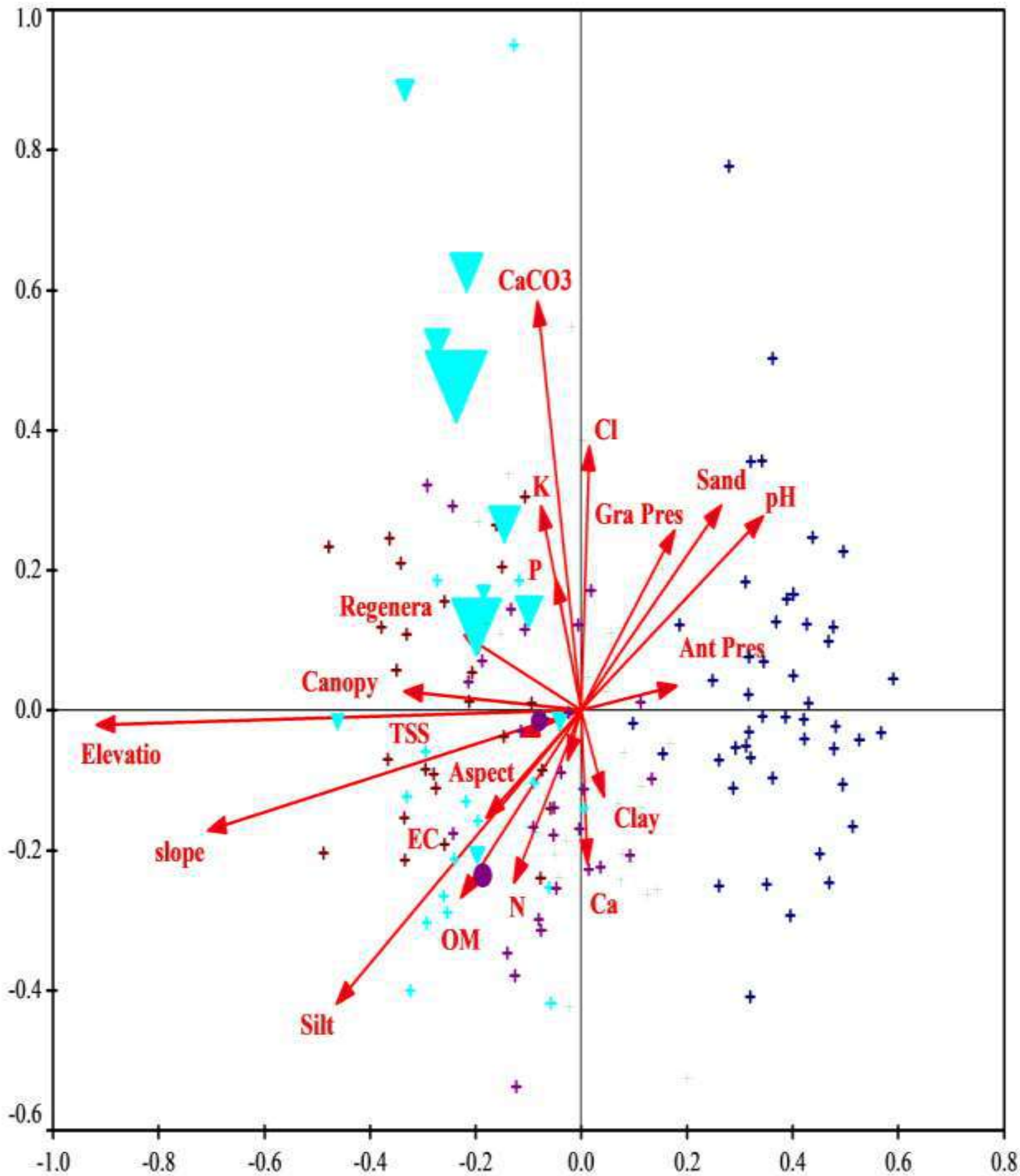

Figure 2.22: Data attribute plots of *Rubus fruticosus*; the second indicator of the 2nd community

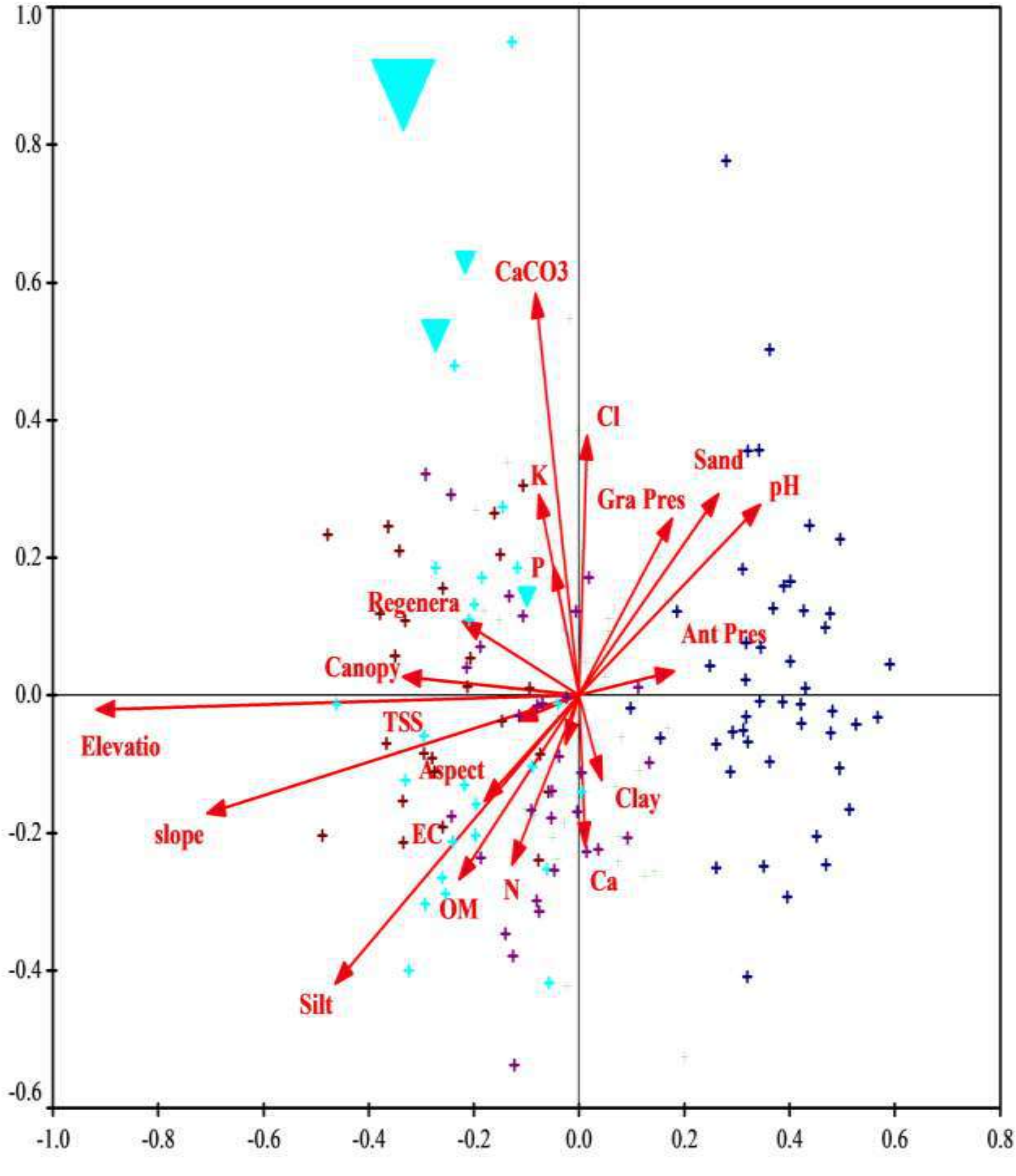

Figure 2.23: Data attribute plots of *Cyperus rotundus*; the third indicator of the 2nd community

2.6.3. Community- 03; ***Salix babylonica, Buddleja crispa, Potentilla reptans***

This community was found at mid elevations of 1301 – 1600 (masl). This community is represented in 31 stations. *Salix babylonica*, *Buddleja crispa* and *Potentilla reptan* were the top indicator species of tree, shrub, and herb layers.

These indicators were under the influence of high phosphorous (P), moderate amount of K, N, EC, aspect (southeast), poor regeneration, $CaCO_3$ and moderate canopy while less effect of Anthropogenic pressure, grazing pressure, sand and pH (Table 2.11 and Figures 2.24, 2.25, 2.26 and appendix 2). The dominant tree species in this community were *Pinus wallichiana*, *Pinus roxburghii* and *Populus ciliata*. The rare trees included *Acer cappadocicum*, *Chamaerops humilis* and *Toona ciliata*. Other co-dominant shrub species in the community included *Isodon rugosus* and *Rosa webbiana*. The rare shrubs in the community included *Coriaria nepalensis, Debregeasia saeneb* and *Ephedra gerardiana*. The dominant herbs included *Ajuga bracteosa*, *Cynanchum auriculatum*, *Lactuca dissecta* and *Cyperus niveus*. Rare herb species were *Aristida mutabilis*, *Hypericum perforatum*, *Senecio analogus*, *Sida cordifolia* and *Tagetes minuta*.

Table 2.11: The detail information of the 3rd association along with characteristic

Total number of stations in association were 31				
S. No.	**Indicator species**	**Variable**	**Important value**	**P* value**
1	***Salix babylonica***	$CaCo_3$	50	0.0232
		Cl	14.3	0.0876
2	***Buddleja crispa***	$CaCo_3$	95	0.0002
		EC	9.1	0.0178
		Clay	28.9	0.0384
		Grazing pressure	8.8	0.041
		N	7.4	0.0382
		P	31.1	0.0786
		Regeneration	10.7	0.0212
3	***Potentilla reptans***	OM	20.1	0.0034
		Elevation	36	0.0444
		N	8.6	0.0678
		Canopy	7.1	0.0892
		K	27	0.0876

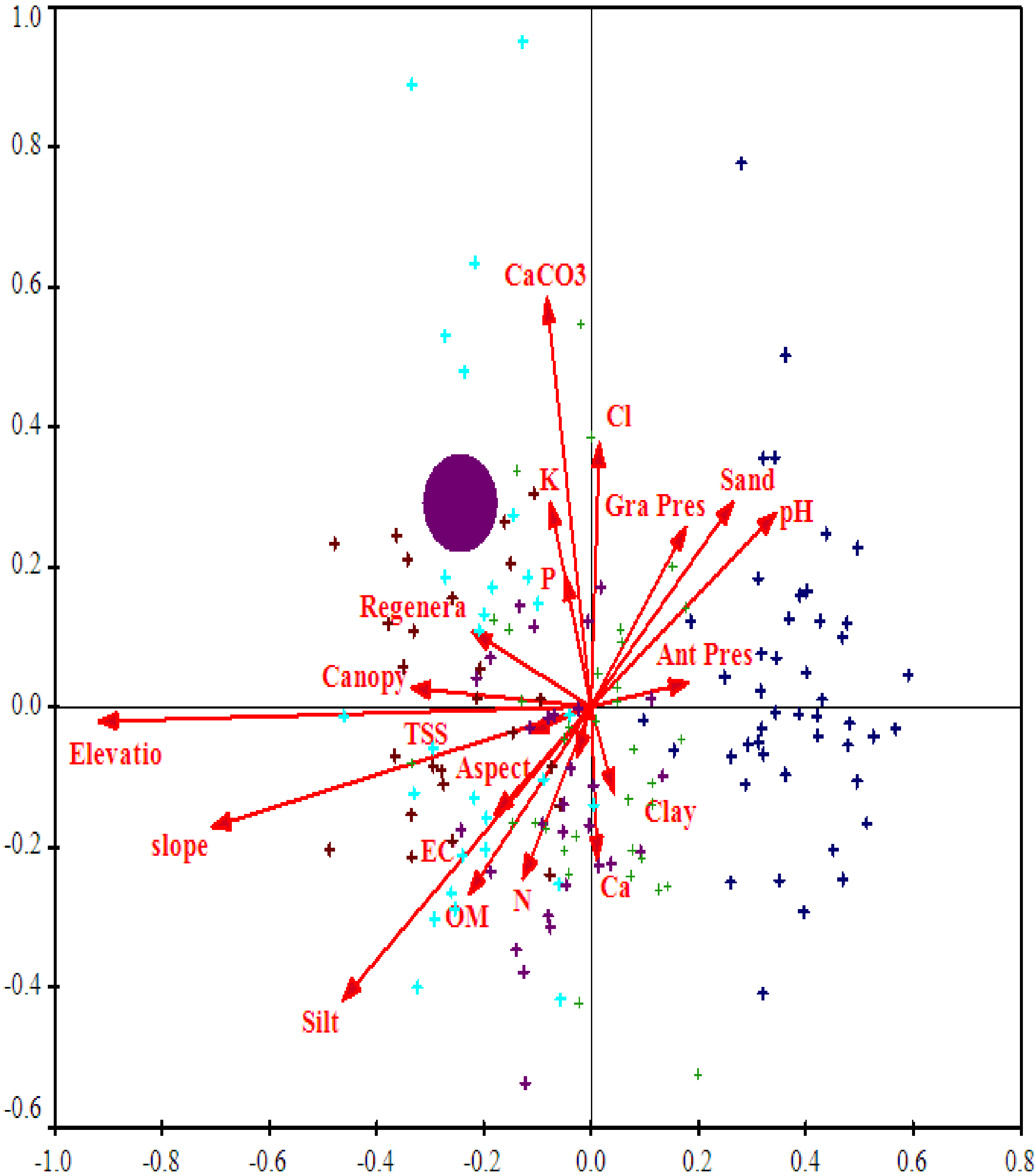

Figure 2.24: Data attribute plot of *Salix babylonica*; the first indicator of the 3rd community.

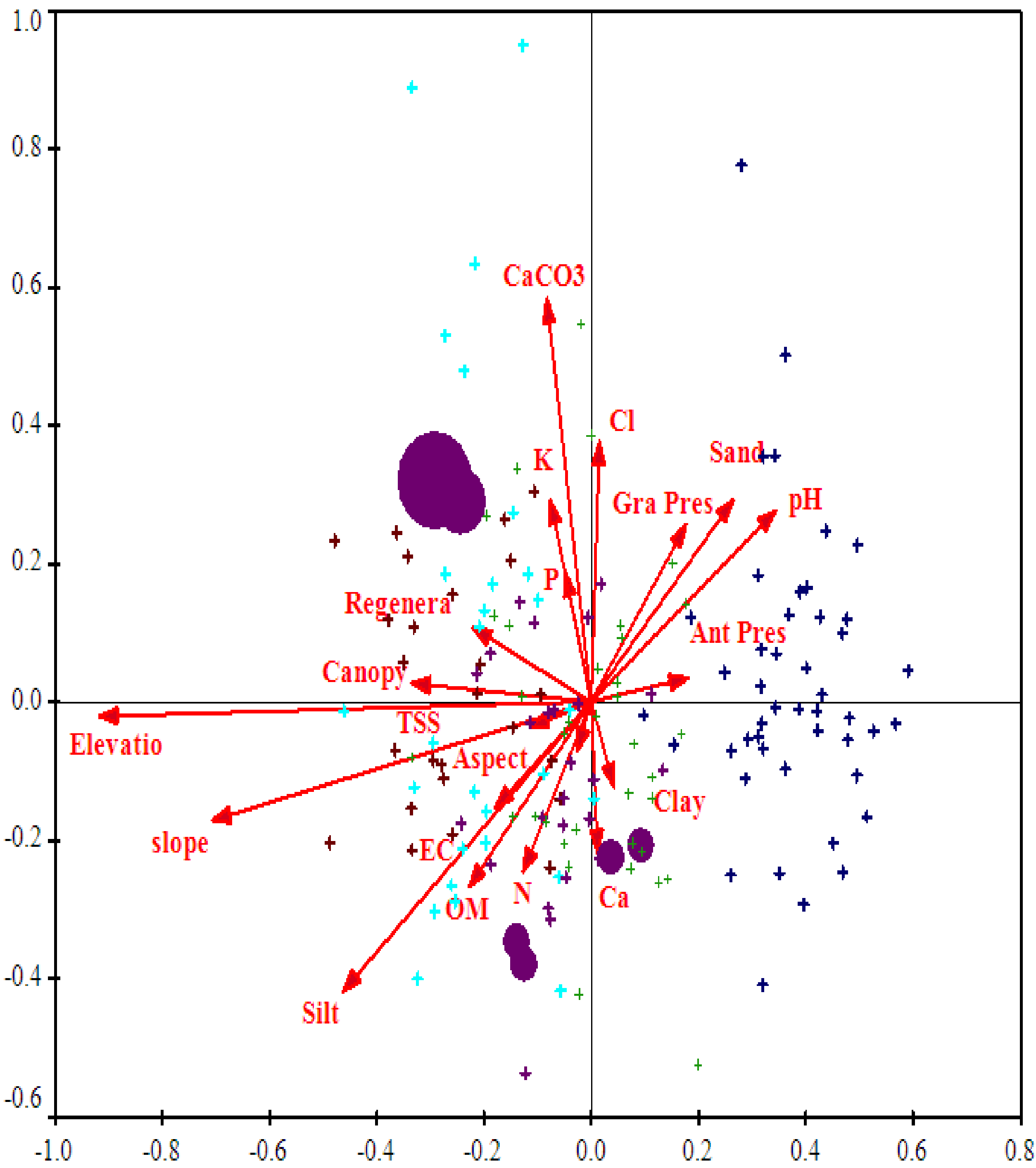

Figure 2.25: Data attribute plot of *Buddleja crispa*; the second indicator of the 3rd community.

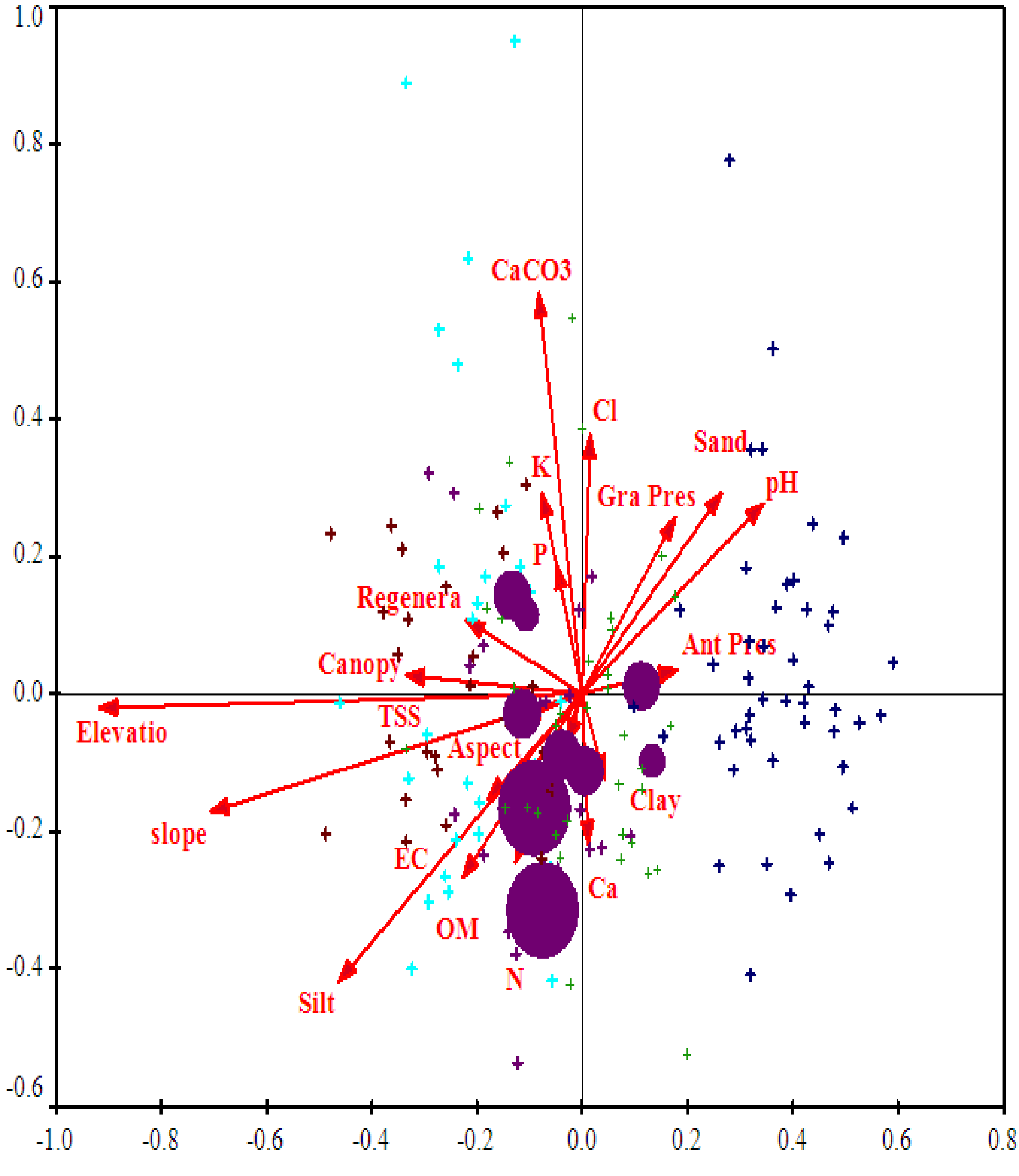

Figure 2.26: Data attribute plot of *Potentilla reptans*; the third indicator of the 3rd community.

2.6.4. Community- 04; *Pyrus bourgaeana, Reinwardtia indica, Gentiana olivieri*

A total of 36 quadrats established this community at lower elevations of 1001 – 1300 masl. *Pyrus bourgaeana*, *Reinwardtia indica* and *Gentiana olivieri* were the top indicator species of the trees, shrubs and herbs layers, respectively. Additional co-dominant tree species in the community were *Pinus wallichiana*, *Pinus roxburghii* and *Quercus incana*. The rare trees included *Platanus orientalis, Populus ciliata* and *Quercus baloot*. Other co-dominant shrub species in the community included *Myrsine africana*, *Sarcococca saligna*, *Carissa spinarum* and *Viburnum grandiflorum*. The rare shrubs in the community included *Debregeasia saeneb*, *Indigofera hebepetala* and *Lespedeza juncea*. Other co-dominant herb species comprised *Leucanthemum vulgare, Ranunculus laetus, Trifolium repens* and *Arthraxon prionodes*. Rare herb species were *Agrostis gigantea, Dichanthium foveolatum, Senecio analogus, Plantago lanceolata* and *Vincetoxicum arnottianum*. Data attribute plots of the indicator species of this community show that it is mainly under the influence of aspect (north west), low nitrogen (N) and organic matter (OM) while less influence of phosphorous (P), K and $CaCO_3$ sand (Table 2.12 and Figures 2.27, 2.28, 2.29 and appendix 2).

Table 2.12: The detailed information of the 4th association along with characteristic species

Total No. of stations in association is 36		Variable	Important value	P* value
S. No.	**Indicator species**			
1	***Pyrus bourgaeana***	Grazing pressure	19.3	0.0032
		Regeneration	14.6	0.0356
		EC	13.7	0.0694
2	***Reinwardtia indica***	Aspect	14.4	0.0054
		Sand	33.3	0.0114
		Ca	30	0.0648
		EC	11.9	0.0846
		Elevation	20.9	0.0782
		Silt	18.3	0.0986
3	***Gentiana olivieri***	Aspect	10.3	0.032
		P	36.9	0.0346

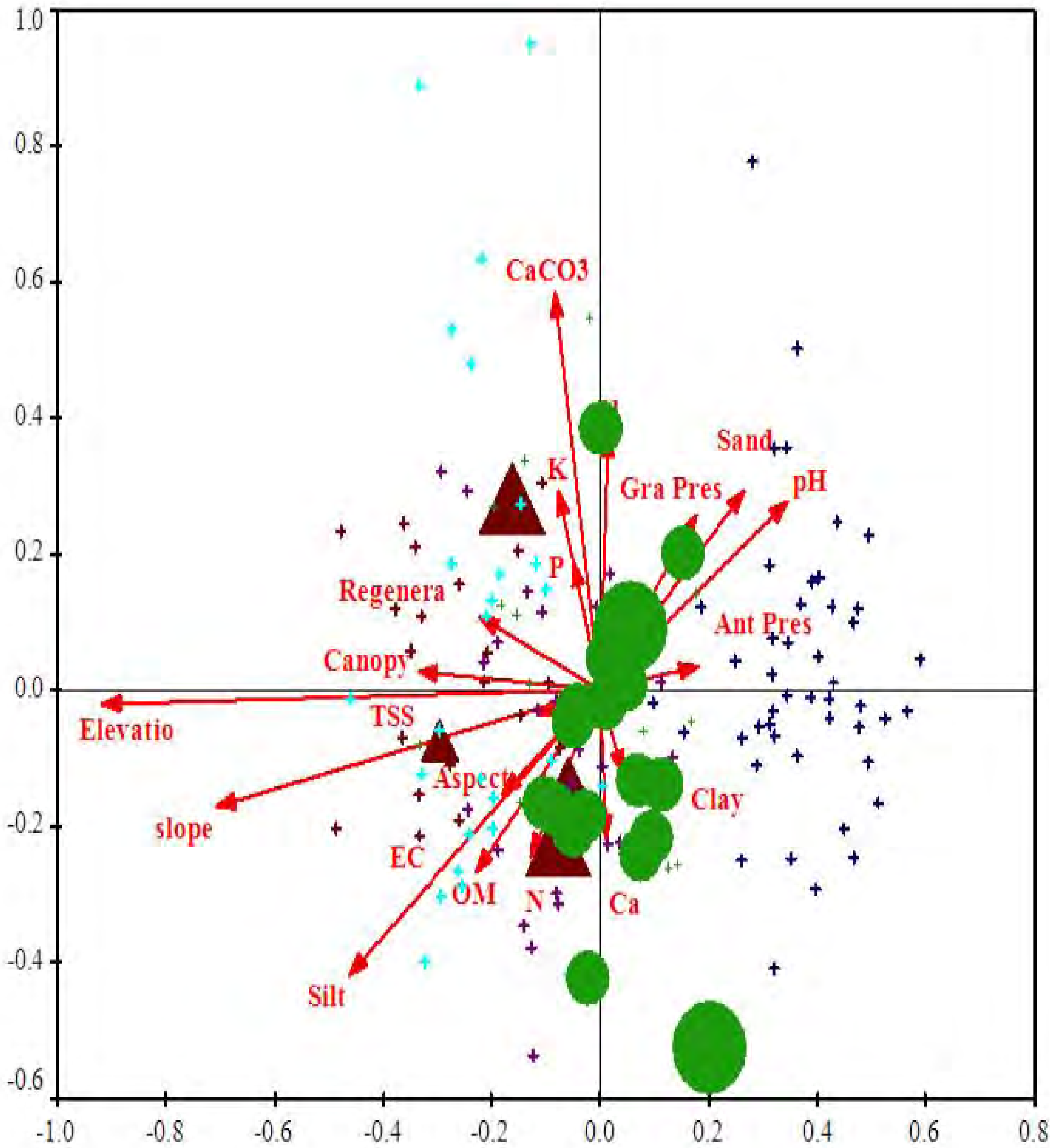

Figure 2.27: Data attribute plots of *Pyrus bourgaeana*; the first indicator of the 4th community.

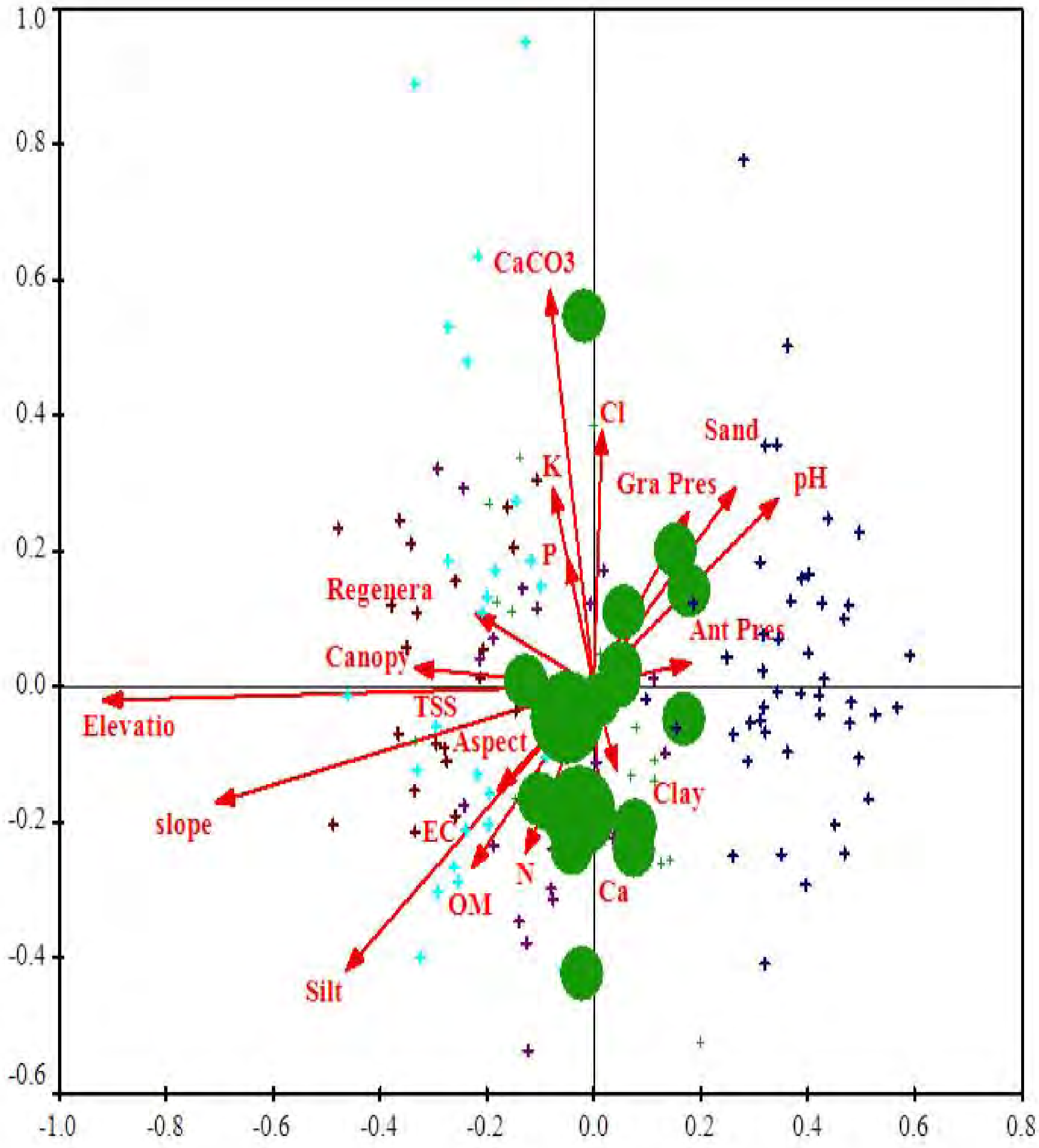

Figure 2.28: Data attribute plots of *Reinwardtia indica*; the second indicator of the 4th communitym).

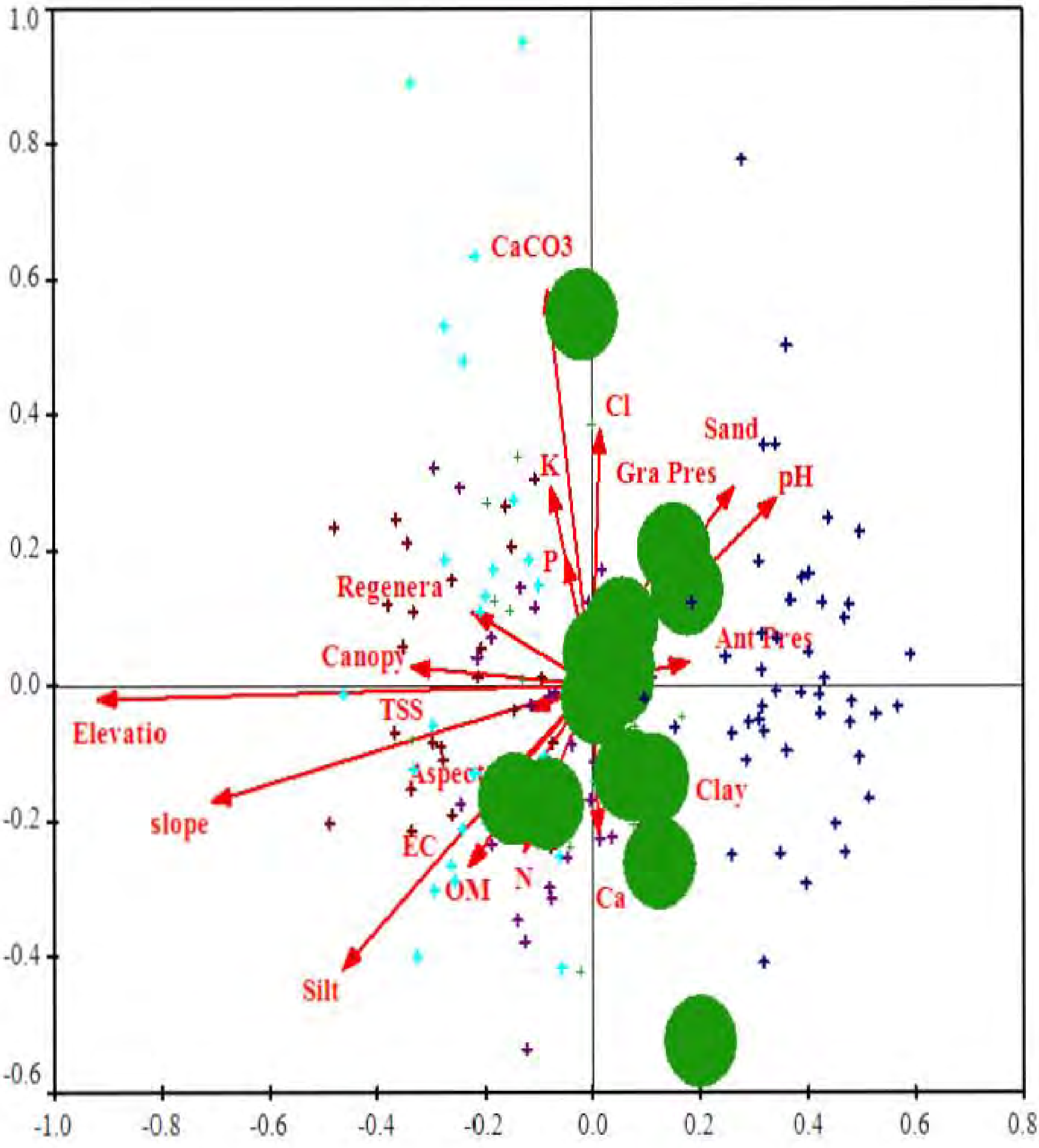

Figure 2.29: Data attribute plots of *Gentiana olivieri*; the third indicator of the 4th community

2.6.5. Community- 05; *Lannea coromandelica, Buxus papillosa, Phyla nodiflora*

This community was positioned at the lowest elevations of 519 –1000 (masl). This community is represented in a total of 46 stations. The topmost indicators of this community were *Lannea coromandelica, Buxus papillosa* and *Phyla nodiflora*. These were the higher pH indicators, Clay and Anthropogenic pressure (Table 2.13 and Figures 2.30, 2.31, 2.32 and appendix 2). The dominant tree species comprised *Acacia modesta* and *Cassia fistula*. The rare trees in the community included *Acer cappadocicum*, *Grewia optiva* and *Rhus chinensis*. Other co-dominant shrub species in the community included *Dodonaea viscosa*, *Lantana camara* and Myrsine *africana*. The rare shrubs in the community comprised *Rydingia limbata, Vitex negundo* and *Indigofera heterantha*. Other co-dominant herbs included *Solanum surattense, Themeda anathera*, *Parthenium hysterophorus* and *Dicliptera bupleuroides*. Rare herb species were *Anagallis arvensis*, *Oenothera rosea, Chenopodium album*, *Gloriosa superba* and *Salvia moocroftiana*.

Table 2.13: The comprehensive data of the 5th association along with characteristic species

Total No of stands in association is 46		**Variable**	**Important value**	**P* value**
S.No.	**Indicator species**			
1	***Lannea coromandelica***	Clay	42.3	0.0016
		Sand	28.3	0.0754
		OM	11.4	0.0084
2	***Buxus papillosa***	$CaCo_3$	47.3	0.0108
		Clay	25	0.0958
3	***Phyla nodiflora***	Clay	34.4	0.0154
		Canopy	8.2	0.019
		Elevation	37.5	0.0246

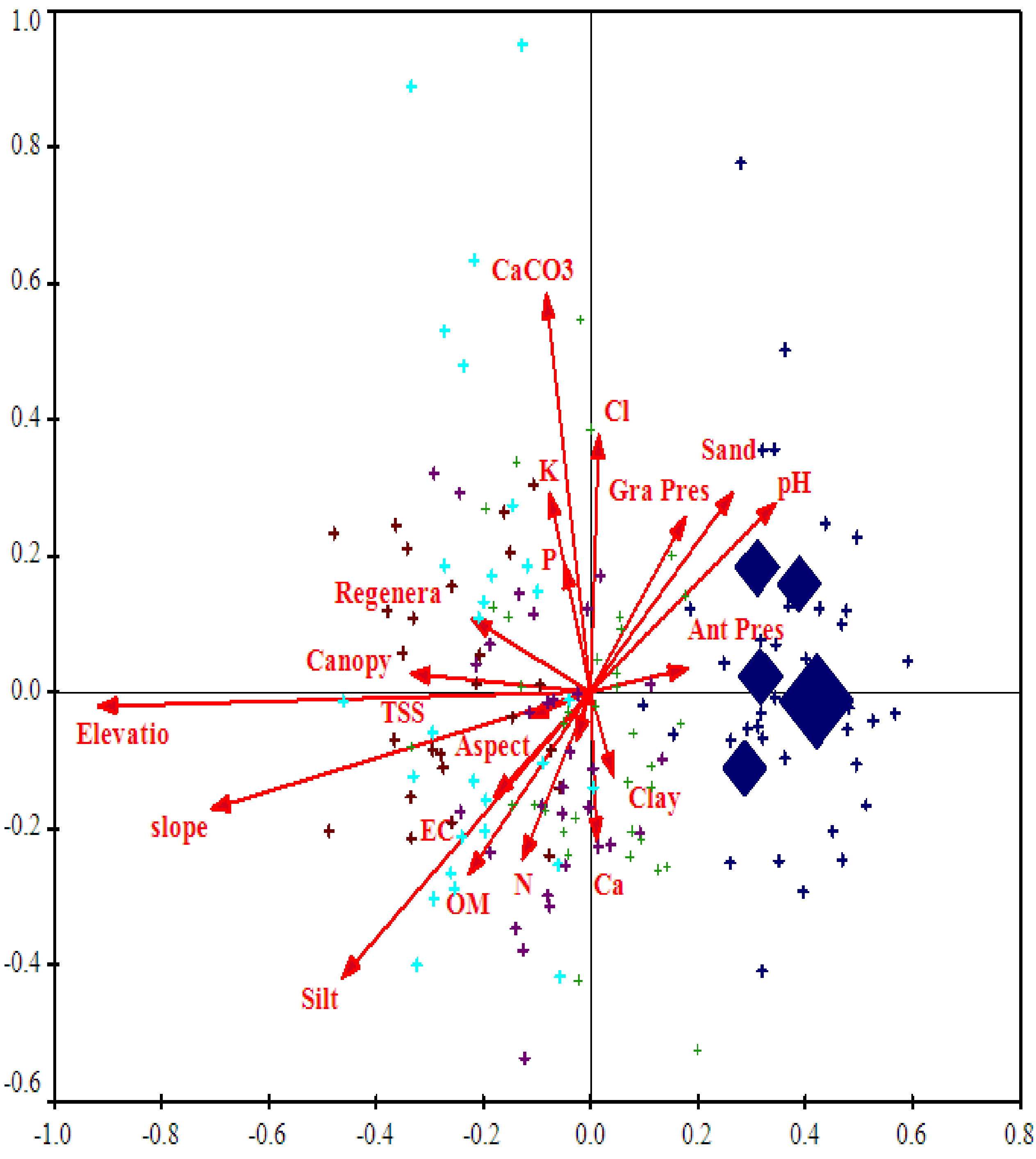

Figure 2.30: Data attribute plots of *Lannea coromandelica*; the first indicator of the 5th community

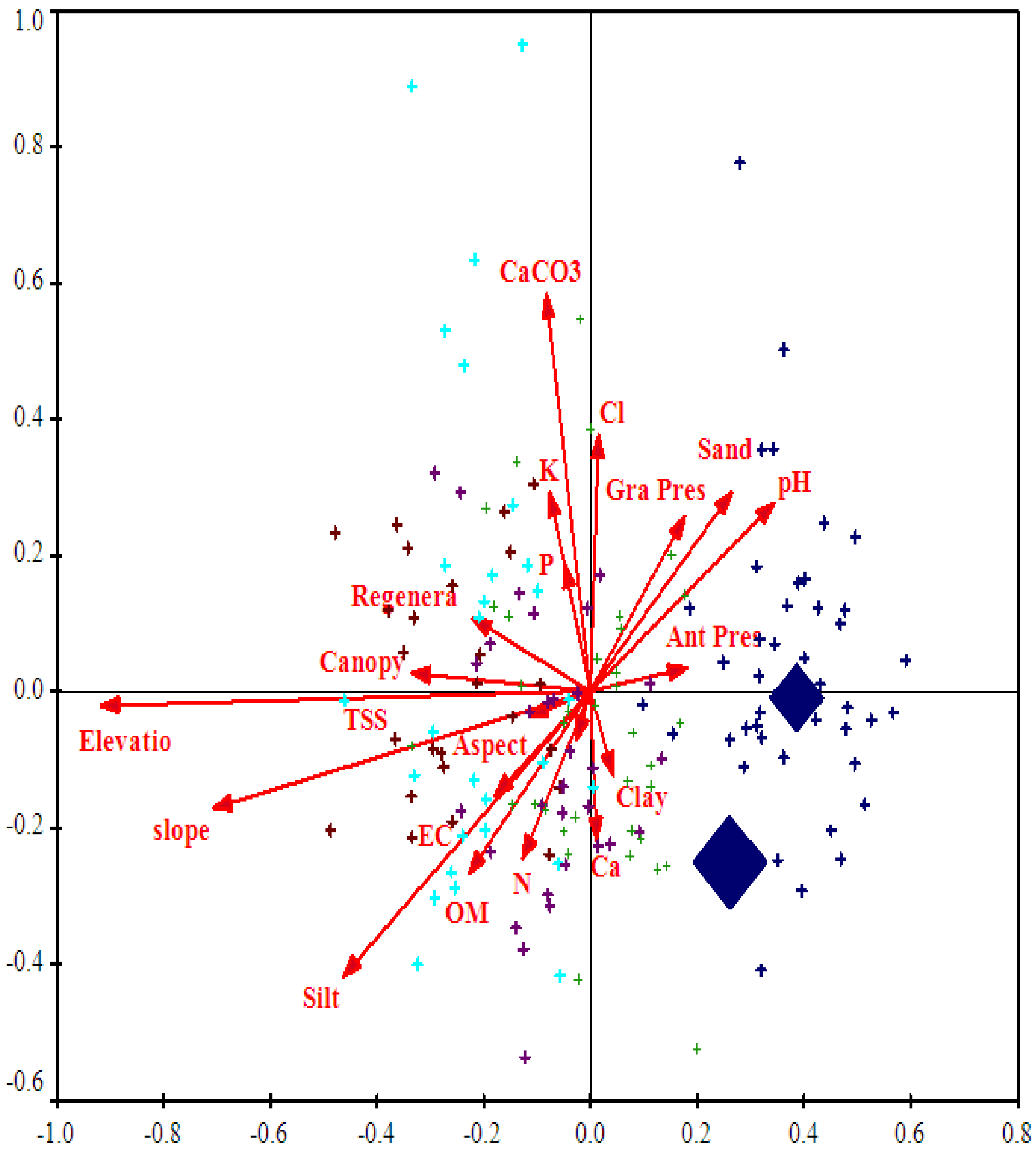

Figure 2.31: Data attribute plots of *Buxus papillosa*; the second indicator of the 5th community

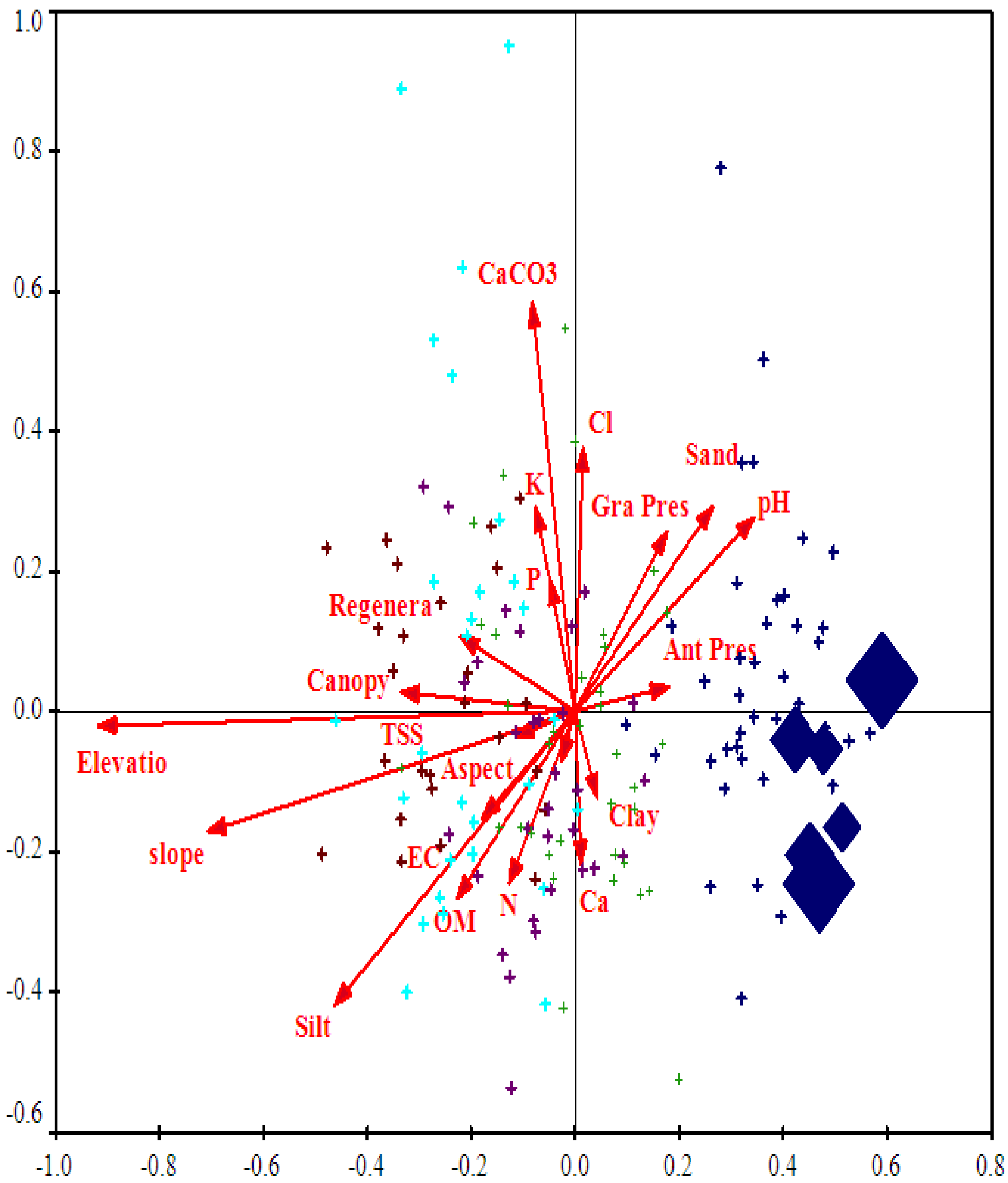

Figure 2.32: Data attribute plots of *Phyla nodiflora*; the third indicator of the 5th community

2.7 Mapping of elevation classes in the MFD

The elevation analyses were processed with the help of Digital elevation model (DEM). Elevation values were derived from ASTER Global Digital Elevation Map (GDEM) of Murree Forest Division. The whole Murree forest division was divided into five elevation classes, namely uppermost class (1901–2258 m), 2nd upper class (1601–1900 m), 3rd and medium elevation class (1301m–1600m), 4th lower class (1001–1300 m) and 5th lowest class ranges (519–1000 m) as presented in DEM and classified by ArcGIS as shown in Figure 2.33. These elevation classes are incorporated into five forest ecological zones, which are indicated by the central plant indicator species of the existing forests, have been recognized in the Murree area as;

i. Elevation class (EC1) 1901-2258 m (**Moist temperate forest**) ZONE 1
ii. Elevation class (EC2) 1601-1900 m (**Moist cool temperate forest**) ZONE 2
iii. Elevation class (EC3) 1301-1600 m (**Mixed Coniferous forest**) ZONE 3
iv. Elevation class (EC4) 1001-1300 m (**Subtropical Mixed Coniferous forest**) ZONE 4
v. Elevation class (EC5) 519 - 1000 m (**Subtropical broad-leaved forests**) ZONE 5

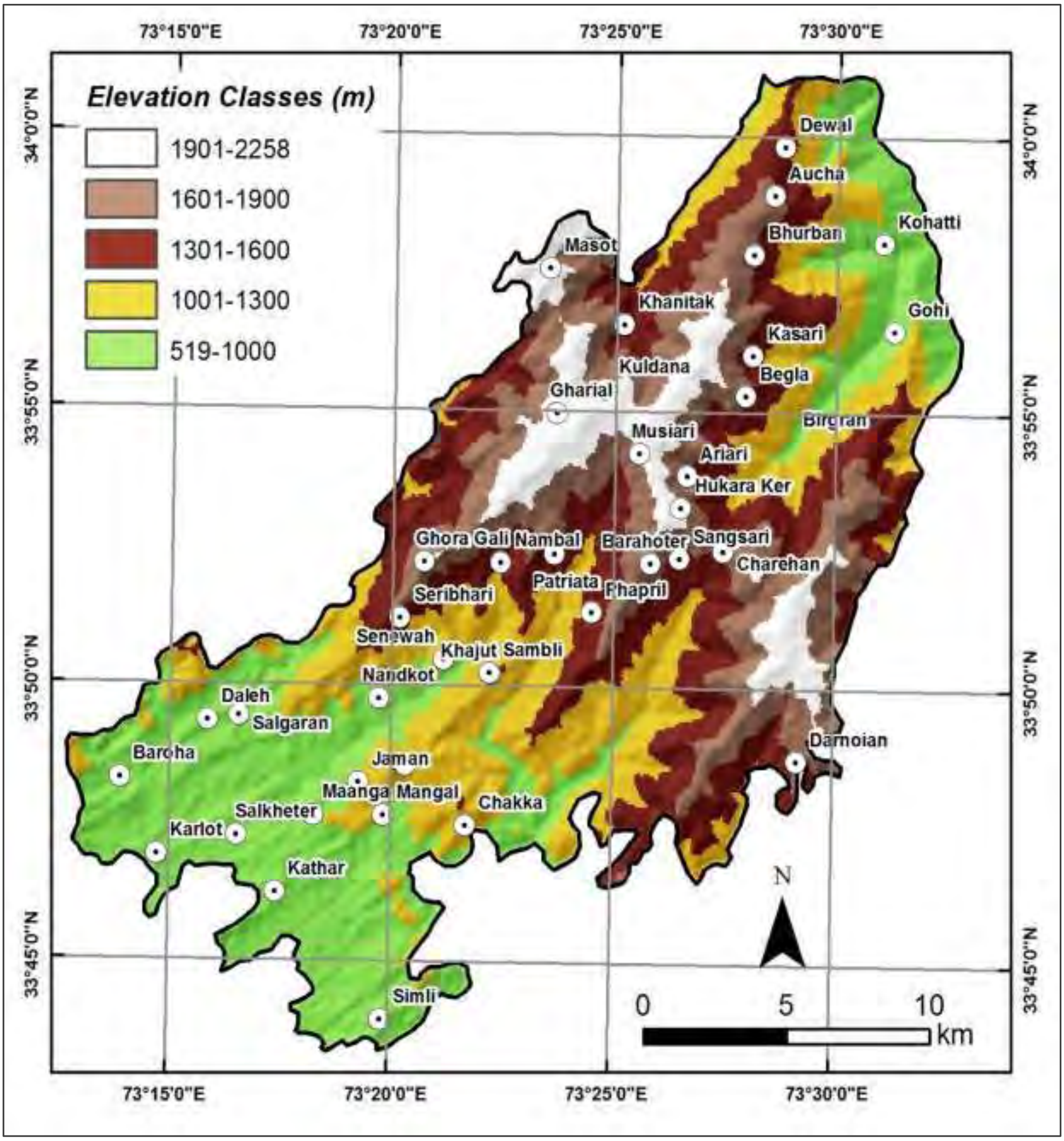

Figure 2.33: Elevation classes based on altitudinal ranges

2.7.1. Highest elevation class 1 (EC1)

The highest elevation class 1 (EC 1) mostly consists of evergreen conifers with some Oaks and deciduous trees. Mostly Moist Temperate Forests occur in EC 1 in the altitudinal zone ranging between 1901m to 2258m (Figure 2.34). This elevation class is extended into dry temperate regions, having more snowfall in winter. The monsoon rainfall ranges in EC1 was between 1300 mm-1650 mm. These are found in Kuldana, Gharial, Bhurban, Musiari, Masot, Ariari, Hukara Ker, Seribhari, Ghora Gali, and Charehan Darnoian, Patriata, Sangsari and Senewah etc.

The forests in EC 1 are separated into upper and lower zones in each of which definite species of conifers and few oaks dominate. *Abies pindrow* and *Quercus semecarpifolia* are dominant in the upper areas. Simultaneously, in the lower zones, *Cedrus deodara*, *Picea smithiana and Pinus wallichiana* are the essential conifer plants in order of increasing elevation, with *Quercus incana* at lower zones and *Quercus dilatata* above 2000 m. The temperate deciduous associated tree species include *Aesculus indica*, *Prunus cornuta*, *Quercus incana*, *Q. dilatata* and few *Juglans regia* and *Ulmus wallichiana* etc are relatively general in this EC 1. The undergrowth shrubs are hardly dense and comprise both evergreens and deciduous species like *Rubus ellipticus*, *Viburnum cotinifolium*, *Cotoneaster nummularia*, *Berberis calliobotrys*, *Sarcococca saligna*, *Indigofera heterantha*, *Rubus fruticosus, Rosa moschata* and *Rosa macrophylla* etc (Figure 2.34).

Figure 2.34: Western Himalayan moist temperate forests of EC 1 at Patriata top

2.7.2. Higher Elevation Class 2 (EC 2)

Higher Elevation Class 2 comprises moist, cool temperate forest, which includes woodland and temperate deciduous forest, temperate needle-leaved forest and woodlands and temperate rainforests. EC 2 occurs in the altitudinal zone ranging between 1601m to 1900m (Figure 5.25). They are extended into moist temperate regions having more rainfall than snowfall in winter. The forests in EC 2 are mostly dominated by needle-leaved and fewer broad-leaved tree growth forms. Trees in the EC 2 forests may get excessive heights and easily exceeds up to 50 m, but trees in these forests more characteristically range from 10 to 30 m in height. The EC 2 is established in Masot, Hukara Keri, Sang Sari, Seneowah, Seri Bhari, Ghora Gali, Charehan, Darnoian, and upper parts of Patriata.

The forest stands in EC 2 comprise pure or mixed stands of evergreen needle-leaved or broad-leaved deciduous forms of tree growth with a green herbal understory. The tall shrub layer is variable and is often deciduous with broad leaves, but it is possible to expect a short shrub layer. In cold rainy and high montane needle-leaved evergreen stands, the moss layer is often scarce, but more prevalent. Between January and May months of the year, snow may be on the ground. Forest structure in EC 2 is typically complex in moist habitats and usually comprised of five layers: (1) the tree layer, 15-50 m tall and dominated by needle-leaved evergreen or broad-leaved deciduous species, often with a substratum of small trees, 5-15 m tall; (2) the smallest and highest stratum of arbors, 2-5 m tall; (3) the short stratum of arbors, less than 2 m tall; (4) the herbal stratum of perennial forbs, containing an ecological group with early spring flowering species (in deciduous broadleaved arbors, less than 2 m long). Mosses and lichens grow on the trunks of EC 2 trees as well. Quercus, Acer, Fagus, Castanea, Ulmus (elm), Tilia (basswood or linden), and Juglans (walnut) in EC 2 are many of the genera covered.

2.7.3. Middle Elevation Class 3 (EC 3)

It is an important elevation class at middle. EC 3 comprises forest type with mixed plant species including *Abies pindrow* (Silver fir) and *Cedrus deodara*, *Picea smithiana* (Spruce), *Populus ciliata*, *Aesculus indica*, *Quercus dilatata*, *Pinus roxburghii* and *Pinus wallichiana* as the leading tree species. The shrub layer comprised *Berberis lycium, Isodon rugosus, Rosa moschata, Rosa webbiana* and *Viburnum* species in EC 3. Important plant species in the herb layer were *Potentilla reptans, Galium boreale, Fragaria nubicola, Geranium rotundifolium, Origanum vulgare, Rumex nepalensis Ajuga bracteosa, Cynanchum auriculatum, Cyperus niveus* and *Lactuca dissecta*.

The forests in EC 3 are usually heterogeneous, having mixed-age classes. The EC 3 occurs in the altitudinal region ranging between 1301m to 1600m (Fig. 2.33) and they are having a moderate rate of rainfall in winter. These mixed coniferous forests of EC 3 are found in regions like Huka Keri, Charehan, Begla, Bara Hoter, Seribhari, Senewah, Dewal, Numbal, Kasari and Phapril etc. The composition of the mixed forests in EC 3 is mainly under the influence of Aspect, Regeneration and canopy while less grazing pressure.

2.7.4. Lower Elevation Class 4 (EC 4)

The EC 4 was found in between the Himalayan moist temperate and sub-tropical broad-leaved region. The altitudinal ranges of this EC 4 are 1001m to 1300m from sea level in the Western Himalayan part and the south-west summer monsoon range (Fig. 2.35). Subtropical pine forests of EC 4 are found in most of the Murree hills, including Begla, Bara Hoter, Kasari, Phapril, Khajut, and Jaman Chakka, Birgran and Nandkot etc. Subtropical pine forests of EC 4 are mostly dominated by *Pinus roxburghii*. These are mostly mixed by *Pinus roxburghii* and other coniferous species like *Pinus wallichiana* at the upper ranges like Dewal, Angoori, Sambli, Nambal, Aucha and Khanitak.

The other associated species of *Pinus roxburghii* are *Quercus glauca*, *Quercus incana*, *Pistacia chinensis* ssp. *integerrima*, *Xylosma longifolium*, and broad-leaved tree species like *Cornus macrophylla* and *Celtis australis* are also found in EC 4. The commonly undergrowth shrub layer of EC 4 consists of *Myrsine africana*, *Carissa spinarum*, *Berberis lycium*, *Rubus ellipticus*, *Dodonaea viscosa*, *Mallotus philippinenis*, *Ziziphus jujuba*, *Daphne papyracea*, *Daphne mucronata* and *Zanthoxylum armatum*. Common ground or Herbaceous flora in Ec 4 are *Themeda anathera* and *Heteropogon contortus*.

Figure 2.35: Subtropical Mixed Coniferous Forests EC 4 in Murree hills

2.7.5. Lowest Elevation Class 5 (EC 5)

In the EC 5, mainly broad-leaved subtropical forests are recorded on the hills and in the lower slopes of Himalaya near Islamabad and Rawalpindi. EC 5 extended from 519m to 1000 m elevation ranges adjacent to the subtropical pine forest. EC 5 is relatively observed in drier and hot climate conditions with some xerophytic thorny plant species. This EC 5 is found in Gohi, Simli, Karlot, Baroha, Salgaran, Maanga, Salkheter, Kohatti, Kathar, Daleh and Mangal etc. located in Murree hills. The subtropical broad-leaved vegetation of EC 5 comprises *Acacia modesta*, *Dodonaea viscosa*, *Woodfordia fruiticosa*, *Ziziphus jujuba*, *Berberis lycium*, *Justicia adhatoda*, *Mallotus philippensis*, *Punica granatum* and *Carissa spinarum*. Noteworthy species in EC 5 that are rapidly being removed are *Acacia nilotica*, *Pistacia integerrima*, and *Olea ferruginea*. These forests in EC 5 subsequently hosts undersized shrubs which are often interspersed with herbs and grasses (Fig. 2.36).

Figure 2.36: Subtropical broad leaved forests in EC 5 at Daleh, Murree Hills, Western Himalaya

2.8 Discussion

2.8.1. Floristic composition, diversity and richness along elevation

The present study documented 454 plant species from the Murree forest division in western Himalaya, Pakistan. Out of which, 292 species were native. However, 162 species are exotic which frequently flourish in disturbed environments of the region. Exotic plant species are typically able to colonize disturbed regions more efficiently than native plants irrespective of their life history scheme because of high disturbance (Dawson et al. 2011; Van Kleunen et al. 2010). Common invasive plant species growing in the region comprise herbs like *Conyza canadensis, Amaranthus caudatus, Leucanthemum vulgare* and trees like *Aesculus indica, Ailanthus altissima* and *Robinia pseudoacacia.* More similar invasive species were documented by (Haq et al. 2019) in the region of northwestern Himalaya, India.

Exotic species such as Dodonaea viscosa, which was the most dominant exotic shrub at lower elevations, invaded many regions. Lower elevations were also dominated by *Carissa opaca* and *Dodonaea viscosa* (Hameed et al. 2012). *Lantana camara* was another exotic plant that is a garden escape and is currently invading our valuable fields, lands and commercial non-crop parts (Dempster 2002). Moreover, *Lantana camara* invades fields, pastures, and natural environments, causing substantial economic damage, degrading our environment, and reducing biodiversity (Goulson and Derwent 2004). Among the perennial herb species, the most deleterious was *Dichanthium annulatum* recognized as a lawn pest followed in almost every grassy land. Even in the most organized conditions and *Taraxicum officinale*, *Phyla nodiflora* L., *Coronopus didymus* and *Lepidum sativum* were also reported as a weed by (Gul et al. 2018) on the campus, University of Peshawar, Pakistan. Most of the water channels and roadsides were infested with perennial *Sonchus arvensis* L. (Sow thistle). Among the invasive tree species, the most notorious one is *Broussonetia papyrifera* L., (paper mulberry) that grows overwhelmingly in the lower altitudes causing allergy due to its proficiency of pollen production, mostly in the spring season. It is easily and rapidly establishing and has become a threat for our native trees, a source of timber, fuelwood, fodder for cattle and shade (Qazi et al. 2019; Huma Qureshi et al. 2014). The above-mentioned exotic/ invasive plant species are a threat to our indigenous and native flora (Gul et al. 2018). The MFD was dominated by the family Poaceae followed by Asteraceae, Papilionaceae, Lamiaceae, Rosaceae, Apocynaceae, Cyperaceae, Ranunculaceae and Rubiaceae. Similar families like Rosaceae, Pinaceae and Polygonaceae were also reported by some previous researchers who stated that these families were the best illustrative families of Himalayan forests (Bano et al. 2018; Ahmed et al. 2013; Shujaul Mulk Khan et al. 2011).

2.8.2. Patterns of biological spectrum and Phytoclimatic variation

The lifeform spectrum of the MFD have a higher proportion of Therophytes, Phanerophytes, Hemicryptophytes and Geophytes. Therophytes' domination is usually connected with dry environmental circumstances in the region (Asri 2003; Mamariani et al. 2009; Haq et al. 2019). Therophytes are abundant in arid and semi-arid environments and disturbed regions (Kovács-Láng et al. 2000). Therefore, the high percentage of therophytes in our study area specifies more dryness during the autumn and summer seasons and anthropological disturbances in livestock overgrazing and deforestation in the Himalayan region. Therophytes are recognized to link their life cycle with an appropriate season and persist as seed due to water scarcity (Van Rooyen et al. 1990; Cain and Castro 1960). Similar dominance of therophytes due to destruction of natural habitat was witnessed in Girbanr and Dabargai hills by (Hussain et al. 1997). These findings support the finding of our recent study. Therophytes are adapted to occupy empty niches due to disturbances like overgrazing and deforestation (Pyšek et al. 2005). (Sher et al. 2011) also reported that therophytes were the dominant life form class from District Swabi, KPK, Pakistan. (Rafay et al. 2013) also revealed therophytes as the dominant class from their research region. (Inayat et al. 2014) also described the therophytes as dominant class followed by hemicryptophytes from District Charsadda, Pakistan. According to (Shaheen et al. 2015), the life form was frequently found therophytes followed by chamaephyte species in dry and unfavorable circumstances.

The reasonable prevalence of hemicryptophytes in the area is probably due to the mountainous and cold climate. Usually, they tolerate water shortage phases by standing as by morphological, physiological and anatomical adaptations alterations that guarantee the inhibition of water loss (Picotte et al. 2007). Close to our conclusions, (Malik et al. 1994; Malik and Husain 2008) witnessed that the moist temperate part of Neelum valleys and Dhirkot of Kashmir area, therophytes and hemicryptophytes were the foremost life form classes. (Malik and Malik 2004) reported that qualitatively hemicryptophytes and Nanophanerophytes were dominant in Kotli hills, Kashmir. (Malik 2005) described hemicryptophytes and therophyte species were leading in Ganda Chotti and Bedori hills at an altitude of 1700 to 3700 m. The geophytes appear in spring and remain resting by the feature of their underground perennating parts under harsh seasons. (Nazir and Malik 2006) stated similar results from Sarsawa hills and observed that vegetation deprivation occurs owing to severe biotic pressure. (Shah et al. 1991; Sikarwar 1996) described that hemicryptophytes are an indicator of high elevation, whereas therophytes represent dry/ desert climate and geophytes are indicators of Mediterranean environment. In open physical characteristics, hemicryptophytes succeed dominantly however, in dense conditions megaphanerophytes are the best indicators (Hussain 2009). In the same way, degraded vegetation supports hemicryptophytic flora.

Leaf form class variation exists seasonally due to the presence of geophyte and annual buds but the evergreen and perennials maintain the same status of leaf spectra class. Nanophylls and leptophyllous represent dry/ hot deserts, whereas Microphylls represent steppes (Cain and Castro 1960; Tareen and Qadir 1993). Plant species with large leaves occur in hotter moist climates, whereas smaller leaves characterize cold and dry microclimates. The current study reveals that nanophylls and microphylls were mostly present at high altitudes, whereas leptophylls were present at a lower altitude. Typically the leaf structure determines habitat circumstances such as smaller leaves usually are physiognomies of adverse and dry environmental conditions. The witnessed association between small leaves and hot or cold desert climates is an adaptive character in holding soil moisture. Moisture holding is reduced when the root is sensitive to low temperature, causing a reduction in water absorption from soil. In our study a high number of microphylls characterizes the cool climate of temperate and moist temperate under cold environments wherever the roots absorb low quantities of nutrients and moisture.

Leaf form spectra revealed that nanophylls and microphylls were prominent in the study area. Our study area also observed that plants suffer from severe conditions such as strong winds and poor soil development. Thus, plants adapt adjust themselves to the prevailing conditions to lessen their requirements by decreasing their height, size, foliage, and growth period. Hemicrytophytic and Therophytic life form together with small leaf size is a good plant species strategy to manage with adversarial deteriorated habitat and environmental conditions. Deforestation and overgrazing in such an environment further strengthen the adverse effects of the environment.

Our findings are comparable with those of (TAREEN and Qadir 1987), who stated a high percentage of nanophylls and microphylls in a temperate type of environment in the district Quetta, Baluchistan. (Malik and Hussain 1990; Qadri 1986) documented many nanophylls and leptophylls observed in dry subtropical evergreen forests of Kotli, Azad Jammu and Kashmir. (Malik 2005) also testified that nanophylls and microphylls prevailed at Ganga Chotti and Bedori hills, Azad Jammu and Kashmir. His results are in closeness with our results. (Malik et al. 2007) stated that microphyll and nanophyll as the foremost leaf size classes from Ganga Chotti and Bedori Hills. (Sher and Khan 2007) also pointed out leaf form spectra as microphyll followed by nanophyll and mesophyll from Chagharzai Valley, District Buner. The findings of (Khan et al. 2014) similarly align with our results as they described the dominance of microphylls followed by nanophyll and mesophyll from northern regions of Pakistan. Analogous studies from Chail valley, Pakistan also testified the relative dominance of mesophylls flora in the area (Ali et al. 2016). Plant habit and their root system also play an essential role. However, the leaf size information helps in understanding physiological processes of vegetation and plant communities and is therefore advantageous while categorizing plants into various associations.

2.8.3. Vegetation dynamics and the driving climatic and edaphic variables

In the last several decades, studies of environmental changes along vegetation dynamics have emerged more rapidly in the life sciences than in other studies. The effects of these abiotic environmental changes alongside biotic factors have been increased by current anthropogenic activities on vegetation diversity (Davis 1992; Waqas Khan et al. 2016). The primary trophic level is made up of vegetation in the mountain environments. For that reason, proper documentation and quantification of flora concerning the abiotic environment and biotic factors are required (Khan 2012; Rahman et al. 2016).

Composition, function and structure are the three important characteristics of forest ecosystems. These characteristics change in response to soil, topography, disturbances and climate. The above-revealed features and succession are also accountable for both landscape-level and local (i.e. within stand) differences in forest features, thus creating spatial heterogeneity (Timilsina et al. 2007). By origins, plant species are limited to a particular habitat and be reached in that particular habitat due to the presence of optimal environmental features, including edaphic chemistry, abiotic and biotic factors, which display that vegetation composition and plant communities changes along the environmental range from point to point (Khan et al. 2018). Being as a function of differences in the environment plant species are successively replaced. Therefore, plant species' structure and distribution in communities differ along ecological gradients (Rahman et al. 2016). The communities are persistent about edaphic conditions, elevation, slope angle, regional climate and landscape features. It is also described that the regional forms of species richness are consequences of several interrelating features such as plant productivity, regional species dynamics, regional species pool, geographical area, competition, historical development, environmental changes and anthropological activities (Eriksson 1996; Zobel and Singh 1997; Criddle et al. 2003). The vegetation parameters achieved for most of the current study locations fall within an analogous range previously described for western Himalaya (Kala and Mathur 2002; Waqas Khan et al. 2016; Haq et al. 2017).

2.8.4. Communities determination and robust statistical approach

The use of multivariate statistical techniques has been increased for the last 25 years. The current study revealed multivariate statistical techniques such as cluster analysis, Two-cluster analysis, indicator species analysis, polar ordination, nonmetric multidimensional scaling, principal component analysis, and detrended and canonical correspondence analysis. These techniques were used to determine the relationship between vegetation diversity, edaphic, climatic and topographic gradients. Cluster and Two-way cluster analyses were used to classify plant species and stations into significant plant communities. The ordination analysis i.e., DCA and CCA were carried out using CANOCO software.

DCA is an ordination method used to describe patterns in multifaceted data sets and produced the ordination axis sequence (Ter Braak 1987). DCA is an eigenvector ordination method based on Reciprocal Averaging (RA), rectifying the arch effect formed from RA. DCA results are superior to those of RA, as reported by (Hill and Gauch 1980). Other ecologists complain about the detrended process of DCA. DCA is extensively used for the investigation of community data along gradients. DCA ordinates species and samples simultaneously. DCA is possibly the most commonly used technique of indirect vegetation ordination. But direct ordination of vegetation and environments is accomplished with canonical correspondence analysis. CCA is a comparatively new technique in which the axes of vegetation ordination are controlled to linear groups of environmental variables (Zhang et al. 2006).

CCA is a direct gradient analysis that demonstrates vegetation's variance in the environmental variables involved in ordering samples using ecological data (Kent 2011). This approach incorporates multiple regression approaches with different correspondence analysis forms (Ter Braak 1986, 1987). Using Monte Carlo permutation studies, the statistical implication of the relationship between the plants and the full collection of environmental variables was evaluated. CCA is the regulated form of CA and is therefore preferred for maximum collection of ecological data. CCA also is suitable under a linear model as long as one is interested in plant species composition relatively than total abundances (Ter Braak and Smilauer 1998). CA and canonical correspondence analysis are commonly used to obtain restricted or unrestricted ordination of data on species abundance and the resulting biplots or triplots, extremely useful for environmental comprehension.

The present study used CCA to evaluate the distribution pattern and show the variation of 454 plant species in 166 stations with diverse micro-environments of five plant communities. After critical analysis of the various environmental variables, it was observed elevation, Slope, Soil texture (Clay, Silt and Sand), pH, Organic matter, canopy, Nitrogen, Potassium, Calcium carbonate, Phosphorus and grazing pressure had a significant effect on species distribution, composition and community classification having P-value ≤ 0.05. Numbers of researchers reported similar impacts on species composition and distribution in the neighboring temperate to Pakistan's subtropical habitat regions (Khan 2012; Rahman et al. 2016). Slight variation in environmental factors and elevation caused a significant effect in the development of communities (Chawla et al. 2008; Khan et al. 2014). In the present research work various statistical methods were used including DCA, CCA, PC-ORD and ISA, to assess various environmental variables on plant species composition and communities distribution, which were also used by others (Khaznadar et al. 2009; Shaheen et al. 2015; Rahman et al. 2016; Haq et al. 2017; Iqbal et al. 2018; Khan et al. 2020) providing a baseline for conservation planning and management for the future.

The multivariate analyses determined 5 diverse plant communities through TWCA and IVI in the Murree forest division area. The quantitative classification technique designates forest communities' distribution patterns in the study region and characteristically categorizes the vegetation into different communities. The vegetation was mainly Sino-Japanese is situated in the Western Himalayan Province. The plant communities were categorized based on environmental factors i.e., soil pH, organic matter, phosphorous contents, K, N, texture, aspect, altitude and soil electrical conductivity, along with biotic factors like anthropogenic and grazing pressure. Our present research work used similar approaches to those of previous researchers in nearby places such as the Sino-Japanese Areas (Takhtajan et al. 1986; Ali and Qaiser 1986; Champion et al. 1965; Khan et al. 2014; Mehmood et al. 2015; Shaheen et al. 2015; Rahman et al. 2016; Waqas Khan et al. 2016; Haq et al. 2017; Khan et al. 2020).

Among the five plant communities, 1st community was represented in 25 different stations at higher elevations of 1901 – 2258 meters above sea level (masl). *Picea smithiana* dominated this community along with *Spiraea canescens*, *Trifolium spp* . These species were mainly under the influence of elevation, aspect, slope, Regeneration, K, organic matter (OM), phosphorous (P) and nitrogen (N) while less influence of grazing pressure. 2nd community was characterized on 28 different stations on the North-East aspect from at second higher elevations of 1601m –1900m. This community was indicated by *Quercus robur, Rubus fruticosus and Cyperus rotundus* whereas the rare species were *Populus ciliata, Grewia optiva* (trees) and *Andrachne cordifolia, Indigofera hebepetala (shrubs) and Persicaria nepalensis, Agrostis viridis (herbs)*. The more effects of organic matter (OM), silt, aspect, Electrical conductivity (EC), elevation, slope, Regeneration, phosphorous (P), K, nitrogen (N) and CaCO3 while less influence of grazing pressure in this community.

31 stations present 3rd community at mid-elevations ranging from 1301m to1600m characterized by indicator species i.e., *Salix babylonica*, *Buddleja crispa and Potentilla reptans* while the rare plant species were *Acer cappadocicum*, *Chamaerops humilis* (trees) and *Coriaria nepalensis*, *Debregeasia saeneb* (shrubs) and *Aristida mutabilis, Hypericum perforatum* (herbs). This community was chiefly under the effect of phosphorous (P), K, N, Aspect, Regeneration, $CaCO_3$ and canopy while less effect of Anthropogenic pressure and pH etc. 4th Community was dominated in 36 different stations lower elevations of 1001m to 1300m. Community 4 was characterized by *Pyrus bourgaeana, Reinwardtia indica and Gentiana olivieri* however the rare species were *Platanus orientalis, Populus ciliata (trees), Debregeasia saeneb, Indigofera hebepetala (shrubs)* and *Agrostis gigantea, Dichanthium foveolatum (herbs)*. This community was mainly under the influence of aspect, nitrogen (N) and organic matter (OM) while less influence of phosphorous (P) and $CaCO_3$ etc. The last 5th community represented 46 stations and located at lowest elevations of 519m to 1000m. The indicator plant species were *Lannea coromandelica, Buxus papillosa and Phyla nodiflora whereas the* rare species were *Acer cappadocicum, Grewia optiva* and *Anagallis arvensis, Oenothera rosea (herbs)*. This community was mostly under the influence of pH, Clay and Anthropogenic pressure while less phosphorous (P) influence and nitrogen (N).

The present study indicated that the subtropical broad leaved species predominated at the lower altitudes vegetation and mainly comprised species including *Dodonea viscosa*, *Acacia modesta*, *Woodfordia fruiticosa*, *Punica granatum*, *Justicia adhatoda, Berberis lyceum* and *Mallotus philippensis*. A comparable community was termed by (Siddiqui et al. 2009) in lesser Himalayan-Hindukush ranges and (Waqas Khan et al. 2016) during vegetation analysis of the Thandiani Forests in Western ranges, lesser Himalaya, Pakistan. In the upper elevation range the forest comprises typical plants of moist temperate type e.g., *Abies pindrow, Aesculus indica, Pinus wallichiana, Prunus padus, Viburnum grandiflorum, Paeonia emodi, Indigofira heterantha, Euphorbia wallichii* and *Trifolium repens*. These results might be associated with the communities described in moist temperate Himalayan forests by other workers (Khan et al. 2013a; Waqas Khan et al. 2016; Ahmed et al. 2006; Saima et al. 2009). The findings of present study reveal subtropical vegetation at the lower elevation ranges, which gradually develops into cool moist-temperate forests in the higher altitudes, i.e. lengthwise the latitudinal gradients and then to moist temperate forests near the peaks of the foothills in response to the altitudinal gradients which were comparable to the findings of (Khan et al. 2014; Waqas Khan et al. 2016). In terms of floristic families, our results can be linked with those of previous studies from Himalayan mountains where the plant families like Poaceae, Rosaceae Asteraceae and Lamiaceae were the most dominant families of vegetation (Shujaul Mulk Khan et al. 2011; Waqas Khan et al. 2015; Shaheen et al. 2011; Ahmad et al. 2012; Bano et al. 2018). At the same time, our study confirms the similar dominant families like Poaceae followed by Asteraceae, Papilionaceae, Lamiaceae, Rosaceae, Apocynaceae, Cyperaceae, Ranunculaceae and Rubiaceae.

The techniques applied in the current study permit researchers to compare multiple vegetation analysis and classification techniques of the same locations to confirm the evidence resulting from the investigation. However, vegetation investigations need to be carried out promptly and with minimal resources, such as flora mapping, in mountainous areas that are difficult to reach. In such cases, it may be ideal to sample the largest possible number of areas, but by focusing on a smaller subset of species that have high analytical value, the fieldwork method may be simpler. A well-known approach for both applied and theoretical determinations in plant ecology in the recent past is the use of indicator species to observe environmental conditions or to determine population or habitat types. These metrics are used to define a complex environmental change in the microclimate. It has been proposed that a set of environmental or ecological multispecies indicators is used rather than a single indicator to improve bioindication systems' accuracy (Carignan and Villard 2002; Niemi and McDonald 2004; Butler et al. 2012). To identify the indicator species, the characteristics to be expected are defined by the classification of the sites compared with the modes of distribution of the species identified at the sites. Indicator Species Analysis (ISA) considers the knowledge that species have different niche ranges for this purpose. .

The design of vegetation classification patterns according to the current methods is another important application of this work. Categories of vegetation are also well established using the overall vascular plant composition (De Cáceres and Wiser 2012). When a full composition is available, there are various alternatives for allocating vegetation plot records to predefined vegetation categories that are preferable to the approach offered here (van Tongeren et al. 2008; De Cáceres et al. 2010). The technique provides the collection of site groups that best conform to the witnessed distribution pattern of the plant species when an indicator value index is used. It enables one to separate those species that distinguish individual types from those that demonstrate the connections between them by using group types. This distinction is useful for regulating the number of types that increase the number of indicator plant species. Considering the configurations of groups of locations provides additional elasticity to qualitatively model the habitat preferences of important species (Acker 1990). If a group of species with a high predictive value is discovered, the position can be confidently assigned to the specified type at a given location. If none of the valid indicators are identified, it might be appropriate to identify a complete vegetation map. Users of the technique should note that they are by definition non-independent of plants when location groups have been well-defined using species composition data. In these conditions, the indicator value figures would be greater than the value expected under the null hypothesis of independence, resulting in a high rejection rate in inferential evaluations (De Cáceres et al. 2010). The limits of the altitudinal ranges found on the foothills, ranging from the direct effects of precipitation and temperature to the indirect characteristics of the mountains and biotic interactions of the species, are concluded by the diversity of environmental gradients. Forest mapping/zoning identifies different populations along an elevation gradient (Haq et al. 2015a; Waqas Khan et al. 2015).

The Western Himalayan Murree forest division (MFD) in Pakistan is an extremely diverse area, predominantly in terms of the wide range of natural diverse forests. These forests are under substantial conversion pressure as land cover land use intensifies with growing economic development and human population. Conservation approaches based on the geographic patterns of species diversity and richness containing the identification of significant floristic areas and priority regions for conservation could advance policy and forest management efficiency. These approaches should also include present threats of loss due to forest conversion to report the more crucial challenges for sustainable development. Our findings provide strong priorities for 454 plant species using multivariate analysis to develop a feasible and sustainable biodiversity conservation strategy for MFD through indicator species methods. The quantitative explanation of plant abundance in our results is similar to that described by (Dickoré and Nüsser 2000) for Chitral Valley. It can be used to compare and evaluate anthropogenic pressure while planning conservation strategies, as suggested by several people. However, our research can be equated to other areas of the Himalayas in terms of prospective for vegetation analysis and mapping.

Chapter 3 DIVERSITY AND ABUNDANCE OF CLIMBERS IN RELATION TO THEIR HOST AND ELEVATION GRADIENTS

3.1 Introduction

Plants that exploit a distinct structure to climb on to provide support are termed climbers. Climbers are fixed in the soil but for their weak stem, support is needed. They compete strongly with large trees and shrubs for light and space, which is a characteristics feature of climbers (Richards 1952). Climber plants play significant ecological part in nutrients recycling, forests dynamics and form an essential component within these ecosystems. Few studies have been done on climbers. (KOKOU et al. 2002) divided the climbers in to three categories namely climbing vines, climbing shrubs and woody climbing plants (lianas). Climbing vines are generally of a herbaceous type in sprawling growth habit or runners. Vines due to their weak nature are not able to reach the mature forest canopy. Climbing shrubs climb without clingy tendrils, or roots. Cracks in the bark of fibrous barked trees supports the stem of these shrubs. Lianas are mostly woody and may reach to the crown of forest trees (Jongkind and Hawthorne 2005). The structure, dynamics and functions of vegetation and ecosystem is contributed by Lianas (Burns and Dawson 2005), the occurrence and abundance of which is more particularly at the forest edge and in clearings of moist tropical forests (Hegarty 1991).

Furthermore, vascular plant families comprise about one half of climbing species. Vitaceae and Hippocrateaceae species are almost climbers; their axes have condensed groups of subsidiary tissue which are extremely light demanding (Hegarty 1991; Schnitzer 2005). There is another group of climbers called Lianas beside the soft tissues climbers which have a considerable amount of supporting tissues allowing them to climb over the height of large trees. Woody climbers (Lianas) are intact structural parasites (Stevens 1987); mostly depend on other plants for their support. Differences in climbing approaches, dispersal and phenological approaches help in distribution gaps and allow effective resource dividing between the climber species (Oldeman 2012). Four dispersion types (a) high regrowth rates, (b) root lateral growth, (c) propagation through seed regeneration and (d) production of branching play a role in the colonization of climbers in forest clearing and boundaries. The diversity of tropical forest (25 % of woody plants total diversity) (Schnitzer and Carson 2001) is contributed by Lianas and yet are frequently unnoticed in many forest records and in models in forest ecological practices (Phillips et al. 2005) throughout the last decades, as compared to trees, shrubs and herb. The overall low care to lianas is most possibly owing to problems in restricting individuals whole lower minimum size limit in details and general absence of taxonomic studies resulted in the elimination of them in many records. The climbers will be the first to be reduced in silviculturally managed forests; therefore they are the most threatened group of plants.

Climbers show great variety in their mechanism of climbing (Bongers et al. 2005; Jongkind and Hawthorne 2005). These include root climbers, branch twiner, stem twiner, scramblers, tendril climber and hook/thorn climbers. The most appropriate to gaps and forest edges are the Tendril climbers, where the common support is through smaller diameter structures called tendrils (Putz and Holbrook 1991). Their small width supports a random distribution of climbers in undeveloped forests areas. On the other hand stem and branch twiners are more consistently spread in late successional forests (Dewalt et al. 2000).

Habits like climbing or trailing show a magnificent case of economy of nature. They permit a plant to reach full disclosure to access sunlight, nutrients and water with least expenditure in vegetation support. They add sustainability to cover shutting the canopy after the fall of a tree and helping to equalize the micro-climate beneath. Forest plant diversity is specifically enhanced by Lianas and they give valuable niche and contacts amongst tree covers which allow arboreal animal to cross the trees tops. At the time of shortage of fruits and flowers many climber species also provide an important share of the diet for numerous animals (Sarvalingam et al. 2015).

From the time of Darwin and his colleagues up to the present climbing species have intrigued plant scientists. The importance of lianas and vines for the world's ecosystems is under deep discussion, mainly for tropical and sub-tropical ecosystems. With continuing studies representing that lianas and vines are increasing in ecological significance, it is becoming progressively necessary to renew, increase and coordinate investigation on all aspects of climbing plants. Climbers studies are lacking with regarding to Pakistan but limited work is available from Indian forests, like the forests of (Muthuramkumar and Parthasarathy 2000; Srinivas and Parthasarathy 2000); Anamalais, Western Ghats (Eastern Ghats, Kalrayan hills) (Kadavul and Parthasarathy 1999).

It has been reported that the structure of host tree bark is important in the determination of climber association (Muthuramkumar and Parthasarathy 2000; Putz 1984; Putz 1980). Some of the host trees lack sites for attachment of climber species therefore smooth barked trees will evade climber plant infestation (Putz 1980; Putz 1984). The outcomes of these studies are different since most of the hosts plants with climber invasion in forests have smooth barks. But, the density of these tree species is high in the forests.

Climber distribution is influenced by type and forest locality (Grubb 1987a; Balfour and Bond 1993). To one side from contributing to biological diversity in forest (Gentry 1991; DeWalt et al. 2006), climbers play a major role in forest renewal, ecosystem and biodiversity level practices for example carbon sequestration, entire-forest transpiration, annual leaf biomass and soil erosion control contribution (Klinge and Rodrigues 1973; Putz 1983). In the forest ecology and biology climbers play diverse roles, and were overexploited (Emmons and Gentry 1983). A climber reduces the surrounding tree damage and further reduces 50% of the post-harvest canopy gaps (Appanah and Putz 1984).

The distribution and abundance of climbers (lianas) are also apparently determined by biotic elements such as the architecture of hosts in comparison to environmental variables such as climate or soil (Balfour and Bond 1993). For instance, a previous study concluded that tall palms had less climber species rising into their crowns than shorter palms (Rich et al. 1987). (Gardette 1996) reported that the major factors that contributed to a high species-richness or great abundance of climbers were the presence of many supports of different height classes and the proximity of climber parents. Observation in the study area found that the dipterocarp species with clear long trunks and branches at about 25 meters from the ground were free from lianas. However, the presence of non-dipterocarp species in the surrounding areas as supporting forms may enhance the success of lianas to reach the canopy of dipterocarp species. If this commercial dipterocarp trees are harvested for timber production, it is anticipated that the forest floor will receive direct sunlight which will further enhance the growth of lianas.

Majority of the previous studies focused heavily on trees and shrubs and little consideration has been given to climber plants in spite of the various roles they play in ecosystems (Bongers et al. 2005). However, similar studies with regard to the forests of Murree forests are lacking and this is the first study of its nature in Pakistan. The specific objectives of the current study investigates the species composition, taxonomic diversity, climbing mechanism and abundance of climbers documentation with associated hosts (trees and shrubs) along different altitudes in five localities of Murree hills forests viz., Baroha, Ghoragali, Numbal, Patriata and Salgaran during the year 2016-2017 in various forests.

3.2 Materials and methods

3.2.1. Sampling of Climbers and host species

Five plots of 1 hectare (each 100 ×100 m^2) were selected from the established plots at five localities viz., Baroha, Salgaran, Numbal, Ghoragali and Patriata between 735 m and 1754 metres above sea level (masl) in the Murree Forests, Western Himalayas Pakistan during the year of 2016-2017. Transect and quadrat procedures were applied on Murree forest slope at all stations. Quadrats size for trees, climbers and shrubs was 10m × 10m (Salzer and Willoughby 2004). Fifty quadrats were recognized in these total 5 localities by using Global Positioning system (Khan et al. 2013a) as presented in sampling design (Fig. 3.1). Each quadrat was orderly surveyed by counting, recognizing and calculating the diameter at breast height (DBH≥1 cm) of tree species and shrubs. All climber plants (woody lianas and herbaceous vines) were identified (Muoghalu and Okeesan 2005). Climbing mechanisms of climbers were also studied and noted for each species (Putz 1984).

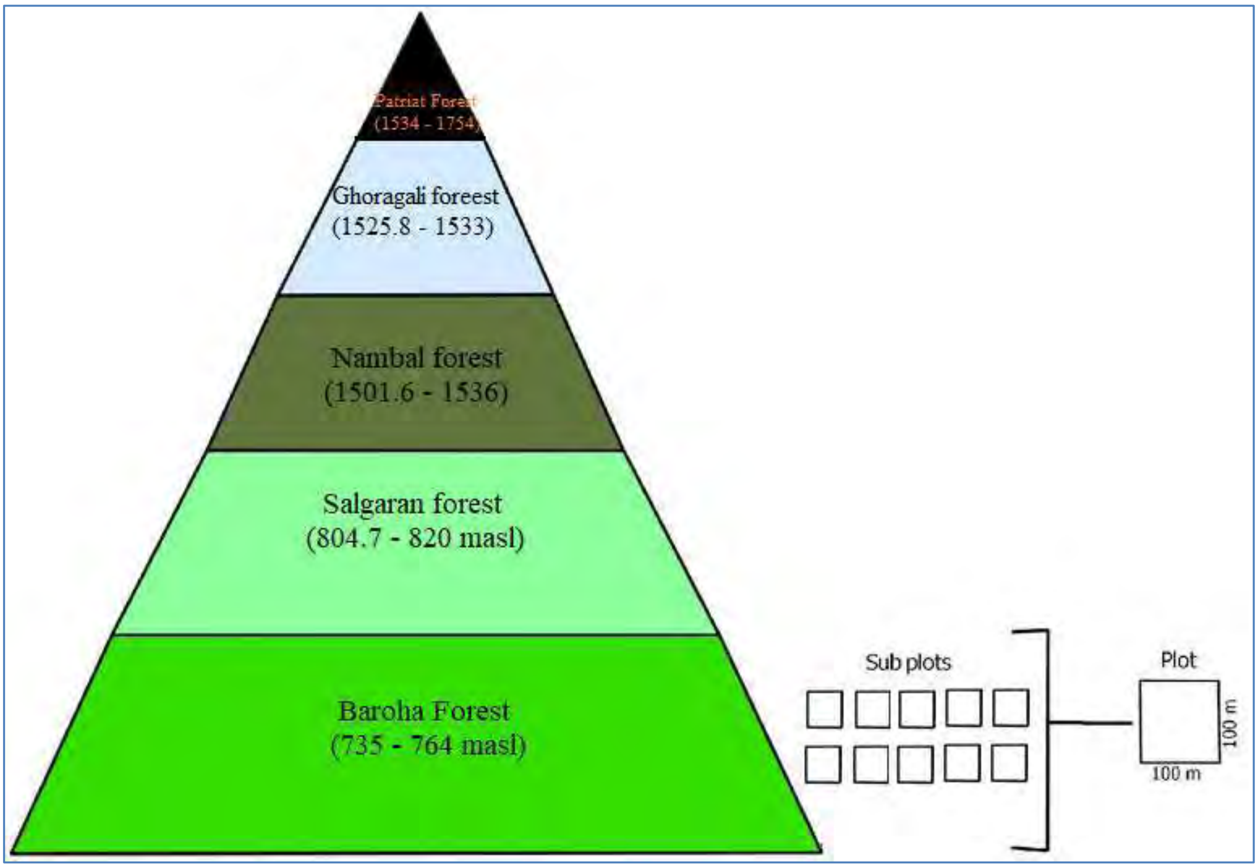

Figure 3.1: Sampling design showing different elevations of 5 localities

The analysed environmental variables were anthropogenic pressure, elevation, grazing pressure, number of hosts, soil pH, electrical conductivity and habit. Study areas were selected on the basis of elevation gradient (varying degree of altitude), disturbance like forest clearing, human interference based on observation. The selection of sites in increasing order of disturbance was based on the assessment of the intensity of anthropogenic (Low=1, High=2) and grazing (Low=1, moderate=2 and High =3) activities in the forest area (Kumar and Ram 2005). The plants were collected in every quadrat, labeled with tabs, and pressed in the fields. Plants were poisoned by using 3 percent (w/v) solution of Ethyl Alcohol and Mercuric Chloride and then mounted on herbarium sheets of standard size (41cm × 29 cm). All plant specimens were identified and confirmed with the help of available literature of the flora of Pakistan (Khan et al. 2013a).

3.2.2. Soil studies

Fifty soil samples for analyses were gathered up to 45 cm depth from all quadrats in five localities by soil sampling tube. The soil samples were filtered to take away large particles. Electrical Conductivity (E.C) and pH of the soil was measured in Plant Ecology & Conservation Lab., Department of Plant Science, Quaid-i-Azam University, Islamabad- Pakistan. The soil pH was calculated by pH meter and hydrometer respectively (Koehler et al. 1984; Khan et al. 2012).

3.2.3. Analyses of data

The data was investigated to indicate the relationship between climber plant species and studied environmental variables. Species were classified by climbing mode/ mechanism based on annotations in the field and consistent references (Putz 1984). For the data analysis of 5 stations and 50 quadrates were put in EXCEL sheet. Cluster Analysis (CA) was performed through PCORD software. The quadrats data were arranged vertically and climber species were organized horizontally as per software requisite (Lepš and Šmilauer 2003). The environmental factors and climber plant species data was examined in CANOCO (4.5 software version) to indicate the climber species distribution and composition difference and influence of various environmental variables on climber plants among quadrats in 5 different localities along elevation.

3.3 Results

3.3.1. Climbers diversity

A total of 3400 climber individuals belonging to 23 species, 19 generas and 13 families and 4788 host individuals including trees and associated shrubs belonging to 20 species, 18 genera and 16 families were documented from Murree forests, Western Himalaya Pakistan (Table 4.1). The number and density of species within five localities varied (Table 3.2). The dominant family was Apocynaceae (22%) followed by Ranunculaceae (13%), Rosaceae (13%), Menispermaceae (9%), Oleaceae (9%), Convolvulaceae (5%), Araliaceae (5%), Dioscoreaceae, Leguminosae, Rubiaceae, Smilacaceae and Vitaceae with 4 % (Figure 4.2).

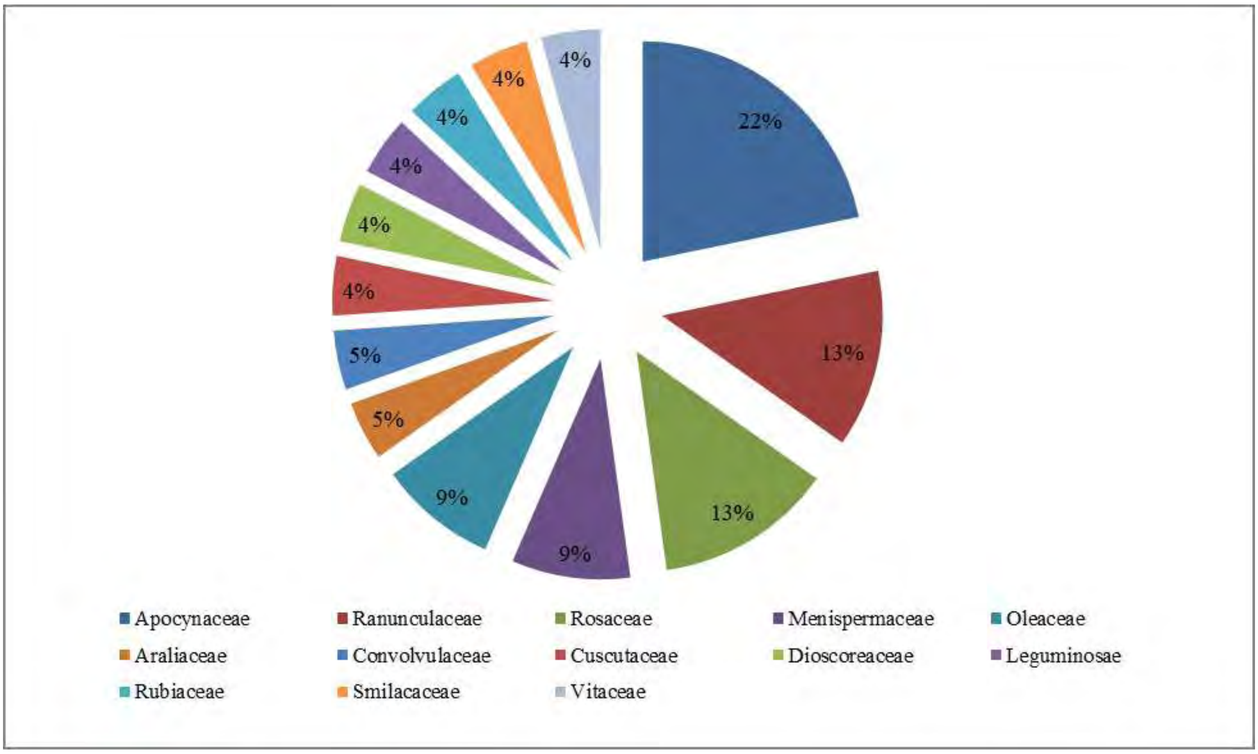

Figure 3.2: Family wise occurrence of climber plants in Murree collected during 2016-2017.

The climber plants were classified into abundant (0.21 – 0.06 RA), moderately occurred (0.04 – 0.02 RA) and rare (0.01 RA) based on occurrence and relative species abundance (RA). The most abundant species was *Hedera nepalensis* accounting for 21% of total climber individuals with 0.21 relative abundance. The second most abundant climber was *Clematis grata* (16%), followed by *Jasminum humile* (12.65%), *Rosa macrophylla* (7.94%) and *Cuscuta reflexa* (6.47%). The rare climber species are *Rosa multiflora*, *Rubia cordifolia*, *Tylophora hirsuta* and *Tinospora malabarica* in terms of occurrence (Figure 3.3).

Figure 3.3: Abundant and rare climber species in study area

There were 20 associated hosts (shrubs and trees) observed in the study areas. These hosts species are distributed over 18 generas and 16 families (Table 3.1).

Table 3.1: Associated hosts (shrubs and trees) of Climbers

S. No.	Plant species	Family	Habit
1.	*Aesculus indica* (Wall.) Hook.	Hippocastinaceae	Tree
2.	*Arundo donax* L.	Poaceae	Shrub
3.	*Berberis lycium* Royle	Oleaceae	Shrub
4.	*Buxus wallichiana* Baill.	Buxaceae	Shrub
5.	*Carissa opaca* Stapf ex Haines	Apocynaceae	Shrub
6.	*Cedrus Deodara* (Roxb.) G.Don	Pinaceae	Tree
7.	*Dodonaea viscosa* (L.) Jacq.	Sapindaceae	Shrub
8.	*Justicia adhatoda* L.	Acanthaceae	Shrub

9.	*Lantana camara*	L.	Verbenaceae	Shrub
10.	*Mallotus philippensis*	(Lam.)	Euphorbiaceae	Shrub/small tree
11.	*Maytenus royleanus*	(Wall. ex Lawson)	Celastraceae	Shrub
12.	*Myrsine africana*	L.	Myrsinaceae	Shrub
13.	*Olea ferruginea*	Wall. ex Aitch.	Oleaceae	Shrub
14.	*Pinus roxburghii*	Sarg.	Pinaceae	Tree
15.	*Pinus wallachiana*	A.B.Jacks.	Pinaceae	Tree
16.	*Punica granatum*	L.	Lythraceae	Shrub/ small tree
17.	*Quercus dilatata*	Royle.	Fagaceae	Tree
18.	*Quercus incana*	W. Bartram	Fagaceae	Tree
19.	*Salix spp.,*		Salicaceae	Tree
20.	*Viburnum grandiflorum*	Wall. ex DC.	Caprifoliaceae	Shrub

3.3.2. Climber-host relationships

Associated hosts (Trees and shrubs) density ranged from 711 to 1188 plants / hectare whereas climber density alternated from 460 to 950 plants / ha. The mean DBH with standard error of climbers alternated from 7.3 $\pm$ 0.5 to 12.3 $\pm$ 0.4 cm in the studied plots. The highest number (950 individuals with 28%) of climber was supported by associated hosts in Patriata at highest elevation while lowest numbers (460 individuals with 13.5%) of climbers were supported by hosts in Baroha at lowest elevation. Density association analysis between climbers and hosts indicated that they were contrary to one another i.e. highest density (1188) of associated hosts only supported least density (460) of climber individuals at Baroha (Table 3.2).

Table 3.2: Climber species richness and No. of individuals in five localities along elevation gradient

Hectares	Baroha (735-764)	Salgaran (804.7-820)	Numbal (1501.6-1536)	Ghora Gali (1525.8-1533)	Patriata (1534-1754)m
Species Number					
Tree/ shrubs	15	13	16	17	20
Climbers	10	12	11	13	18
Family Number					
Tree/ shrub	15	14	16	15	16
Climbers	10	12	11	13	13
Density					
Trees & shrub	1188	1065	972	852	711
Climbers	460	560	610	820	950
Basal area					
Hosts	25.5	32.4	35.5	37.2	37.7
Climbers	7.3 $\pm$ 0.5	8.5 $\pm$ 0.7	9.3 $\pm$ 0.4	10.4$\pm$ 0.5	12.3 $\pm$ 0.4
Climbing mode					
Twiner	40	70	160	250	290
Woody	330	350	300	430	460
Hook	60	90	150	140	130
Tendril	30	50	0	0	0

3.3.3. Climbing mechanism

Climbing modes differ greatly among the five localities. The changes in the amount of climbing modes among plots correspond with the alteration in richness of climber species along altitude. The twiner and woody climbers increased along elevation (Table 2). The climber plants are separated into 4 groups based on their climbing mechanism /modes. The majority of climbing plants exhibited the twining mode 11 (48%) characterized the leading group followed by woody mode 6 (26%). Hook mode was exhibited by 5 (22%) climber plants while only 1(4%) plant used tendrils ascending the host plant (Table 3.3). There were greater proportions of twiners and woody climbers in all plots in general.

Table 3.3 Different species and their climbing modes recorded

S.No.	Plant species	Family	Climbing mode	Rel. Abund
1.	*Hedera nepalensis* K.Koch	Araliaceae	Woody climber	0.21
2.	*Ipomoea purpurea* (L.) Roth	Convolvulaceae	Twiner climber	0.01
3.	*Jasminum humile* L.	Oleaceae	Woody climber	0.13
4.	*Rosa macrophylla*	Rosaceae	Hook climber	0.08
5.	*Cuscuta reflexa* Roxb.	Cuscutaceae	Twiner climber	0.06
6.	*Caesalpinia decapetala*	Leguminosae	Hook climber	0.04
7.	*Cissampelos pareira* L.	Menispermaceae	Twiner climber	0.04
8.	*Smilax aspera* L.	Smilacaceae	Hook climber	0.03
9.	*Cissus carnosa* Lam.	Vitaceae	Tendril climber	0.02
10.	*Clematis connata* DC.	Ranunculaceae	Woody climber	0.02
11.	*Rosa brunonii* Lindl.	Rosaceae	Hook climber	0.02
12.	*Dioscorea deltoidea* Wall. ex	Dioscoriaceae	Twiner climber	0.03
13.	*Pergularia daemia* (Forssk.)	Apocynaceae	Twiner climber	0.02
14.	*Jasminum officinale* L.	Oleaceae	Woody climber	0.02
15.	*Clematis gouriana* Roxb.	Ranuculaceae	Twiner climber	0.01
16.	*Cryptolepis buchananii* Roem.	Apocynaceae	Twiner climber	0.01
17.	*Ceropegia macrantha* Wight	Apocynaceae	Twiner climber	0.01
18.	*Clematis grata* Wall.	Ranuculaceae	Woody climber	0.16
19.	*Cynanchum auriculatum* Royle	Apocynaceae	Twinerclimber	0.01

20.	*Rosa multiflora* Thunb.	Rosaceae	Hook climber	0.01
21.	*Rubia cordifolia* L.	Rubiaceae	Twiner climber	0.01
22.	*Tinospora malabarica* (Lam.)	Menispermacea	Woody climber	0.01
23.	*Tylophora hirsute* Wight	Apocynaceae	Twinerclimber	0.01

3.3.4. Phytosociological classification and Cluster analyses of Climbers

The Cluster and Two-way Cluster analysis (TWCA) of PCORD separated the plant species into two main climber plant associations which could be obviously witnessed in the cluster dendrograms.

3.3.4.1. Climber Plants Association

Cluster analyses result were carried out using PCORD version 5. It broadly divided the 23 climber species and 50 quadrats into two associations based on compositional differences of the studied plots. Association 1st was establish at an elevation range of 735-820 masl. in the sub-tropical region while association 2nd was established the elevation ranges of 1501.6 to 1754 masl. in the sub-temperate region. The cluster dendrogram show these associations of the climbers in study area (Fig. 3.4).

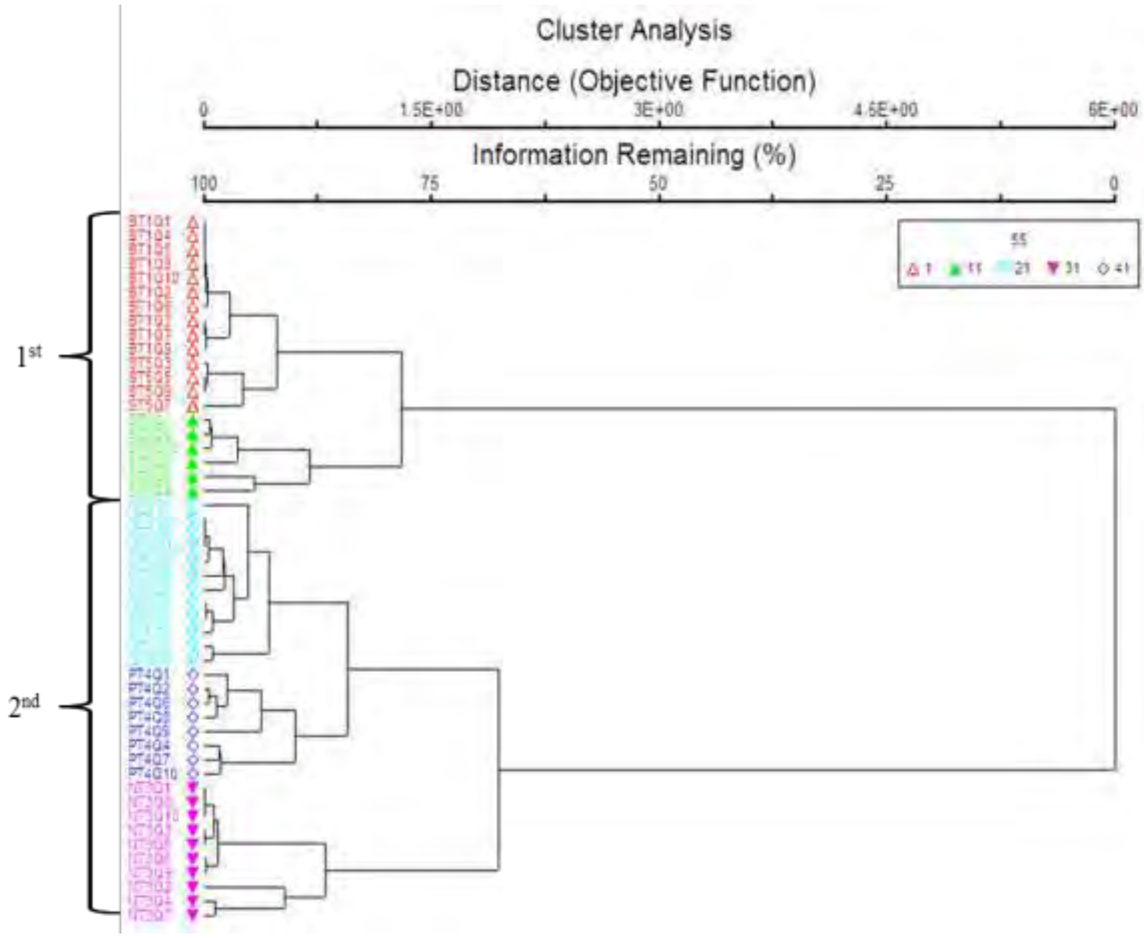

Figure 3.4: Cluster analysis classifying climber plant species into two associations

3.3.4.2. Distribution of climbers

Two-way Cluster Analysis elucidated the absence and presence of the climber species in the study area along with the establishment of the distinct associations. For this purpose 1, 0 data of plant species was used to construct a dendrogram. The white dots show the presence while black show the absence of climber species in the dendrogram. Fifty sampling quadrats of five localities were categorized into two groups; Association 1st was found by Baroha and Salgaran (735-820 m.a.s.l.) in the sub-tropical region while association 2nd was established by Nambal, Ghoragali and Patriata (1501.6 to 1754 m.a.s.l.) in the sub-temperate region (Fig. 3.5).

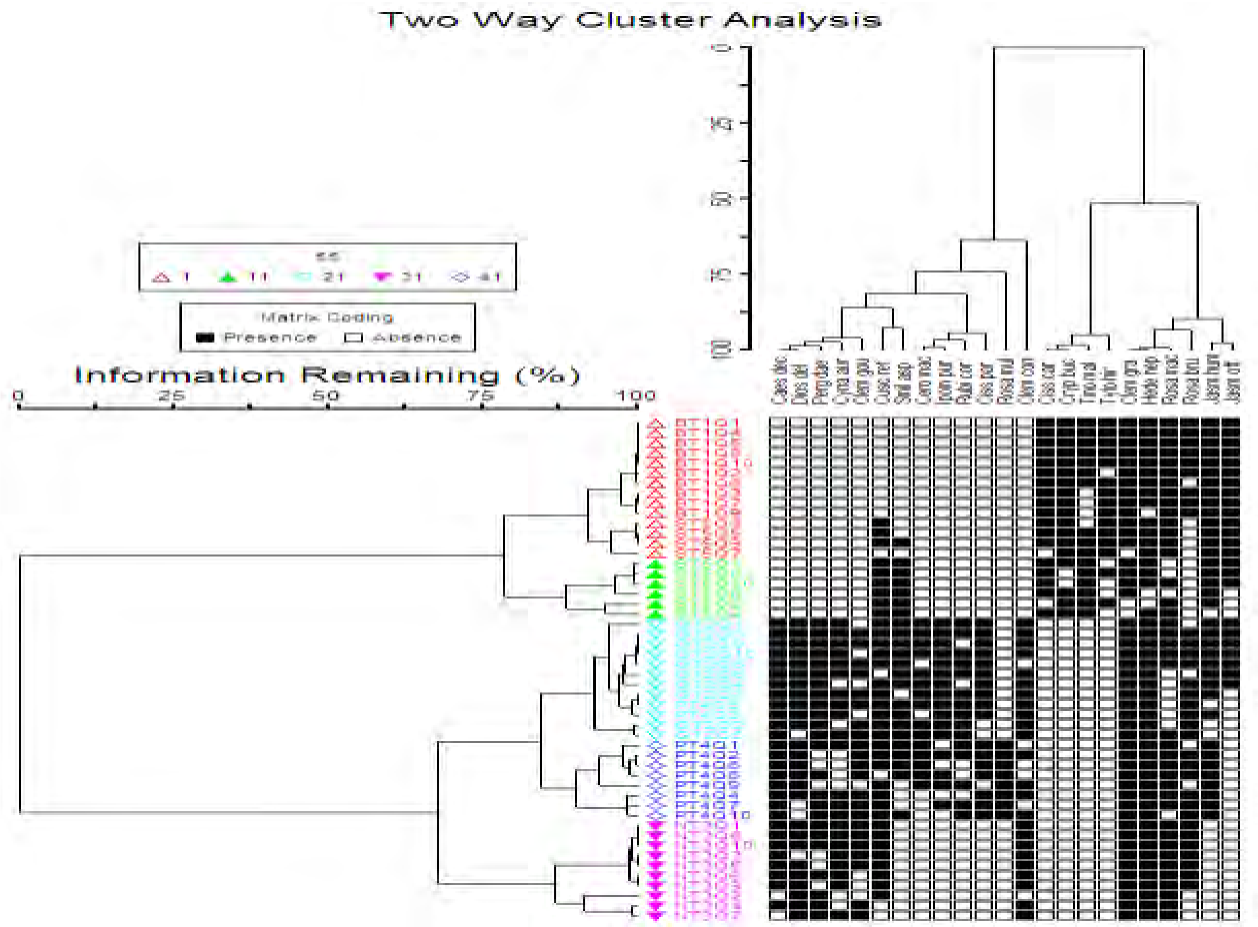

Figure 3.5: Two Way Cluster Analysis showing distribution of climber plants in the sampled sites

3.3.5. DCA Analysis of climbers

DCA diagram (Fig 3.6) shows the distribution of climber species in 50 samples. In DCA ordination for 23 climber species, the maximum gradient length recorded for axis 1 was 2.333 with eigenvalue 0.492. The gradient length for axis 2 was 1.453 with eigen-value 0.078. The total inertia in climber plants data was 1.169 (Table 3.4).

Table 3.4 Summary of the all four axes of DCA for 23 climber species

Axes	1	2	3	4	Total Inertia
Eigen-values	0.492	0.078	0.048	0.032	1.169
Length of gradients	2.333	1.453	1.325	1.331	
Cumulative % variance of species data	42.0	48.7	52.8	55.5	

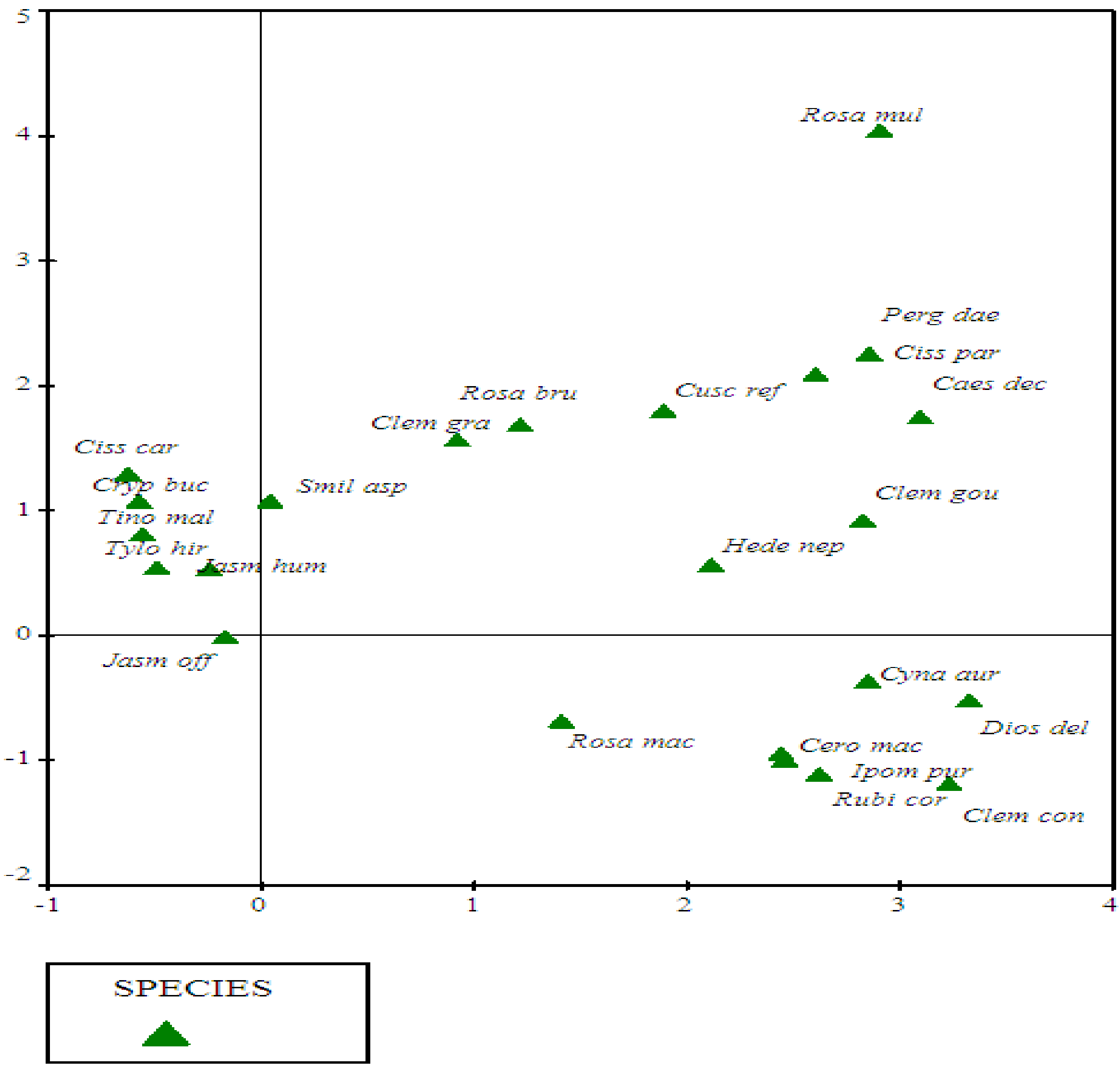

Figure 3.6: DCA diagram displaying distribution of climber species and habitat type among 5 localities.

In study area two vegetation regions/ zones i.e. Sub-tropical and temperate forests regions were reported. DCA diagram (fig 3.7) shows the distribution of samples and habitat type for 50 samples. DCA ordination analysis showed maximum samples occurred in temperate region followed by sub-tropical region.

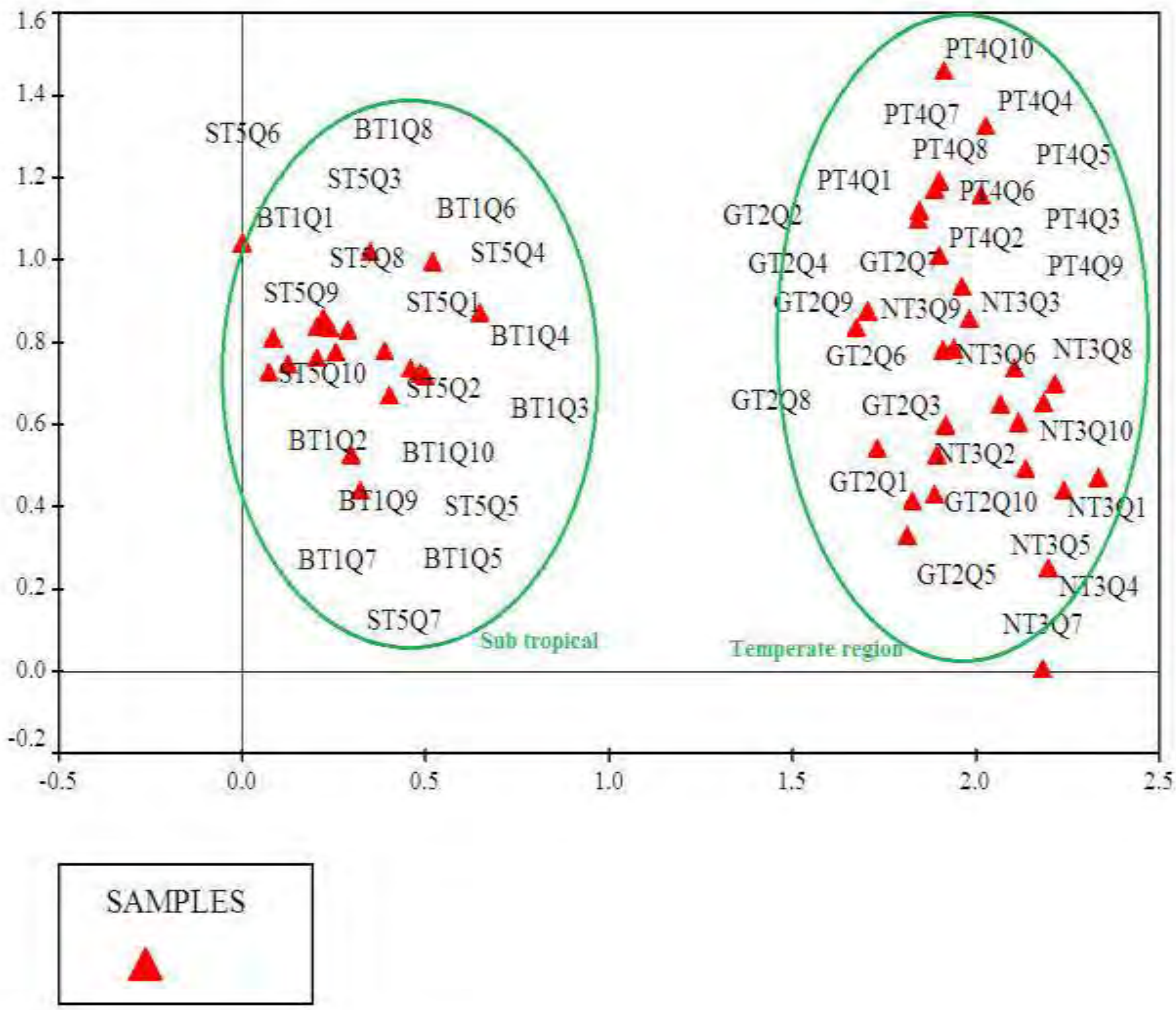

Figure 3.7: DCA diagram showing distribution of samples and habitat type for 50 samples.

3.3.6. Climbers in relation to associated environmental variables

The environmental variables and Climber species data were placed altogether in CANOCO (version 4.5). Seven environmental elements including biotic features (Anthropogenic, grazing pressure and No. of hosts) and abiotic factors (topographic and edaphic) display significant consequences with ($p \leq 0.002$) p value on climber species composition, distribution pattern, and abundance (Table 3.5).

Table 3.5: Summary table of CCA results of 23 climber species in relations to the environmental variables

Axes	**1**	**2**	**3**	**4**	**Total Inertia**
Eigen values	0.466	0.042	0.035	0.019	1.169
Species- environment correlations	0.976	0.636	0.627	0.555	
Cumulative % variance of species data	39.8	43.4	46.4	48.0	
Cumulative % variance of Spp-environment relation	80.4	87.6	93.6	96.8	

**** Summary of Monte Carlo test ****

Test of significance of 1st canonical axis		**Test of significance of entire canonical axis**	
Eigen value	0.466	Trace	0.579
F- ratio	7.792	F-ratio	5.887
P- value	0.002	P-value	0.002

3.3.6.1. CCA bi-plot Analysis of climbers

The analyzed environmental variables were anthropogenic pressure, elevation, grazing pressure, number of hosts, soil pH, electrical conductivity, and habit. In ordination of numerous climber plant species every triangle in the figure characterized climber plants and the distance between plant species indicate the differences and similarity index. Entirely the climber plants were associated with soil and ecological gradient data through CANOCO. The CCA illustrates the distribution of climber species with environmental variables accordingly. The first quadrants of CCA (bi-plot diagram) revealed most of the climber plants were under the influence of higher grazing pressure and of number of associated hosts (trees and shrubs). Whereas going through 2nd quadrant plants were clustered mostly under the effect of electrical conductivity. While going through 3rd quadrant maximum of the climbers were under the impact of elevation gradient. The 4th quadrant assembled plants under higher anthropogenic pressure, habit and pH (Fig. 3.8).

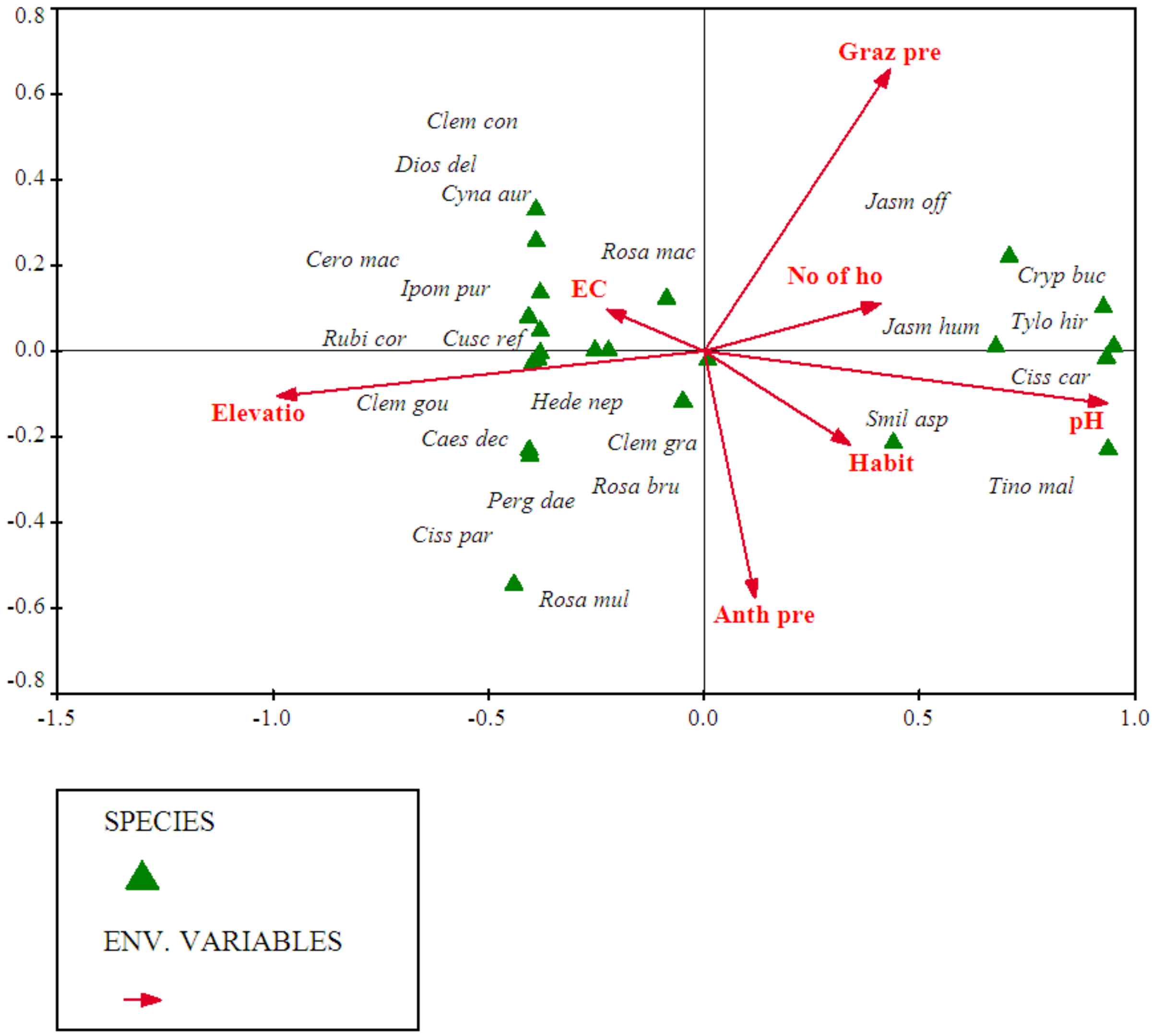

Figure 3.8: CCA figure presentation the climber plants dispersal under the influence of 7 environmental factors.

The variance explained by the first CCA axis was 39.8 whereas the same for the second axis was 43.4. The third and fourth axes of CCA elucidate 46.4 - 48 of the accumulative variance in climbers data demonstrating that, altitude and anthropogenic pressure had the maximum correlation with 3 and 4th which may strongly affect the climber species distribution pattern. Conferring to CCA results, several species were common to all elevations; few unique species emerged in special elevation. Climber richness increased with elevation. The CCA ordination bi-plot established on sample and environmental factors represents the samples of first and second axis were correlated with both grazing and EC axis and negatively correlated with respect to each other (Fig. 3.9).

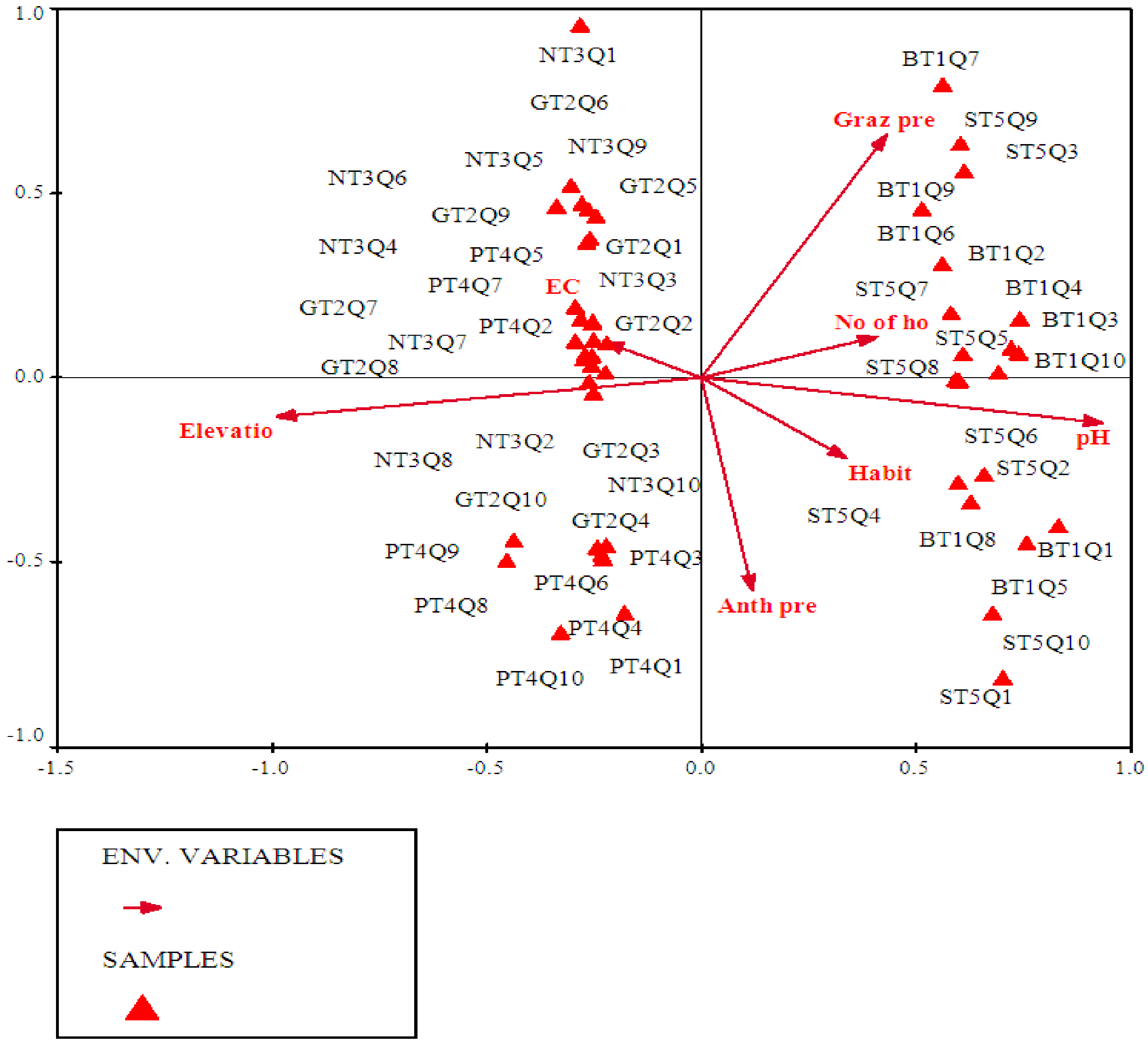

Figure 3.9: CCA bi-plot figure display the distribution of stations in relation to environmental variables

3.4 Discussion

In the present study, 23 climber species along 20 associated hosts (shrubs and trees) were recorded in five 1 ha plots at Murree's five localities, western Himalaya Pakistan. Similar and some different data of climber species diversity, abundance and richness were reported from other forests in the world like; (Villagra et al. 2013) recorded 72 climber species abundance between Nascentes de Paranapiacaba Municipal Natural Park (NPMNP) and Alto da Serra de Paranapiacaba Biological Reserve (ASPRB) in the Atlantic Forest, Brazil which varied significantly because of the succession and current disturbance in the ASPRB forest. (Ghollasimood et al. 2012) reported 4901 climber individuals belonging to 45 climber species in 37 genera of 20 families, in Perak coastal hill forest, Malaysia. Forty nine climbers comprising 35 lianas and 14 vines species spread over 41 genera and 28 families in the Nigerian secondary forests were reported by (Muoghalu and Okeesan 2005). (Putz and Chai 1987) reported 53 species of climber in Lambir, Malaysia and 69 climber plants in the low lands forest of Ecuador (Gentry 1991) with a variety of 35 to 50 hemi-epiphytes and lianas per 0.1 ha for five plots and 12 to 65 liana climbers per 0.1 ha in terrafirme in Yasunni, Ecuador (Nabe-Nielsen 2001) in neotropical forest of America. The climber species richness in our study areas is conversely lower than that (89 lianas) reported in lowland rain forests of Panamanian (Dewalt et al. 2000). The lower climber species richness is due to various disturbances and unplanned infrastructure development in the study area. Care must be paid to the survival of climber plants in the Murree areas through sustainable conservation when more broad study of climber species in forest area confirm their scarcity in the area. Conservation of climber has also became significant as these group of plants not only provide valuable plants for the benefit of humankind but moreover play a key role in the forest regeneration as they attractkeep many pollinators throughout the year by flowering at different seasons as in many other flowering species.

Climber species density and richness increased along altitude in the study area. This is in resemblance with the study conducted in the Nigerian forests (Muoghalu and Okeesan 2005) but is in contrast to the described changes in abundance of climber species along elevation gradient in South African Knysna forest, where higher climber densities were observed with lower altitude than at higher elevations (Balfour and Bond 1993). These alterations affirmed the qualitative findings and quantitative suggestion of (White 1978; Putz 1984) who reported greater climber abundance being linked with soil nutrient gradient. This also follows to the affirmation that climber species composition is a function of geographical site (Dewalt et al. 2000; Grubb 1987a).

Climber relationship with hosts (Trees and shrubs) size seems to be a vital aspect in shaping the occurrence of climbers on associated hosts. The most important and influential relationship between the girth size of hosts of 35–37.7 DBH and those of climbers on them shows that these size of hosts are more inclined to climber species occurrence than hosts of other sizes in these forests. The highest numbers (950 individuals with 28%) of climber were supported by associated hosts in Patriata at highest elevation. There is a consistent and clear association between hosts (tree and shrub) species and their climber species in these forests. Few host trees hosted great frequency of climber species in particular *Pinus roxburghii* while numerous other hosts species hosted least climber species. This designates that this tree species are very inclined to climbers. These results are in resemblance with the outcomes of mixed Sarawak forests, Malaysia (Putz and Chai 1987); and also follows the findings of Campbell and Newbery (1993) in lowland of Sabah forest, Borneo and climber association with host tree by (Muthuramkumar and Parthasarathy 2001).

The modes through which the climbing plants climb their host plants play a vital role in their diversity, distribution and abundance (Nabe-Nielsen 2001). Many authors (Gentry 1991; Dewalt et al. 2000; Nabe-Nielsen 2001; Parthasarathy et al. 2004; Jongkind and Hawthorne 2005; Kuzee and Bongers 2005) have stated similar findings in various forests. Four major modes of climbing mechanism system were documented in the current study. Of these twisting climbing modes around the hosts were the most prominent, 43% of the climber species in the research areas are modified to this climbing mode. The twinning mode of climbers in the forest is also specified by (Nabe-Nielsen 2001; Senbeta et al. 2005) with small to medium-sized diameter.

Climbing mechanism used by lianas to climb to the forest canopy was characterized by twiners, hook climbers, tendril climbers, root climbers, horns and slender stranglers. However, a few lianas use a combination of climbing modes to reach the forest canopy such as twiner-tendril climbers, twiner-hook climbers or twiner-thorn climbers as represented in the families Apocynaceae, Leguminosae, Rosaceae, Capparaceae, Menispermaceae, Oleaceae, Convolvulaceae, Araliaceae, Dioscoriaceae, Leguminosae, Rubiaceae, Smilacaceae and Vitaceae respectively. However, previous studies reported that the climbing mode in liana was confined only to one climbing technique (Putz 1984; Ghollasimood et al. 2012; Kumar et al. 2013; Addo-Fordjour et al. 2014; Ghosh 2014). Overall the top five most abundant families were Apocynaceae, Leguminosae, Rosaceae, Capparaceae and Menispermaceae. Other studies reported that Annonaceae, Arecaceae, Leguminosae, Sterculiaceae and Connaraceae were among the maximum abundant climber families (Gentry 1991; Putz and Chai 1987; Appanah et al. 1993; Kammesheidt et al. 2009; di Negeri Sembilan 2012; Ghollasimood et al. 2012).

In the current study the density and richness of climber species increased with elevation in the study area. This is in divergence to specified clear variances in richness of climber species over elevational gradient in Knysna forest, in the lower altitudes of South Africa having higher density of climber with respect to those at higher elevations (Balfour and Bond 1993). These variations declared to a large extent to the qualitative suggestion and the quantitative findings (Putz 1984; Fogden and Proctor 1985) and also the gradient of soil nutrients with climber abundance being related with greater concentration. Of these plots none is sufficiently high to be categorized as Afromontane forest which (White 1978) proposed would have less lianas than in lowland Guineo Congolian forests. Our findings may be a reflection of the particular microenvironment demands of maximum infrequent climber species. It also follows the declaration that climber species composition is a function of geographic location (Grubb 1987a; Putz and Chai 1987; Dewalt et al. 2000).

It was found that the altitudinal gradient and number of associated hosts influence the number, family and species distribution in the study area. In this regard, the study revealed that climber species were found to be more concentrated between altitudes 1501m to 1754 m a.s.l. Furthermore, it was found that climbers also favor growth adjacent to high EC, low grazing and anthropogenic pressure areas. This finding was dissimilar to other studies where lianas were found in abundance at lower altitude (Fogden and Proctor 1985; Appanah and Putz 1984; Putz and Chai 1987; Campbell and McC 1993; DeWalt et al. 2006; Wai 2009; di Negeri Sembilan 2012; Ghollasimood et al. 2012). Therefore it was generally indicated that different locality, habitat and variation in the altitudinal gradient are possible factors that limit the distribution and abundance of lianas as suggested by previous published studies (Bhattarai and Vetaas 2003; G. and Givnish 1998; Gentry 1991; Wai 2009; Schnitzer 2005).

Floristic composition and pattern distribution of climbers is related to the elevation and other macroclimatic variables. Associated host species, grazing, anthropogenic pressure and altitude were the most significant factors that inclined the abundance and distribution of climbers. The current study shows that Murree forests have a great floristic diversity and density of climbers, which add significantly to the whole biodiversity of these forests. The significance of climber plants can attract research to provide additional knowledge in different fields which can be utilized in forest management plans. This type of baseline inventory is a much needed area of research in order to understand better the role of these dependent life forms in forest function and to provide data for their conservation.

Chapter 4 SPATIAL VEGETATION COVER DYNAMICS AND CLIMATE CHANGE IMPACTS ASSESSMENT THROUGH GIS & REMOTE SENSING IN THE MURREE FORESTS; WESTERN HIMALAYA, PAKISTAN

4.1 Introduction

Forest evaluation, mapping and classification are essential for the surveillance of spatial and temporal changes in vegetation, as well as for the planning and execution of forest restoration projects (Rikimaru 2003). Conventional techniques of mapping and classifying forests via field surveys and secondary data assessment are tedious, time consuming, and costly to maintain. Therefore, GIS and Remote Sensing technology are often being used for mapping, monitoring and evaluation of forest vegetation, as these techniques are economical and fast (Kumar et al. 2010). Obtaining high- resolution satellite images is expensive. Landsat imageries are commonly used as it is a free medium spatial resolution and multispectral imaging platform for mapping global surface shift (Siyal et al. 2017; Goward et al. 2006; Wulder et al. 2008; Xie et al. 2008; Bhandari et al. 2012).

In the recent decades, GIS and remote sensing tools have been used extensively to identify as well as quantify variations in types of land use land cover changes. In particular the investigation of the image by remote sensing may provide direct records on small as well as long-term effects on past or recent land use land cover. The prospective of Landsat imageries data set is to deliver a precise classification of land uses fluctuations over time-series (Joshi and Nagare 2009; Tsarouchi and Buytaert 2013) and categorization of diverse land components at large scales (Ozesmi and Bauer 2002). The Landsat Imagery data set likely provides an accurate classification of land uses over time-series (Joshi and Nagare 2009; Tsarouchi and Buytaert 2013) and largely on the categorization of various land components (Ozesmi and Bauer 2002). In addition, the identification of changes by remote sensing indicates a change in the spectral signatures corresponding to the difference in land cover. Change detection can be accurately well-defined by using geographical information system due to its high capacity of non-spatial and spatial data sets handling abilities (Sakthivel et al. 2010). Several methods of change detection have recently been developed that use remote sensing imageries. For their advantages and disadvantages, a variety of change detection techniques have been developed and studied. Fuzzy classification, unsupervised classification or hybrid classification and supervised classifications are the most widely used classification methods (Zhang et al. 2000; Lu et al. 2004; Butt et al. 2015a).

Forest cover is extremely sensitive to both climatic factors and non-climatic transformation in mountain areas, with the effect of slow and sometimes faster recovery (Bugmann et al. 2007; Halada 2010). The change in anthropogenic pressure along with weather trends is disrupting the ecosystem services offered along the dynamics of mountain landscapes (Ezzine-de-Blas et al. 2016). Climate change is one of the greatest significant factor among the unplanned, unavoidable tourism of land use practices, and the development of infrastructure are all leading drivers of land cover changes. The fragile mountain ecosystems are affected by the fragmentation of forests and the transfer of conventional land use activities by current agriculture (Baritz et al. 2010; Spehn et al. 2012; Fürst et al. 2011; Maxwell et al. 2017).

Climate change studies in Pakistan typically examine climate factors. In MFD high-altitude regions of Pakistan, climate and forest cover appear to have responded to past climate changes. Mountain forests are vulnerable to more adverse effects of climate changes (Rajagopalan et al. 1997; Gopalakrishnan et al. 2011). Forest cover development furthermore depends on the amount of rainfall received by the region and in turn affects the environment (Tiwari 2006). This indicates that the impact of climate change on forest ecosystem is of major importance in long-term forest conservation planning (Ravindranath et al. 2006). Similar to India, the monsoon rainfall and land surface temperature greatly affect the vegetation in Pakistan (Sarkar and Kafatos 2004). Meanwhile vegetation needs rain, moisture and favorable temperature; it may be characterized by regional weather. For wide areas, the Normalized Difference Vegetation Index (NDVI) approach is best suited when research is carried out using past and present imageries along with ground data (Bose et al. 2012). Forest cover and land uses variations are closely associated with rainfall variations on a seasonal scale that in turn respond to local climates.

Various supervised classification methods have been comprehensively applied for the study of land use land cover change analysis around the world. Supervised approach relies to a greater degree than others on a combination of personal experience and background knowledge of the study area. Using this knowledge, pixel signatures are taken and stored in the signature files and the raw digital numbers of each pixel in the scene are thus converted into radiance values (Jensen 1996; Imagine). Accurate results (95 percent) were obtained by similar methods which were applied to diagnose variations found in neighboring watersheds of Rawal and Simly, Pakistan (Butt et al. 2015a; Butt et al. 2015b). The same method has been used by many other researchers and has obtained highly acceptable results. (Boori et al. 2015) investigated land use land cover disturbances caused by tourism by using a variety of procedures based on GIS and Remote Sensing, including supervised classification. (Rawat and Kumar 2015) used the same tool to track changes in land use cover in Hawalbagh, Almora District, Uttarakhand, India. (Rawat et al. 2013) followed the same methodology to monitor the variations in the time period between 1990 and 2010 observed in the study area of Ramnagar, Uttarakhand, India.

Investigation of detected variation is the degree of the thematic change information and discrete data framework. This exploration can lead to further concrete refinement of fundamental processes linked in background of land use and land cover variations (Rawat and Kumar 2015; Ahmad 2012). Change detection study of land use and land cover is vital for a better knowledge of the links between natural phenomena like climate change and human activities. This knowledge is compulsory for better-quality management of resources and enhanced decision-making (Lu et al. 2004; Seif and Mokarram 2012). GIS and multi-temporal Remote Sensing application reveal changes and evidence to investigate the historical impacts quantitatively. They assist in the assessment of the variations in land cover properties in relation to multi-temporal dataset (Seif and Mokarram 2012; Zoran and Anderson 2006; Ahmad 2012).

The study area was designated for land use land cover changes detection for the reason that this area was being exposed to deforestation, over grazing, and other anthropogenic pressures including; non sustainable use of forest resources, cutting of trees, urbanization expansion and nonexistence of any indigenous communal livelihood opportunities in the area. Beside these, a growth in agricultural practices and the construction of a number of poultry farm was rapidly increasing in the area and is one of the major concerns confronted by the Murree region (Mangrio et al. 2011; Pakistan 2005). The rapid urbanization development in the Murree area has led to environmental complications; including deforestation, soil erosion, fragmentation of forests, and destruction of aquatic habitats. Discharge of municipal and industrial waste water also causes pollution in the area (Ali et al. 2006; Hagler 2007). The lack of knowledge on the present and past land use changes in mountainous landscapes like Murree is a problem for policy makers and land-managers. Mountainous landscapes posed a significant obstacle to sustainably managing the ecosystem by efficient decision-making for sustainable development and conservation in the far away mountainous areas (Reyers et al. 2009). There is limited information on impacts and changes, especially at a regional level (Reyers et al. 2009; Balsiger and Debarbieux 2015). Routine evaluation is suggested to understand and detect changes, helps to conserve forest ecosystem integrity and lead managing policies for sustainable development and conservation that will improve mountainous forest ecosystems and the associated indigenous communities (Nelson et al. 2010; Tovar et al. 2013). A thorough understanding of land cover, climate change and its consequences are often seen as important steps at the regional and local levels (Martín-López et al.).

There are persistent changes in the pattern of rainfall and temperature as a result of climate change. Owing to anthropogenic activities, atmospheric CO_2 concentration is increasing which contributes to climate change. Consequently, the impacts of climate change on the forested area under study are important to identify key factors in mountainous forest for appropriate management and planning. The key objective of the current investigation was, therefore, to use GIS & Remote sensing techniques to detect the extent of changes that have occurred in Murree Forest Division, western Himalaya, Pakistan in the time period from 1988 to 2018. It is apparent from the current literature that very limited research studies have been focused to study the impacts of climate changes on forest cover. Hence, the specific objectives included in this study attempts to (a) assess the effects of the climate change on vegetation index and to (b) Demarcate different land use land cover classes focusing on forest area in the Murree Forest Division, western Himalaya from 1988 to 2018 using satellite imageries data.

4.2 Methodology

Vegetation spatial cover dynamics in relationship to climate change (focusing on rainfall and temperature) were used to evaluate the effect in this study. The methodology flowchart followed in the current study is presented in figure 4.1.

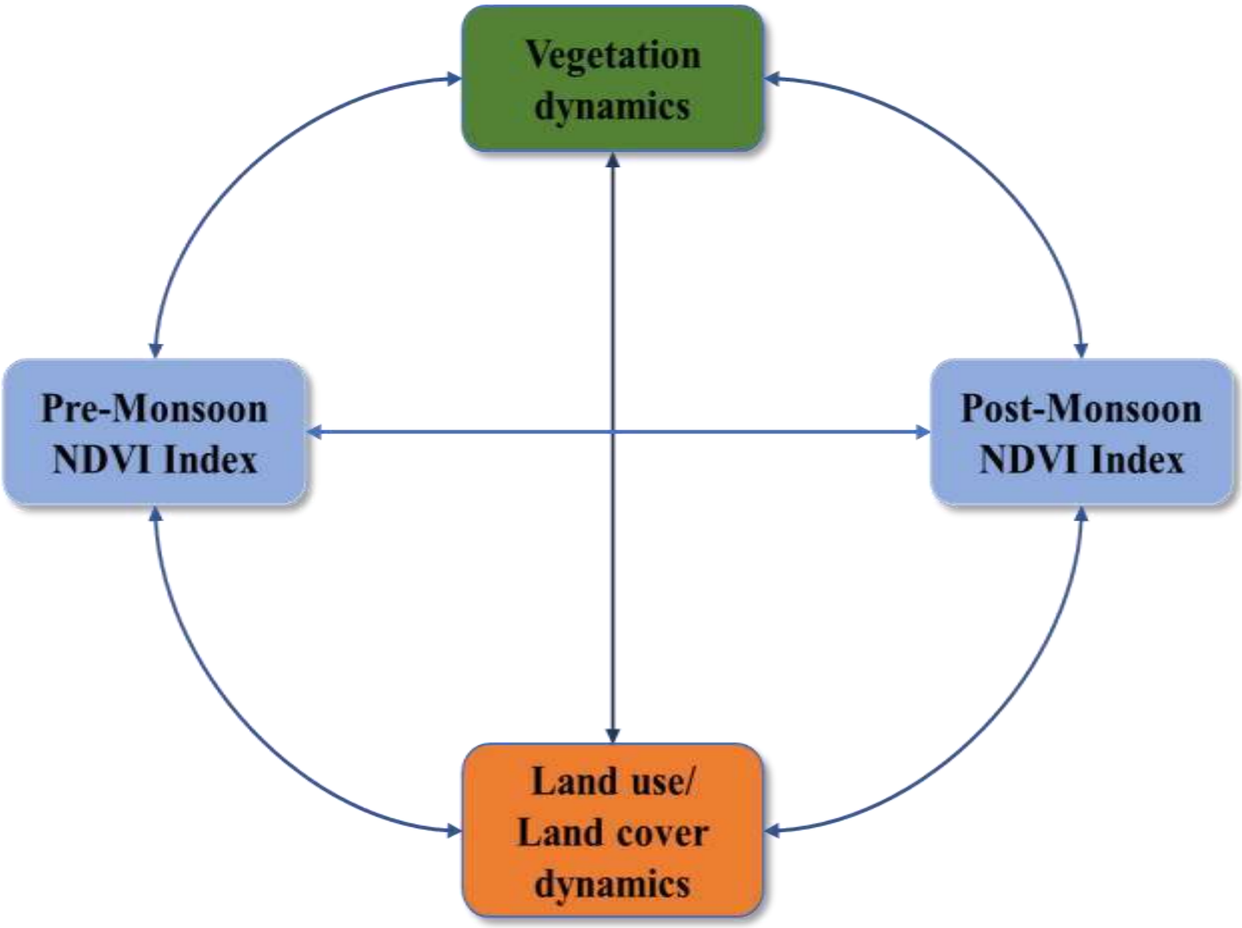

Figure 4.1: Flowchart for Vegetation dynamics

4.2.1. Statistical and Remote sensing datasets

The climate data sets of rainfall and temperature for pre and post-monsoon seasons were provided by Pakistan Meteorological department. The forest-cover dynamics and satellite images of different Landsat series i.e. Thematic Mapper (TM-5), Enhanced Thematic Mapper (ETM- 7) and Operational Land Imager Plus (OLI^+-8) type data were taken from the USGS web (http://glovis.usgs.gov) for the years 1988, 1998, 2008 and 2018. The satellite images data were downloaded, stacked and mosaicked by ERDAS Imagine 2012 version software. Area of interest (AOI) i.e. Murree was extracted from the mosaicked images. The data were classified into pre-monsoon (March to June) season and post-monsoon (October to December) season unveiling least interferences of cloud cover for climate change impacts. Images for respective (pre and post monsoon) seasons within each year were obtained as presented in figure 5.2.

The widespread NDVI (normalized difference vegetation indices) technique was used for observing temporal variations of the forest cover dynamics in the Murree forest division. Landsat data was used to distinct green vegetation indicated by spectral vegetation indices. This method depends on the differential interaction between the electromagnetic wavelengths of the near infrared and the red wavelength.

These techniques depend on distinct relations between spectrum of red and near infrared wavelength. Leaf pigment chlorophyll absorbs more red wavelengths and shows a low reflectance of red wavelengths about (0.6 to 0.7µm). High reflectance approximately (0.8 to 0.9µm) disseminates more infrared wavelengths by cell structure of the leaves. NDVI determine the relationship of red wavelength bands to that of infrared wave-length bands. NDVI is the proportion of differences between near infrared wavelength bands and red wavelengths summation of these bands. It is represented by the following formula (Richardson and Everitt 1992):

$$\mathrm{NDVI} = \left(\frac{\mathrm{NIR} - \mathrm{RED}}{\mathrm{NIR} + \mathrm{RED}}\right)$$

whereas NIR is Near Infra-Red, color spectral bands and RED is Red color spectral bands.

NDVI index is frequently used to measure vegetation index and it ranges between (-1 to 1) values. NDVI values (-1 to 0) shows no vegetation whereas values ranges from 0 - 1 shows vegetation growth. NDVI calculates total vegetation coverage areas of the study area by using two spectral bands i.e. red and near-infrared bands. It determines the greatest vegetation variation detection (Lyon et al. 1998). This method of applying spectral data advances the efficacy of predictive variation relationships for vegetation cover (Richardson and Everitt, 1992). The value of NDVI was calculated by using NIR (Band 4) and RED (Band 3) of Landsat imageries in this study. ArcGIS raster calculator was used to calculate NDVI values and images of the Murree area were prepared such as presented in figures 5.7 and 5.8.

Seasonal average values of temperature and rainfall in the respective seasons were derived for corresponding years. Regression technique was applied to define the relationship between vegetation index (NDVI) which was dependent variable and two independent factors i.e. rainfall and temperature. The linear regression technique used single variable and assessed the responses of additional variables to it. Regression coefficient values in this scheme showed correlation and change response. Regression coefficient method has been applied to examine relationship between the two variables connected with their variation.

For land use and land cover mapping of the study area, supervised Maximum Likelihood classification was used. Study area was visually surveyed to recognize and categorize signatures of different class objects and land use categories in raw images. In our research work, forest cover, water, build-up and bare lands were considered for land use/ land cover classes. Each class cover in the study area was recognized in software ArcGIS 10.2 version and then again classified there to include them in the subsequent forest cover classes of Kappa coefficient (kˆ) ranges from 0.6554 to 0.7825 between 75 and 85 % for classified images.

4.2.2. Geographical location of Murree

Geographically Murree Mountains lies within 73º 03´ to 73º 24´ E longitudes and 33° 41´ to 33° 54´ N latitudes and positioned on lateral spur of the Western Himalayan Foothills region of Pakistan (Abbasi et al. 2002) (Figure 4.2) with altitudinal ranges from 500 to 2,900masl (Khan 2000). The climate of the Murree Mountains varies from moist temperate to subtropical continental uplands. Vast differences in climatic conditions are triggered by the variances in elevation, quantity of winter snowfall and rainfall. The Murree Mountains receives the highest quantity of rainfall an average of 1640mm per year (Rabbani 1986; Farooq and Malik 1996; Archer and Fowler 2008). The majority of the precipitation is expected in the course of the monsoon during July-August. This varying climate can badly affect biodiversity, biomass production, forest ecosystems and eventually the socio-economic conditions. The growth of Murree’s population has been varying since freedom and in recent times has been noted as growing at an alarming rate of 3.1% per year (Ishfaq 1999). In the same way each year further than 1 million travelers visits Murree. The amount of tourists is increasing by 5% per annum in times of political calm. As consequences the buildup land has been growing at the cost of natural resources degradation (Amir Nawaz Khan et al. 2011).

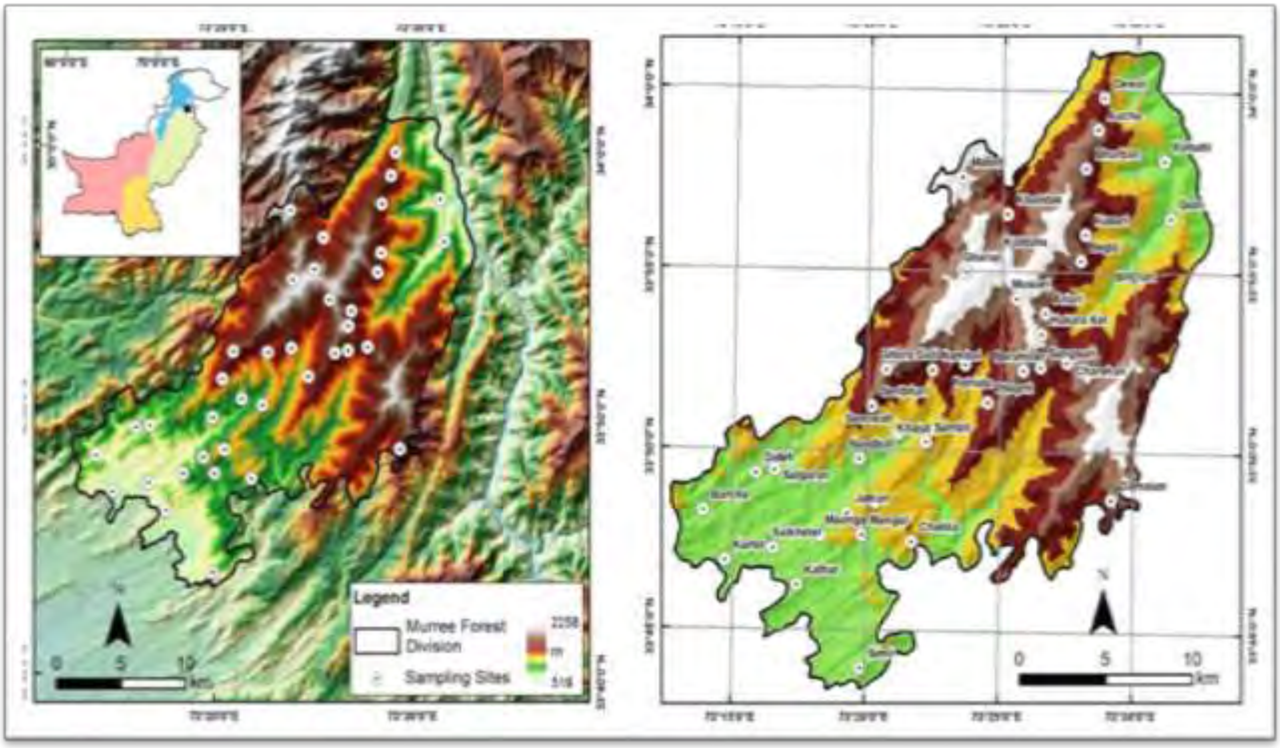

Figure 4.2: Murree Forest Division (MFD)

4.3 Results

The satellite data and climatic data results are discussed in this part. Climatic data of years (1988, 1998, 2008 and 2018) were used to analyze pre and post-monsoon seasons average values. Vegetation index was achieved by NDVI method by using satellite data. The average values of the seasons for rainfall (mm), temperature (^{o} C) and NDVI are presented (Tables 5.1 and 5.2).

4.3.1. Pre-monsoon relationship

Pre-monsoon seasonal values of NDVI, rainfall (mm) and temperature (^{o} C) are shown in Table 4.1. The relationship among two variables related with variations were examined in graphics and demonstrated in the Figures. A direct relationship was exhibited between vegetation NDVI and climatic (temperature, rainfall) variables as shown in Figures 4.3 and 4.4.

Table 4.1: Pre-monsoon season relationship between vegetation index and climate factors

Year	Mean Temperature (^{o}C)	Mean Rainfall (mm)	Vegetation NDVI
1988	22.38	89.50	0.356
1998	25.21	98.85	0.323
2008	24.27	75.88	0.369
2018	27.32	58.66	0.320

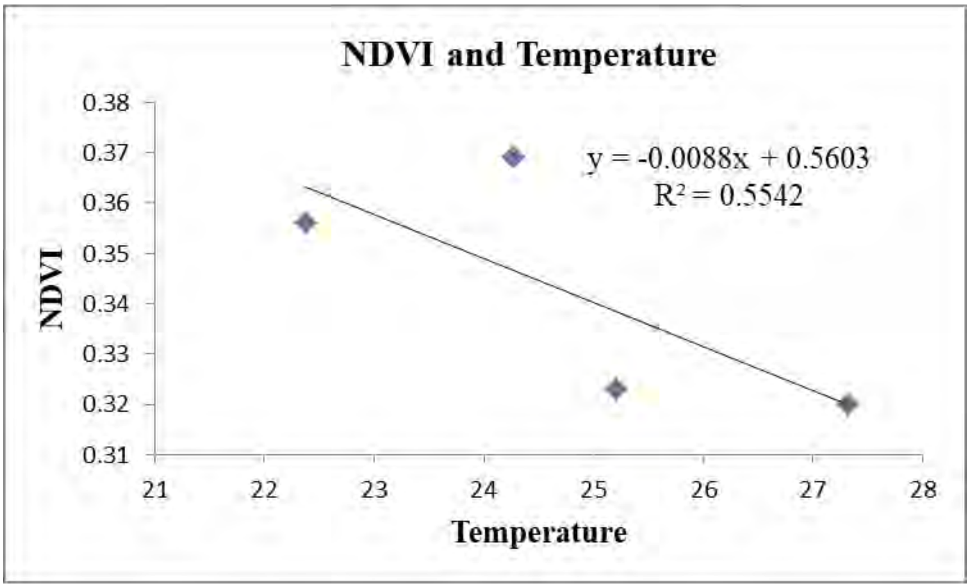

Figure 4.3: Pre-monsoon season NDVI and Temperature relationships

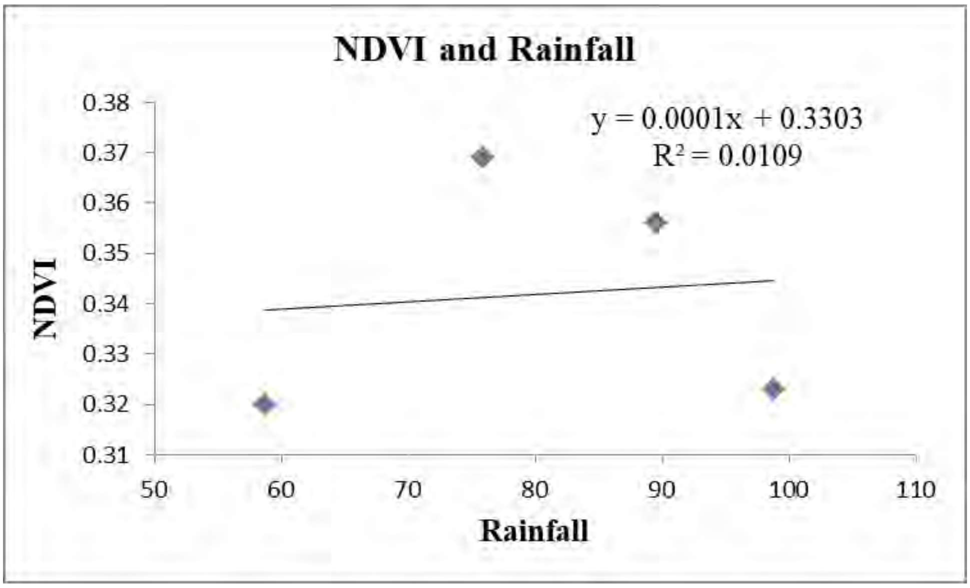

Figure 4.4: NDVI and Rainfall relationship (Pre-monsoon) season

Figures 4.3 and 4.4 depict graphical illustration of climatic factors and vegetation index acquired through NDVI. Regression investigation between vegetation index and temperature demonstrates moderate regression with coefficient rate of 0.5542 (Fig. 4.3) and demonstrated significant correlation. Correspondingly, regression examination between vegetation index and rainfall illustrates lowest regression coefficient rate of 0.0109 (Fig. 4.4).

The above investigation exhibited significant association of vegetation index with temperature in the season of pre-monsoon. Vegetation index have moderate response to temperature. Water provides nutrients to the plants during the pre-monsoon season. In the Murree forests during pre-monsoon season temperature greatly correlated moderately with vegetation index in changing climate scenario. The same response direction was shown by NDVI under the influence of rainfall. Anthropogenic activities caused changes in vegetation and forest cover in the Murree.

4.3.2. Post- monsoon season relationship

Post- monsoon season amounts of rainfall (mm), temperature (^{o} C) and NDVI values are presented in Table 4.2. The correlation between two variables related with fluctuations were analyzed in graphs and exhibited in figures 4.5 and 4.6.

Table 4.2: Post-monsoon season relationships between vegetation index and climatic factors

Year	Mean temperature (^{o}C)	Mean rainfall (mm)	Vegetation NDVI
1988	17.33	160.50	0.390
1998	19.08	179.31	0.385
2008	19.83	132.84	0.348
2018	22.92	97.88	0.305

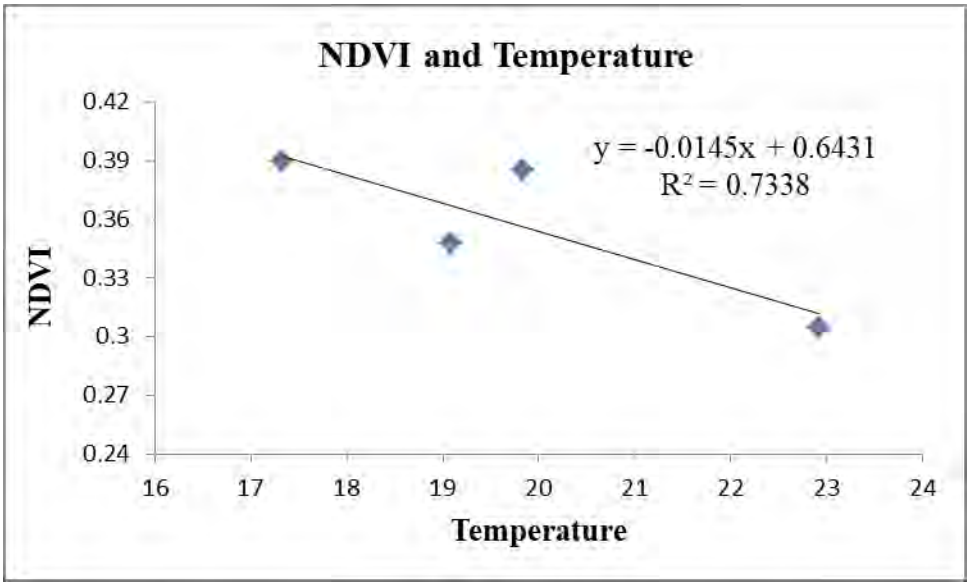

Figure 4.5: NDVI and Temperature relationship (Post-monsoon) season

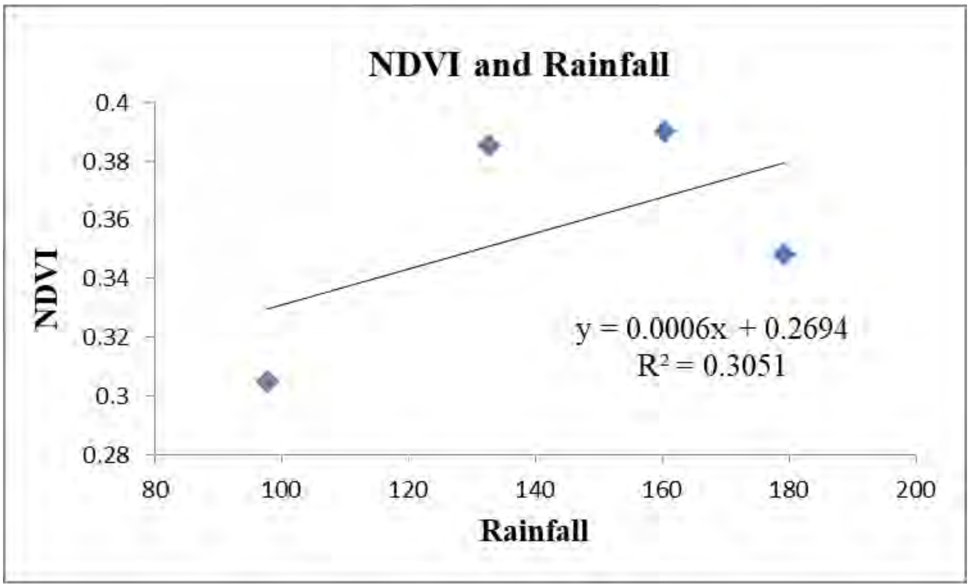

Figure 4.6: Post- monsoon season NDVI and Rainfall relationship

Figures 4.5-4.6 illustrates the graphical association of vegetation and climatic variables. Regression investigation between vegetation and temperature displays high regression coefficient rate of 0.7338 (Figure 4.5) and showed significant relationship. Regression examination between vegetation and rainfall displays low regression coefficient rate of 0.305 (Figure 4.6). In post- monsoon season, sufficient monsoon rainfall fulfilled water requirement of plants. Rainfall supports sufficient moisture accessibility in soil consequently the plants roots can simply absorb water from soil for normal growth and other activities. Therefore, relationship between forest cover and rainfall caused high regression coefficient that succeeds rise in forest cover during post- monsoon season.

4.3.3. Spatial and temporal vegetation index dynamics

The study area experienced significant spatial and temporal changes in vegetation indexes as shown in Figures 5.7 and 5.8. NDVI thematic maps indicated that NDVI values for the study area varied regularly from -0.45 to 0.74 in the pre-monsoon season (Figure 4.7). The thematic maps of NDVI showed that NDVI values were between -0.30 and 0.80 in the post monsoon season (Figure 4.8). It is apparent that in post monsoon season there was increased vegetation cover. The NDVI values above zero to one indicated that the forest vegetation increased in their maximum quantity. The maximum NDVI value was 0.80 pointed relative dense vegetation cover. The NDVI included both cropland and forest vegetation as it was very difficult to separate cropland from vegetation area.

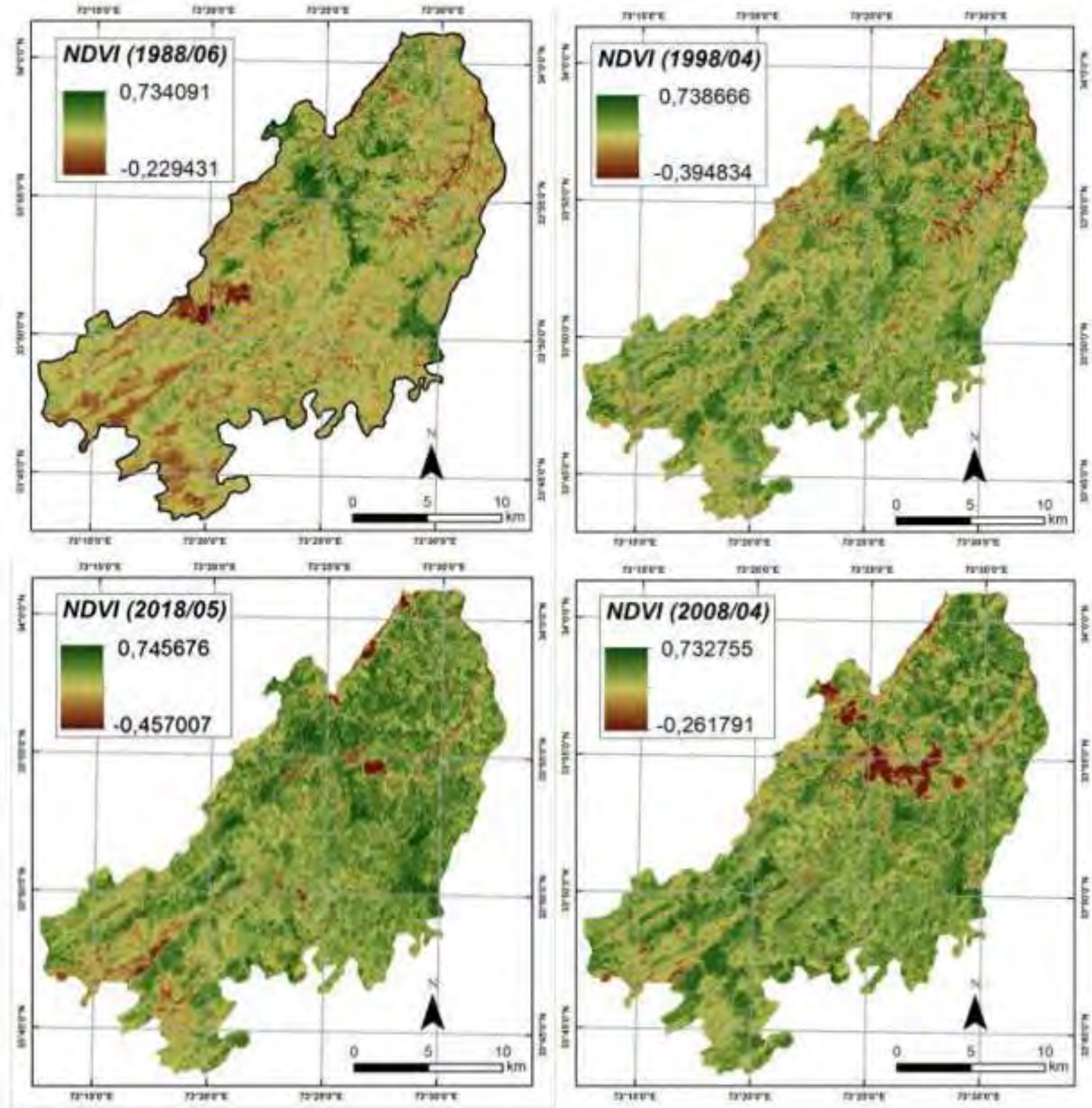

Figure 4.7: Pre-monsoon season NDVI maps of study area

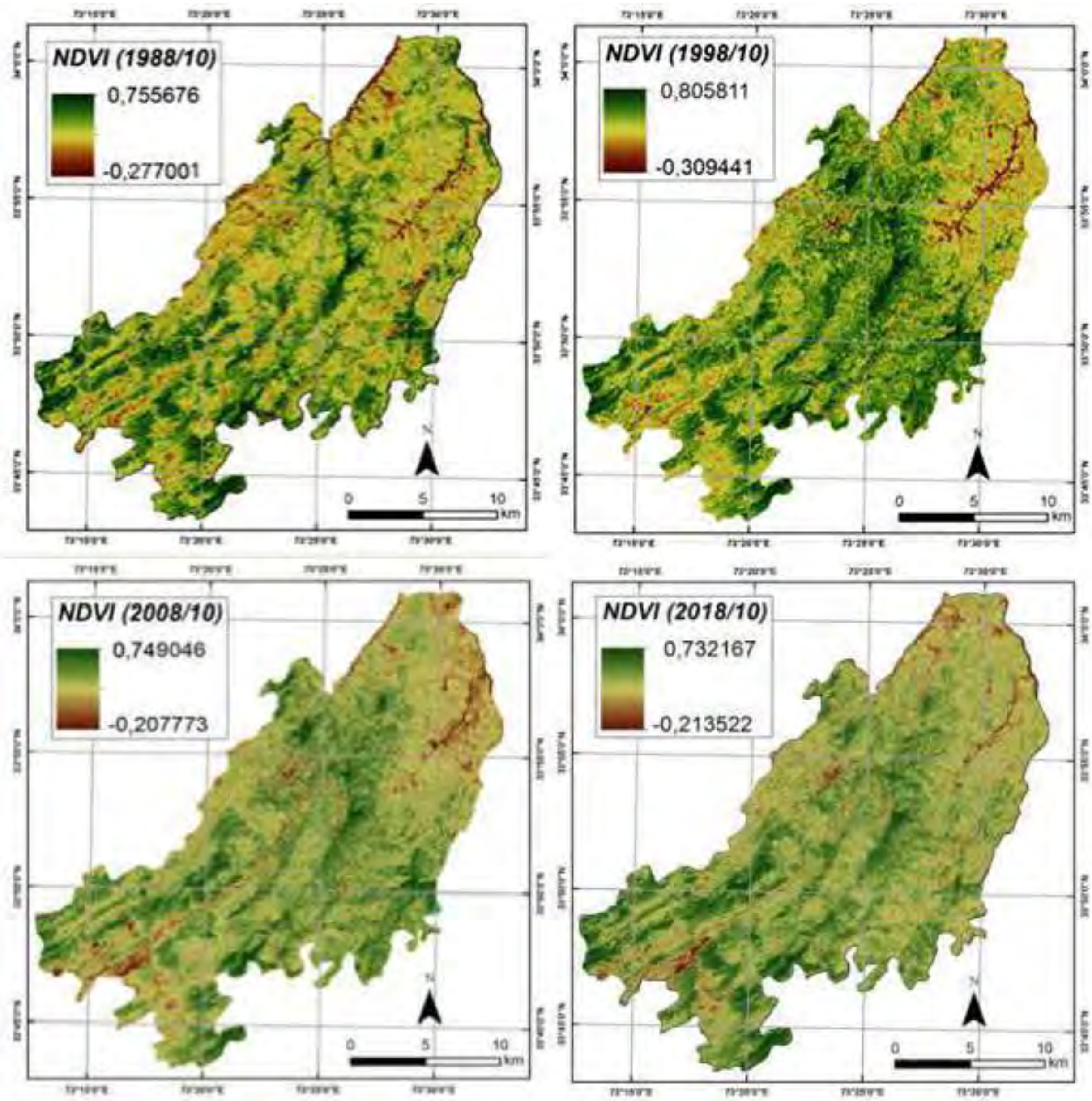

Figure 4.8: Post-monsoon season NDVI maps of study area

Different classified land use land cover practices with their respective percentage were detected for the years 1988, 1998, 2008 and 2018 (Table 4.3). The presented results showed a decrease in the forest cover with respect to the area. In comparison, the bare land, built up/settlements area and water classes have been increased. Forest cover decreased from 71% - 66.5% out of total area, whereas the bare land showed an increase in the total share from 11% to 16.5%. The minimum area covered by the water class class during 1988 - 2018 was further reduced from

1.04% to 0.32%. Land use land cover classification data assisted the aforementioned details that forest cover reduced in the past four decades (40 years) by 4.5% from 1988 to 2018. Forest cover in the study area mainly comprised moist temperate forests, mixed coniferous forests and Subtropical broad-leaved forests. This land cover class was also substituted by built up and bare lands. Deforestation and extensive cattle grazing, in addition to the cutting of fuel wood by the indigenous communities, have undermined the vegetation present in the study region into forest patches. The chief accelerators of forest deterioration in the area were the anthropogenic activities like illegitimate forest wood cutting, severe use of wood for domestic necessities and similarly for timber. In addition to inadequate management of these forests these practices have played a significant role in their decrease. The built up area was drastically increased during 1988 - 2018 from 1.3% to 9.5% of the total area (Figure 4.9).

Table 4.3: Land use land cover classes statistics for four decades (1988 to 2018) in the MFD

Year **Landuse**	**1988** (ha)	**%**	**1998**	**%**	**%**	**2008**	**%**	**2018**	**%**
Forest cover	30819	71%	30772	70.9%		31720	73%	28904	66.5%
Build up	596.53	1.3%	2893	6.6%		2384.6	5.4%	4113.5	9.5%
Bare land	4586	11%	3175.6	7.3%		6794	15.6%	7123.5	16.5%
Water	452	1.04%	569	1.3%		183.65	0.42%	142.5	0.32%

The second major class was bare land which experienced an increase in the overall area with 6% increase during the four decades. This rise in bare land class was due to rapid deforestation in the region, which reduced vegetation cover from the surface and exposed the land. The losses of soil as a result thus followed less fertile land that were eventually neglected by indigenous communities for agricultural yield. Eventually barren land area increased due to economic inefficiency. According to the land cover classification indicated that the built up area presented 8.2% increase from 1988 to 2018. Notable causes were building new recreational areas, housing schemes and farmhouses that have been built over the past 40 years in the region. In addition to these expansions, the development of new roads and highways to acess these areas is on the increase. The areas occupied by the water class also decreased during 1988 - 2018. During the last four decades, land use land cover changes witnessed in all land classes influenced the water class. An increased rate of surface runoff due to the lack of plant roots to retain the water was one reason for the decrease. The rise in surface runoff has also been greater than before deforestation and is responsible for downstream sediment and nutrient flow.

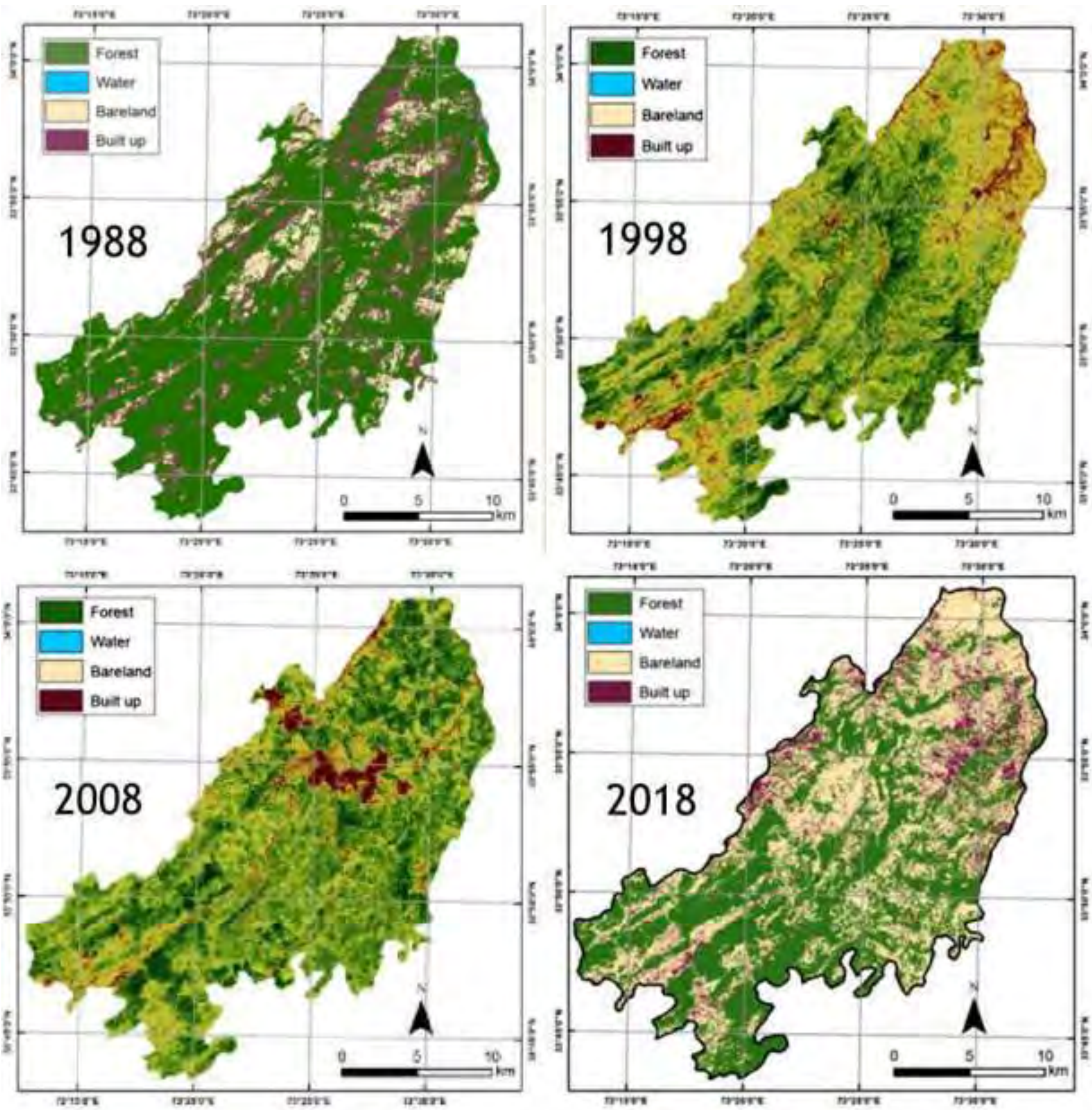

Figure 4.9: Land use land cover dynamics during 1988 - 2018 in the study area.

4.4 Discussion

MFD is part of the western Himalayan Eco-region. MFD is an important region in the context of forests conservation, and different biodiversity influenced with reference to probable climate change impacts. Most parts of the MFD have been influenced by considerable climate changes (Hameed et al. 2012).

Forest vegetation fluctuations varied regionally in the MFD and were driven by different features. In the Murree forest division the primary factor causing loss of vegetation was due to changes in precipitation and temperature. In vegetation growth, decreasing precipitation has experienced a significantly decreasing trend. We also found that the mean vegetation NDVI values showed relatively strong positive correlations in the study region with seasonal rainfall. This result is predominantly attributed to the fact that natural vegetation is extensively distributed and subject to the rainfall in lack of water for irrigation. Temperature is frequently used as an indirect variable that is required for the growth of vegetation. Significant increase in vegetation greenness may be the consequence of an increase in temperature as reported by some previous studies (Zhao et al. 2017). Though, higher temperature characteristically increases evaporation of the surface water which can greatly limit the growth of vegetation, especially the growth of shrubs and scrub vegetation. The mean vegetation NDVI values showed a negative relationship with temperature in the pre-monsoon season. Consequently, any long term rise in the temperature of the pre-monsoon season will prevent photosynthesis of various types of vegetation, resulting in a decrease in the greenness of vegetation during the summer.

In the current study, the vegetation cover dynamics and climate change impacts was assessed. In this study, we created four land use land cover classes data sets of Murree Forest Division (MFD) for 1988, 1998, 2008 and 2018 data from Landsat imageries series i.e. 5 TM, 7 ETM, 8 OLI by using ArcGIS and ERDAS Imagine in the analysis. We developed a land cover classification system taking into account the regional land cover characteristics of the Murree hills. Meanwhile, we developed some secondary classes to provide a description of the patterns and variations of Murree land cover, e.g. water, bare land was split into barren land and hills and build up area was allocated into buildings and construction. In terms of regional physical characteristics, these features make our data more optimistic than those of previous studies (Chen et al. 2017).

Previous studies also realized that an increasing influence of a “ land mafia ” , poor management, illegal cutting, forest fires caused deforestation. Commercial over-exploitation, overgrazing and illegal land intrusion are also the major threats to forests (Irshad et al. 2011). The main causes of forest degradation in the region are the absence of adequate record-keeping and the lack of an efficient surveillance system (Butt et al. 2015b; Jamal et al. 2018). Due to uncontrolled fires, large forest areas are destroyed each year. Natural forests do not have fire belts to prevent fires in most regions, so combating this particular threat is very difficult (Khan et al. 2014). MFD consisted of temperate and sub-tropical forests and the sub-tropical pine and sub-tropical broad leaved scrub forests are the most fire-prone habitats in Pakistan among all of these forest types (Bukhari 1997; Shaw 2015). The "Himalayan ecosystem degradation" is driven by growing human population that has contributed to greater exploitation of natural resources (Ali and Benjaminsen 2004; Hasan 2007). The overpopulation in the region contributed to deforestation by depletion of natural resources. In the study area forests are especially vulnerable to illegal land grabbing due to their natural beauty and as a source of dual benefits, i.e., timber and land. The influence of state forests on the supply of timber and fuel wood was previously reported (Hussain et al. 2012).

Forest cover acts as a shield and plays a significant role in the prevention of landslides in mountainous regions (Kamp et al. 2010; Rahman et al. 2014). We indicated that forest vegetation (1988 to 2018) decreased from 71% to 66.5% in the study area. The reduction in the forest cover is chiefly due to forest cutting and encroachment both in community managed and state managed forest lands. This is predominantly due to un-demarcated and ambiguous forest borderlines. Moreover, no modernized forest records are available. This lack of administration has led indigenous communities to reach Reserved and Protected Forests by taking the benefits of them and converting land into agriculture and different housing societies. According to a joint venture, conducted by WWF–Pakistan the Survey of Pakistan, Punjab Revenue Department and Punjab Forest Department identified 2,862 acres (1,158 ha) of encroached land in the state forests. To date, 1,279.21 acres (517.68 ha) of invaded land has been recovered by the Punjab Forest Department, though, left over encroached land should also be regained. A further decrease in the coniferous trees in Murree will lead to climate change (Hasan 2001). Tangible measures need to be demarcated in order to retrieve the encroached forest land, and rehabilitate the recovered forest.

Many business-oriented individuals invest in real estate and thus provide resources to encroach on state lands. Supported by findings found in the results of the classification, mainly the built-up class has increased from 1.3% to 9.5% during 1988 to 2018. However a decline in the built up area was observed from 6.6% to 5% during 2005 because of substantial earthquake. (Butt et al. 2015a) indicated that in the Simly area of lower Murree, the built-up area showed an 80 percent rise between 1992 and 2012. New housing schemes, farmhouses and recreational areas have been established all around the region over the past 40 years. There is a rise in the development of new highways, pavements and roads to reach these regions alongside other changes. Development of ‘‘New Murree’’ activity in the Simly area of Murree hills contributed to urbanization expansion. The " New Murree " plan indicated that it would extend over the upper parts of Patriata and that the planned project would remove 5-8% of the area's forest (NESPAK, 2004). This could disturb the rainfall and surface runoff driven by snow melt. On the other hand, (Adeel 2010) argued that built-up parts mostly along Simly dam in Zone IV of Islamabad have little potential for future growth, mainly due to uneven topography and relatively poor accessibility to the town.

Simly dam is among the largest water sources in the Murree hills and also one among three main water supplies to twin cities (Rawalpindi and Islamabad). It not only provides water to the Murree indigenous communities, but also to the ever-increasing twin city population. It also supplies water for agricultural purposes. Current study reported that water decreased from 1.04% to 0.32 in the area during 1988 to 2018 while (Butt et al. 2015b) also showed decrease in area covered by water from 1992 to 2012. The land use land cover variations detected in all the classes impacted the water class over four decades. Heavy depletion of water resulted in dry streams and was replaced only by compact surfaces or barren land due to easy accessibility of water. Due to the absence of plant roots to hold the water in the area, another reason for the decline was a substantial amount of surface runoff. As the runoff surpassed recharge capacity of ground water it caused a fall in the water table. Greater than before deforestation rate also contributed to the rise in surface runoff and is accountable for down flow of sediments and nutrients (Hagler 2007; Ali et al. 2011;

Mendoza et al. 2011). Greater deforestation than before also increased surface runoff which is accounted for by the downflow of nutrients and sediments. Along with a reduction due to urbanization demands, evaporation, agriculture, percolation and seepage are also most important reasons of quantifiable drop of water in reservoirs (Ashraf et al. 2007; Hagler 2007; Butt et al. 2015b; Keller et al. 2000). Prompt agriculture practices and suburbanization expansion not only reduced the water in quantity but also played a major role in contamination (Pakistan 2005).

Our study interprets the significance of integrating GIS and Remote Sensing for land use land cover classes (LULC) and forest cover change detection study of an area as it collects evidence about the land cover changes as well as the nature of spatial distributions. The results of our study ratify that land use land cover in study area has altered from 1988 to 2018. Deforestation and land degradation are continoulsy increasing along with urbanization expansion. Climate change increased socioeconomic shifts, natural disasters, grazing and wide-ranging exploitation of natural resources and are the most important factors to spatio-temporal variability in land use changes. If proper recovery measures are not implemented the forest ecosystems of the region and even whole western Himalaya will be badly affected and the associated livelihood and production will be endangered. Consequently, it is necessary to implement reasonable and effective measures and develop new forms of management practices and implement strategies designed to ensure sustainable development.

The findings showed losses and gains in vegetation cover of different trends and degrees in the current decades. It was noted from the change detection process that there was a net improvement of forest cover between 1988 and 2008 and subsequently uninterrupted net loss over the period till 2018 although forest cover changes happened in all and at diverse times of the study. The most important drivers of the cover loss were recognized as anthropogenic factors that have given rise from population expansion and poor implementation of applicable rules and regulations. The dynamics of forest cover variations witnessed in this study were critical in the administration of indigenous plantation forests in the area. Our study identified that the effect of climatic factors was significant on forest cover in pre-monsoon by temperature however in post-monsoon season forest cover with rainfall were observed. Rainfall was not significantly correlated to vegetation and forest cover in the pre-monsoon. During post-monsoon season rainfall demonstrated a significant positive response to temperature and forest cover.

Results of this research offer an important foundation for geospatial information for the development of forest cover rebuilding and management strategies in the area. The situation of forest dynamics in western Himalaya demonstrates that the utilization of multitemporal Landsat data is vital for investigating historical forest changes and remains an important asset to follow forest monitoring, which is important for sustainable organization of ecosystems. Future research prerequisites are necessary to examine the impacts of forest cover variations on socio-economic welfare of the neighboring societies.

Chapter 5 DISCUSSION AND SYNTHESIS

In the current PhD study, ecological attributes, vegetation dynamics and the impacts of climate change on the forest cover in the western Himalayan forests in Murree Mountains were evaluated from ecological, geoinformatics, and conservation view point. The results of the present research provide significant insight into the vegetation composition patterns, diversity, and dynamics. Overall rationale and syntheses of the current dissertation is presented under the following subheadings.

5.1 Why Murree Forest Division

Murree Forest Division (MFD) is a lower and outer part of the Western Himalayas that is acknowledged as one of the G200 (Global 200) ecoregions of the world. Murree Forest Division has an environmental specialty comprising Moist Temperate Forests to Sub-tropical pine forests. The Murree Forests harbors valuable conifer species like *Pinus wallichiana* and *Pinus roxburghii*. Murree is the most famous site in Pakistan. During holidays the people from Pakistan and surrounding countries come here to enjoy the attractiveness of the nature. However the consistent deforestation oppresses the nature's beauty. The deforestation in hills causes the soil erosion which also affects the growth of vegetation (Jamal et al. 2018; Hameed et al. 2012).

Ecosystem services, biodiversity and human well being are linked together and are very important for sustainable management. Human beings have a long history of consuming certain plants as food suppliers and some as therapeutic agents for injuries and different diseases. Community livelihood is mostly supported by valuable forest ecosystem services especially in the rural parts of the MFD. Sustainable use and management of forest structure is most important for the livelihood of the community as well as for the prevailing climate conditions (Cronin and Pandya 2009). On the bases of their ecosystem services and indigeous uses, forest plant resources of Murree hills may be classified as medicinal plants, fodder plants, fuel wood species, poisonous plants, thatching & sheltering, wild ornamental plants, fencing plants, timber plants and wild edible plants.

The important medicinal plants are; *Acacia nilotica*, *Acacia modesta*, *Ajuga bracteosa*, *Artemisia vulgaris*, *Bergenia ciliata*, *Berberis lycium*, *Plantago lanceolata*, *Punica granatum*, *Mentha longifolia*, *and Viola canescens* etc. The fodder plant species include *Cynodon dactylon*, *Avena fatua*, *Themeda anathera*, *Cyperus* species, *Poa* and *Trifolium* species. The fuel wood species are *Acacia modesta*, *Aesculus indica*, *Ailanthus altissima*, *Berberis lycium*, *Broussonetia papyrifera*, *Cassia fistula*, *Dodonaea viscosa*, *Pinus roxburghii* and *Indigofera heterantha*. Some of the timber plants are *Cedrus deodara*, *Aesculus indica*, *Abies pindrow*, *Juglans regia*, *Pinus roxburghii*, *Picea smithiana*, *Pinus wallichiana*, *Ulmus wallichiana* and *Olea ferruginea*. Edible plants included *Berberis* species, *Carissa spinarum*, *Diospyrus lotus*, *Ficus* species, *Duchesnea indica*, *Juglans regia*, Morus species, *Phyllanthus emblica*, *Pyrus pashia*, *Punica granatum*, *Rubus* species, *Solanum nigrum* and *Zizyphus* species. (Ahmed et al. 2013) described most of these plants that were used in Murree areas.

The rapid decline in forests is currently arising as consequences of anthropogenic pressures. Common causes of deforestation are the consequence of factors like logging, cattle grazing and crushing as well as indirect features like urbanization, overpopulation, roads, dams, and hotels construction. Secondary reasons include regular forest disturbances like fires, earthquakes, volcanic eruptions and land slides (Decker 1994; Pringle and Scott 2001; Negi et al. 2008; Bhat Jahangeer et al. 2012). The Himalayan moist temperate forests dominated by conifer species like *Abies pindrow*, *Pinus wallichiana*, *Quercus dilatata* and *Cedrus deodara* have very high commercial and environmental value, used for fuel wood, timber, agriculture, fodder, resins and manure source as well as services for example mountain springs recharge (Shaheen et al. 2012). Grazing pressure is one of the significant factors of vegetation distribution patterns and have a direct influence on the floral biodiversity of a region (Vallentine 2000). Over-grazing can be caused by several animals or their abandoned action. The animals like sheep, cows and goats can shift to woody flora alongside shrubs and grasses (Gordon 1992). They prefer leaves and tree branches compared to herbs and grasses ultimately resulting in losing saplings (Child et al. 1985; Beever et al. 1992). The overgrazing increases soil erosion; reduces soil depth, organic matter, and fertility which also decreases the land production (Fort et al. 1992; Rayburn 1992; Rayburn 2000). The regions with open livestock entrances demonstrate noticeable decrease in vegetation diversity, distribution patterns, community structure and phytosociological characteristics (Hameed et al. 2012; Reynolds et al. 2002; Landsberg et al. 2002).

Other anthropogenic actions like overexploitation of plants for economic practices, intense use of land for agricultural and construction purposes and population density are constantly changing the plant composition and structure in Murree area. This influence is comparatively stronger at lower and hotter parts where complete domination of scrub plant species is quickly substituting tall vegetation (Hameed et al. 2012). Several important plants having small ecological habitat and being constantly exploited are vulnerable to their presence (Shinwari and Gilani 2003; Watve 2013; Tali et al. 2013). Mountainous regions like Murree, the inaccessibility, their complexity of environments and the time cost issues make it tremendously challenging to notice every feature of the vegetation structures. Definitely these were the causes that considering its extraordinary phyto-geographical significance, there have been very limited or partial previous studies of the quantitative vegetation in this area (Hameed et al. 2012; Ahmed et al. 2019). In such conditions basic phytosociological knowledge along with GIS & remote sensing advanced techniques application for vegetation dynamics and distribution is compulsory to develop a conservation plan. Therefore, in the present study an integration of both i.e. ecological multivariate analysis and Geoinformatics (GIS & Remote sensing) tools for long-term historical forest dynamics assessment was used.

5.2 Vegetation dynamics and future prospects

Vegetation is under tremendous anthropo-natural pressures in the MFD, like deforestation, agricultural land expansion, pollution, invasion, urbanization expansion and climate changes. These pressures are still present and are likely to continue in the future. Future plans can only be successful if we quantify and understand the magnitude of the current problem related to vegetation, land use and cultural shifts of the studied area.

5.2.1. Floristics of the studied area in the scenario of regional plant diversity

The research region was previously unexplored except for some research on forests by certain previous authors (Adnan et al. 2006; Sher and Hussain 2007; Amir Nawaz Khan et al. 2011; Ahmad et al. 2012; Bano et al. 2018) and partially supported by World Wide Fund (WWF) Pakistan. The aim was to report on the vegetation of the research area and quantify their abundance along with effects of climate change and land use land cover dynamics. The outcomes of the floral study were associated with other studies on broader environments of Himalayas. Diverse plants (454) belonging to 98 different families were reported from 166 stations from the MFD. The dominant families were Poaceae followed by Asteraceae, Papilionaceae, and Rubiaceae. Like wise families were documented by few previous researchers who reported these families were the significant illustrative families of adjacent Himalayan forests (Bano et al. 2018). In accordance with several other researchers (Amir Nawaz Khan et al. 2011; Ahmad et al. 2012; Ahmad 2012), who described that Polygonaceae, Rosaceae, and Pinaceae etc. were also the most prevalent Himalayan plant families and identified them as the dominate families in other areas of the Himalayas.

Three different categories were used for evaluating diversity amongst three diverse habit types i.e., herbs, shrubs and trees along altitudinal gradients in the Murree mountains. The habits of vascular species comprised 70 trees (15.41%), 85 shrubs (18.72%) and 299 herb (65.85%) species were recorded. Some patterns of the species richness found in the nearby regions are similar to other past studies in the Himalayan regions (Vetaas and Grytnes 2002; Bhattarai and Vetaas 2003). Though our findings contrast to that of several previous researchers from nearby areas (Gairola et al. 2010; Chawla et al. 2012; Rahmatullah Qureshi et al. 2014; Waqas Khan et al. 2015; Haq et al. 2019), our results are in close hormony with (ARSHAD MAHMOOD Khan et al. 2015), who reported the tendency for a range of microhabitats to be preferable for the development of herbs prevailing compared to trees and shrubs in the region.

Biological spectrum (life forms) has a significant role in assessing geographically differentiated habitats. It characterizes the ecosystem of an area. Different species reported from the Murree Forest Division were categorized into main groups according to life forms. In the present work life form spectra, Therophytes followed by Nanophanerophytes and Hemicryptophytes dominated the vegetation. Similar dominance of therophytes due to destruction of natural habitat was reported in Girbanr hills (Hussain et al. 1997). The deforestration, over grazing and human disturbance adopted and dominated the Therophytes in empty niches and different habitats (Pyšek et al. 2005). The unfovrable and sometimes dry climatic conditions dominated the therophytes and chamaephytes in the near adjacent regions of Kashmir (Shaheen et al. 2015). The climate condition of the study region varies from subtropical to moist temperate type of vegetation at different elevations. (Malik et al. 1994) indicated that Therophytes and hemicryptophyte were the leading groups that support our findings in the humid temperate region of Kashmir areas. Habitat damage was also a common practice in the areas due to over exploitation, crushing, deforestation, and overgrazing. Therefore, therophytes lead in such disturbed regions. (Nazir and Malik 2006) described comparable outcomes from Sarsawa mountains that vegetation degradation takes place due to severe disturbance. Hemicryptophytes prevailed in open physiognomies while Megaphanerophytes in dense, is best demonstration class (Hussain 2009). Hence, the dominance of Therophytes can accomodate human disturbance, anthropogenic pressure and harsh climatic conditions of the region.

Leaf form spectra revealed that Microphyllous (nanophylls and microphylls) plants were prominent in the Murree areas which are an indicator of the moist temperate areas. The current study has revealed that nanophylls and microphylls were mostly present at high altitudes whereas leptophylls existed at lower altitudes. Our results are similar to those documented (Malik and Hussain 1990; Sher and Khan 2007) that a high number of nanophylls, microphylls and leptophylls were observed in the dry sub-tropical evergreen forests of Kashmir and District Buner. Dominance of microphylls followed by nanophylls and mesophyll from northen regions of Pakistan (Khan et al. 2014) were described which are in close agreement with the current findings. The relative prevalence of mesophyll flora in the region was also illustrated by related research from the Chail valley, Pakistan (Ali et al. 2016). Typically the leaf arrangement defines habitat circumstance for instance smaller leaves usually are physiognomies of adverse and dry/harsh environmental conditions. Vegetation leaf adaptation towards fluctuating climatic conditions is a good adaptative character in the retaining soil moisture contents (Khan et al. 2018). Similarly, a high percentage of nanophylls and microphylls characterize the humid temperate conditions where roots absorb low amounts of nutrients and moisture.

5.2.2. Phytosociological associations/communities and the driving factors with special emphasis on the indicator Species

Community composition, structure and vegetation functions are the significant features of forests displaying differences in response to anthropogenic as well as diverse environmental factors (Timilsina et al. 2007; Gairola et al. 2008). Differences in vegetation composition, structure, distribution and richness are directly interconnected with factors like productivity, geographical locations, competition and forest-human interactions (Eriksson 1996; Criddle et al. 2003; Timilsina et al. 2007).

The present research work of plant communities is not the first relating to MFD. However, this research work is novel because it uses modern multivariate statistical tools for the measurement of the plants and communities around ecological gradients unlike other studies which only compare the diversity indices among plant communities and treated entire plants correspondingly without surveying their ecological location in those particular ecosystems (Oommen and Shanker 2005; Ren et al. 2006; Siddiqui et al. 2009; Malik and Husain 2008; Dasti et al. 2007). The vegetation diversity along gradients as well as other criteria was measured. PCORD software was used to compute the indicator values of species abundance data. Therefore statistically significant only one indicator plant was nominated from each of trees, shrubs and herb layer in every plant community by using Indicator Species Analysis (ISA). The use of sets of multi-species environmental or ecological indicators other than a single indicator has been suggested to rise constancy of bioindication methods (Ren et al. 2006; Butler et al. 2012). Such indicators can be used to comprehend the necessities and long-term management of natural habitat (Kati et al. 2009). Indicator species recognized in this research can be used as a base for wide-ranging conservation studies on bio-diversity at a local and even at country level in the manner of most Asian and European countries where the flora has been systematically mapped by conservationists (Roy et al. 2000; Noroozi et al. 2008; Giam et al. 2010).

The multivariate studies carried out as portion of this project recognized five diverse plant communities in the study area of Murree Forest Division. Murree is situated in the Western Himalayan Province the vegetation was predominantly Sino-Japanese in nature and the communities were classified on the basis of soil and environmental gradients/factors i.e., pH, electrical conductivity (EC), organic matter (OM), nitrogen (N), phosphorous (P), potassium (K), chlorine (Cl), calcium (Ca), Total Soluble Solute (TSS), calcium carbonate ($CaCO_3$) and physical (Sand, Silt and Clay) features of the lithospheric forest ecosystem. Other factors included were anthropogenic pressure, grazing pressure, slope, elevation, aspect and canopy) influencing the distribution patterns of trees, shrubs and herbs. This permits our studies to be paralleled with the results previously generated in other nearby localities in the Sino-Japanese areas (Champion et al. 1965; Ali and Qaiser 1986; Hussain et al. 1992; Hussain et al. 1995; Shaheen et al. 2011; Hameed et al. 2012; Khan 2012; Mehmood et al. 2015). At the higher elevation ranges the flora comprises feature species of Cool and moist temperate forests, e.g., *Picea smithiana*, *Abies pindrow*, *Pinus wallichiana*, *Aesculus indica*, *Indigofira heterantha*, *Prunus padus*, *Viburnum grandiflorum*, *Spiraea canescens* and *Trifolium repens* etc, which might be matched with the plant communities described in the moist temperate Himalayan forests (Saima et al. 2009; Shujaul Mulk Khan et al. 2011). At lower altitudinal ranges, the flora was of sub-tropical type with indicator species containing *Pinus roxburghii*, *Dodonea viscosa*, Lantana camara, *Myrsine Africana* and *Berberis lyceum* etc. Similar communities have been described (Siddiqui et al. 2009) in the lesser Himalayan and Hindu Kush ranges and in Himalayan valley of Naran in the northwestern Pakistan (Khan et al. 2014).

The classification of natural biomes into prospective plant associations or communities and habitat forms is significant for the long term management of the natural resources (Abbasi et al. 2002; Waqas Khan et al. 2016; Rahman et al. 2016). The correspondence analyses (DCA and CCA) described that altitude, soil features and aspect as the strongest descriptive factors. Effects of slope, aspect and soil pH in plant species zonation was also witnessed by a number of researchers in other mountain regions around the globe (Wang et al. 2003; Davies et al. 2008; Hegazy et al. 1998; Khan et al. 2012). However, the above stated studies vary from ours as they lack the usage of any kind of statistical analysis. In DCA ordination clusters of diverse species demonstrate their correlation either positive or negative. The cool and moist temperate plant species showed positive correlation at one side of ordination whereas the subtropical species showed negative correlation and clusters on other side. Between these two types plant species of other vegetation zones exhibited correlations. DCA ordination displayed that the cool and moist temperate vegetation is negatively correlated with subtropical vegetation owing to ecological conditions. Comparable outcomes have also been shown (Khafagi et al. 2013) during the vegetation composition and ecological gradients exploration in Egypt. CCA was used for the ordination of the species and samples constrained by their associations to ecological variables. The association is between sample score derived from the plant species data and sample scores which are linear grouping of the environmental variables. Our outcomes are in line with the work of others (Khafagi et al. 2013; Khan et al. 2013b) who also recorded correlations of plant species with environmental variables.

Micro-climate is a native atmospheric region where climate changes from the neighboring regions range over few square metres or large as several square kilometers (Haq et al. 2015a). The microclimate has a great influence on the vegetation of the study region. The microclimate of Murree mountains fluctuates from sub-tropical to cool temperate (Haq et al. 2015b; Khan et al. 2013b). The latitude, longitude and altitudes were responsible for variation in micro-climate. Edaphic factors show an imperative part in the local change of plant communities in Murree area (Hameed et al. 2012). The top soil is continuously being eroded by runoff water from the upper slopes (Malik et al. 2007). Soil under spruce and fir is profound and rich in humus while it is shallow and deprived under pine and scrub regions (Haq et al. 2012). The relative amounts of soil particles indirectly affects communities by bringing differences in soil water (Charan et al. 2013). Coarse, fine sands, Gravels, clay and silt particles were documented in diverse communities (Ajaib et al. 2008).

5.2.3. Elevation zones - a baseline for future vegetation and climate dynamics

Vegetation of MFD is under the influence of monsoon and can be classified into different floristic elevation zones based on altitude, humidity and temperature (Champion et al. 1965) Takhtadzhian and Cronquist, 1986). MFD has a considerable range of elevations from 500masl to 2258masl. The quantitative methods of vegetation analysis and description used in this project fill clear technical gaps and deficiencies in the literature including the ordination and classification of flora along environmental gradients. Further this work delivers a well-founded basis for spreading this methodology to the adjacent mountains regions that are in need of updated status of vegetation (Mucina 1997; Fosaa 2004). In addition to the current study reports and offers recommendations for the conservation of mountains plants diversity under a scenario of nonstop human exploitation.

Diverse ecological gradients define the borders of altitudinal ranges and establish on mountains fluctuating impacts of precipitation and temperature in addition to the indirect features of mountains such as biological connections of plant species. Impact of climate change and hence change in vegetation is much clearer at higher altitudes in mountains. Vegetation Zonation or mapping creates discrete communities along an altitudinal gradient (Haq et al. 2015a; Waqas Khan et al. 2015). In adding to the environmental features other aspects correlated to the historical plant geography may also be accountable for the determination of vegetation type (Poore 1955). Vegetation forms are frequently well-defined using comprehensive composition of plant species which are under the influence of altitude and climate change (Zisadza-Gandiwa et al. 2013; De Cáceres and Wiser 2012). Once whole plant composition is presented there are a number of methods for allocating vegetation datasets to pre-defined vegetation forms (De Cáceres et al. 2010; van Tongeren et al. 2008), which are preferable to the approach presented here.

The whole Murree mountain area may be divided into five elevation classes based on indicator species, altitudinal range and guidance (Champion et al. 1965); EC 1 comprising Moist temperate forest (1901-2258 m), EC 2 composed of moist cool temperate forest (1601-1900 m), EC 3 comprising Mixed Coniferous forest (1301-1600 m), EC 4 consisting of Subtropical Mixed Coniferous forest (1001-1300 m) and EC 5 comprisingSubtropical broad-leaved forests (519-1000 m). Similarly three main vegetation types along altitudinal gradients were determined including alpine vegetation, moist temperate vegetation and subtropical-broad leaved vegetation have been described (SHAHEEN 2010) in the adjacent areas of district Bagh, western Himalaya, and Kashmir. Likewise the forests of Galis located in western Himalaya, Pakistan were also classified into Himalayan moist-temperate forest, Subtropical pine-forests and Dry-subtropical broad leaved forest types of forests by (Waqas Khan et al. 2015) on the basis of elevation ranges and vegetation patterns. Four phytoclimatic elevation classes were established in the Naran valley, western Himalayas, Pakistan (Khan et al. 2013b).

The Murree forest division, Western Himalaya, Pakistan is an extremely diverse area predominantly in terms of extensive variety of natural forests. Those forests are under significant change stress as land use increases with economic development and increasing human population. The current research investigation can be used as a base line for future vegetation comparsion. Like, how climate change and athrpopogenic pressure can restructure the vegetation pattern of the region using identified elevation ranges/classes. The conservation policies based on geographic patterns/elevation classes of vegegation diversity could progress the efficiency of forest plan and management in the current scenario of climate change. These policies should also include present dangers of vegetation loss to discourse the more crucial challenges for sustainable development and future plan for urbanization.

5.3 Climbers - a reference for future vegetation dynamics

Climbers grow in a conducive environment especially in moist conditions due to high rainfall in MFD. Climber plants are the species which sprout on the forest floor and develop by winding round, anchoring, leaning on or adhering to several other plant species (hosts) to achieve great size (Addo-Fordjour et al. 2008; Jongkind and Hawthorne 2005; Swaine et al. 2005). Climbers exist throughout all woody habitats in the world, while higher abundance is regarded to be the representative of subtropical forests (Bongers et al. 2005). Climber plants play a major environmental role in the dynamics of the forest ecosystem (Bongers et al. 2005). Climber plants composition and abundance directly respond to canopy and species composition of forests (Schnitzer and Bongers 2002). Globally forest structure and composition is being changed in the context of climate changes. Similarly this process directly affects the structure and abundance of climber plants (Sala et al. 2000; Laurance et al. 2001; Londré and Schnitzer 2006).

In the current study 23 climber plants associated with 20 shrubs and trees (hosts) were documented in selected parts of MFD. Previously there are no such studies of climbers in Pakistan, but limited work is available on Indian forests (Rahman et al. 2020; Kadavul and Parthasarathy 1999; Srinivas and Parthasarathy 2000). The altitudinal gradient and the number of related hosts have been found to affect the number, species distribution and family in the study region. The current research indicates that climber species were found to be more concentrated between elevations from 1500 to 1754m (Rahman et al. 2020). Consequently earlier it was usually indicated that different locality, habitat and variation in the altitudinal gradient are the possible factors that limit the distribution and abundance of climbers as recommended by previous published studies (Rahman et al. 2020; G. and Givnish 1998; Schnitzer 2005).

Our study indicated that anthropogenic pressure, altitude, host species and grazing were the most important factors that affected the abundance and distribution of climber plants. The present research showed that Murree forests have great floristic diversity of climbers that add significantly to the plant diversity. The importance of climber plants can attract researchers to identify additional information which can be used in forest management plans. This type of climber's baseline record is much needed area of research in order to understand better the role of these dependent life forms in forests (Rahman et al. 2020). This current climber diversity can be used as a reference as to how anthrpogenic pressure, grazing pressure, species turnover and climate change influence the diversity and composition of climber in the MFD.

5.4 Geo-informatic mapping for understanding of the recent past and step forward to the near future

Geo-informatics is the art of science and technology that deals with character and structure of the spatial informations, prerequisite and classifications. Geo-informatics study deals with acquisition, production, processing, dissemination, storage and presentation of geoinformation (Raju 2003; Ehlers 2008). Forest dynamics including recovery and disturbance levels and other related causal factors mapping via GIS and remote sensing is important. The Landsat data approach of geoinformatics can be used for the determination of forest changes over long decades (Nguyen et al. 2018). MFD lies in the western Himalayan Eco-region, which is important in the context of forests conservation, and different biodiversity contributions concerning expected climate change impacts (Hameed et al. 2012; Chawla et al. 2012). Most parts of MFD have experienced considerable anthropogenic as well as climatic changes under the effect of global warming. Decreasing precipitation has experienced significantly declining trend in vegetation growth. We have also established that NDVI mean values of vegetation demonstrated relatively positive correlation with seasonal rainfall in the study area. This finding is predominantly attributed to the fact that natural vegetation is extensively distributed and is subject to the rainfall in the absence of irrigation water. Temperature is frequently used as an indirect factor to provide the available indispensable energy for plant growth. A significant increase in vegetation greenness could result along an increase in temperature were reported by some previous studies (Liu et al. 2016).

In the current study, the vegetation cover dynamics and climate change impacts was assessed. In this study, we created four land use land cover class data sets of Murree Forest Division (MFD) for 1988, 1998, 2008 and 2010 data from Landsat imageries series in the analysis. In the classification system, we established land cover classes to provide information on Murree land use patterns and variations, e.g., water, bare land was allocated into barren land and hills and build up area into buildings and constructions. These characteristics mark our data in terms of regional physical features compared to previous studies (Chen et al. 2017). Forest cover acts as a shield and plays a significant role against landslides in mountainous regions (Kamp et al. 2010; Rahman et al. 2014). We indicated that forest vegetation (1988 to 2018) decreased from 71% to 66.5% in the Murree hills, Pakistan. Our study interprets the significance of integrating GIS and Remote Sensing for land use classes and forest dynamics/ variation detection in the study area as it provides evidence about the land cover changes as well as nature of spatial distributions. The results of our study ratify that land use land cover in Murree hills varied from 1988 to 2018 and that deforestation and land degradation is increasing along with urbanization expansion. Climate change increased natural disasters, socio-economic changes, grazing and widespread exploitation of natural resources are the combination of causes most important to spatial and temporal variability in land use changes. Geo-informatics of this study can be used for long term future researchers in terms of climate changes.

5.5 Utilization of current study for conservation management and policy making

The present study provides numerous suggestions for the conservation management and planning of forests in the mountain region. The study discloses that Murree Mountains within highland forests are definitely a cherished source of plant diversity. The plant groups/ communities in such environments are characterized by having a distinguished combination of diverse species some of which dominate the population whilst others are rare. From moist temperate to subtropical habitats the MFD region has a range of models for conservation. Conservationists and ecologists often lack knowledge of lesser forest areas due to absence of clear rationality of habitat forms. Indicator species recognition for a representative region (Abd El-Ghani et al. 2011) and the result presented now should enable the identification and conservation of these valued habitat forms. Communities and forest types recognized now will also support whole stakeholders to comprehend the conservation significance of diverse places and plant diversity.

Conservation management needs an understanding of anthropogenic influences on the forests and their societal indicators comprising lack of awareness, poverty, and low education. Non-sustainable consumption of plants has caused over-exploitation of natural resources. Different techniques are progressively being used for conservation development of natural ecosystems by pinpointing plants of high significance for conservation. Apart from the ecological indicator species, perceptions and social indicators can also be well-known and when applied together with traditional knowledge and economic drivers can play a dynamic role in planning conservation policies (Tarrasón et al. 2010; Zou et al. 2007). In the consequences of anthropogenic and climate change impacts on the forests, a broad evaluation of plant diversity at both national and regional level is needed (Sintayehu 2018; Zobel and Singh 1997). The rare plant species and climber diversity of the current research project can be used as baseline for conservation management in relation to rapid rate of population increase, industrialization and climate change. The findings of the current study can be used for short term as well as long term plannings and policies by Ministry of climate change, forest department, conservationists, agriculture department, herbalists and academia. We recommend conservation assessment through IUCN red lisitng and criterias for rare and endemic plants in the region for future studies and generations. Land use land cover mapping is the best tool for sustainable land use management (Figure 5.1).

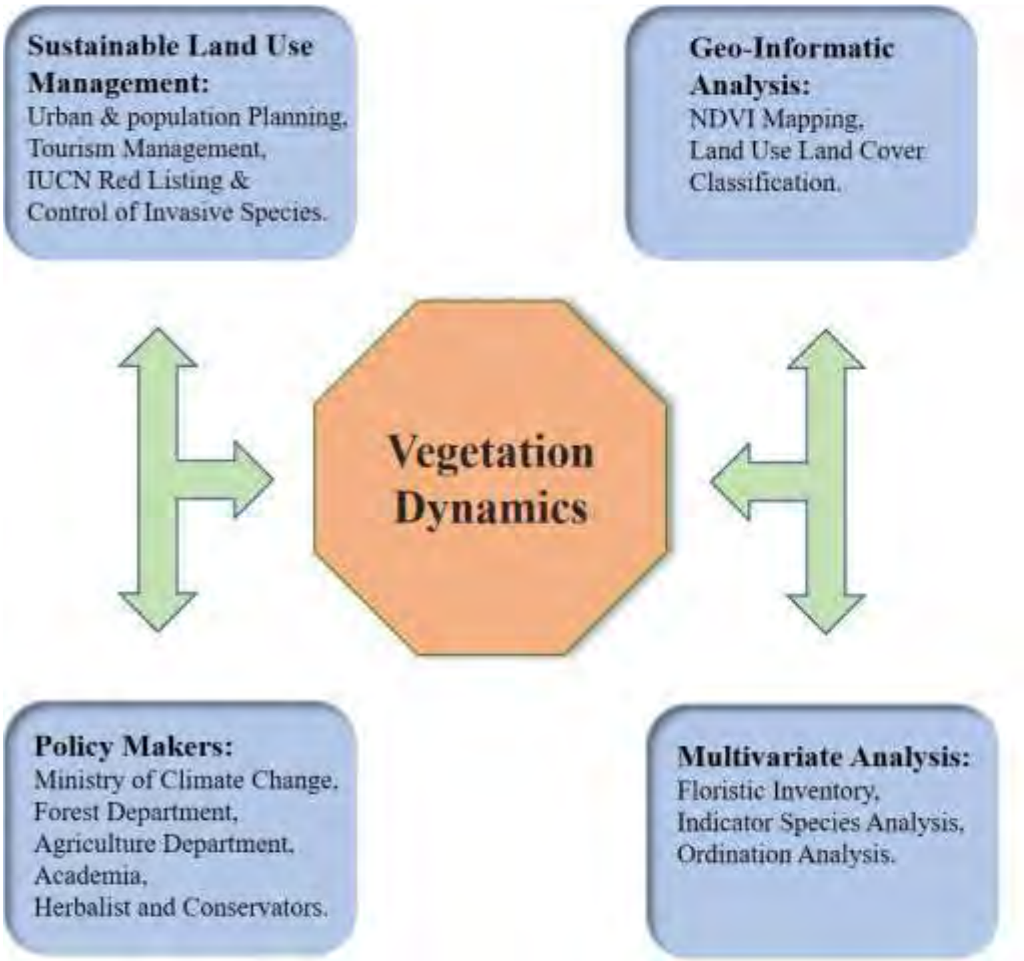

Figure. 5.1: Plan displaying the potential topics of current study for conservation management and policy making

5.6 Conclusions

The vegetation of Murree Forest Division illustrates a difference over broad diversity of specific factors and regions. Therefore a combination of multivariate statistical methods and Geo-informatics (GIS & RS) tools were used as most appropriate method to evaluate and map the forest vegetation and classification of communities in the study area. It was determined that environmental variables have considerable effect on the vegetation diversity and pattern. Plant composition and distribution patterns provide a relationship linking climatic, topographic and edaphic features in broad-spectrum. Furthermore the vegetation varies with differences in soil electrical conductivity, potassium, pH, phosphorous, aspect and altitude ranges as compared to other accompanying factors.

The three key implications of the present research comprised: (1) How to record plant species composition, distribution pattern and abundance at growing seasons by listing a floristic inventory along other ecological characteristics. How to quantify the present day vegetation and to categorize different communities based on indicator plants in different habitat forms by combining multivariate classification and ordination statistical tools for example CA and TwCA via PCORD and CONOCO. (2) How to assess the diversity and abundance of climber plant species with hosts (trees and shrubs) and affected by parameters like biotic and abiotic factors in the Murree forest Division (MFD) by using multivariate techniques. (3) How to analyze various data sets related to climate change and land use land cover classes for estimation of vegetation dynamics in Murree Forest Division and to estimate the loss of vegetation due to expansion in infrastructure through GIS & Remote Sensing tools whose ultimate aim was to create a comprehensible map for public and natural resources managers. These procedures give a perfect approach to recognize indicator plants of particular habitats. Therefore directly or indirectly these add to the biodiversity, habitat management and conservation policies not only in this region but also in neighboring areas display to similar type of environmental circumstances. Therefore there is an urgent need to develop an appropriate conservation management plan for the sustainable usage of indigenous forest areas which should contain improving the socioeconomic position of natives by providing them with alternative sources of livelihood.

5.7 Future Conservation and Recommendations

- Overutilization of the vegetation resources is the major reason of biodiversity loss in the region. Neverthless, it is rich in plant biodiversity and can be declared as a protected site due to its important conducive environment and geopolitical location (junction of three different administrative set ups i.e., Khyber Pakhtunkhwa, Punjab and Kashmir).
- The main threats to the plant diversity loss of the study region such as overgrazing, soil erosion, deforestation, urbanization expansion, habitat loss, invasive species and over exploitation of natural resources should be managed properly to mitigate the anthropo-driven vegetation dynamics. The rangelands are degraded because of livestock pressure and hence can be checked via controls of grazing.
- Afforestation drives for specific plants especially the medicinal plants in the research area can reduce pressure on the medicinal plants collection. The native people of the region have the information relating to traditional uses of the medicinal plants which must be properly documented and community participatory approaches can be utilized for aforsttation and reforestation drives.
- Populations of threatened (rare and endangered) species can be improved in habitats by taking regional scale protective measures. Conservation of threatened plant species with the help of indigenous people and societies outside their natural habitats can be carried out. Both *Ex-situ* and *In-situ* conservation measures should be taken. Nurseries can be established for important rare and endemic species at regional scales. The resource of updated Red List Categories of threatened plants of Pakistan as per reference of IUCN does not exist; therefore Red Listing of the threatened plants of Pakistan can be initiated.
- The growing population place an enormous pressure on the environment and is the main reason for the loss of natural resources and biodiversity in the environment. This matter has to be given top priority while planning long term national national policies.
- Awareness of community masses and training of social groups on sustainable usage of natural resources is merely effective if conducted by well trained persons.

- Detailed socio-economic records of the local people can be documented and steps can be taken for the improvement of their life values to reduce pressure on the natural resources in general and vegetation in particular.
- There is a dire need to develop cooperation among stakeholders/ policy makers, if brought together and these can consistently reach some decision concerning Biodiversity Action Plans (BAP) based on which future conservation strategies can be framed.

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7 Appendices

7.1 Appendix 1: Floristic composition in the MFD

S.No	Plant Name	Family	Habit	Life form	Leaf size	IVI
1	*Abies pindrow*	Pinaceae	Tree	Megaphanerophyte	Nanophyll	6427.02
2	*Acacia catechu*	Mimosaceae	Tree	Megaphanerophyte	Leptophyll	3776.95
3	*Acacia modesta*	Mimosaceae	Tree	Megaphanerophyte	Leptophyll	1679.03
4	*Acacia nilotica*	Mimosaceae	Tree	Megaphanerophyte	Leptophyll	1526.55
5	*Acer caesium*	Aceraceae	Tree	Megaphanerophyte	Leptophyll	1059.72
6	*Acer cappadocicum*	Aceraceae	Tree	Megaphanerophyte	Macrophyll	1025.78
7	*Aesculus indica*	Hippocastanaceae	Tree	Megaphanerophyte	Mesophyll	757.49
8	*Ailanthus altissima*	Simarubaceae	Tree	Mesophanerophyte	Microphyll	747.05
9	*Albizia julibrissin*	Mimosaceae	Tree	Phanerophyte	Leptophyll	684.67
10	*Albizia lebbeck*	Mimosaceae	Tree	Megaphanerophyte	Leptophyll	536.80
11	*Albizia chinensis*	Mimosaceae	Tree	Phanerophyte	Microphyll	403.98
12	*Albizia odoratissima*	Mimosaceae	Tree	Phanerophyte	Leptophyll	388.26
13	*Alstonia scholaris*	Apocynaceae	Tree	Microphanerophyte	Microphyll	368.41
14	*Bauhinia variegata*	Caesalpiniaceae	Tree	Megaphanerophyte	Mesophyll	363.61
15	*Broussonetia papyrifera*	Moraceae	Tree	Megaphanerophyte	Microphyll	343.93
16	*Cassia fistula*	Caesalpiniaceae	Tree	Megaphanerophyte	Mesophyll	296.22

17	*Cedrus deodara*	Pinaceae	Tree	Megaphanerophyte	Nanophyll	287.41
18	*Celtis australis*	Canabinaceae	Tree	Mesophanerophyte	Microphyll	277.79
19	*Cornus macrophylla*	Cornaceae	Tree	Hemicryptophyte	Microphyll	265.20
20	*Cupressus sempervirens*	Cupressaceae	Tree	Microphanerophyte	Leptophyll	229.45
21	*Dalbergia sissoo*	Papilionaceae	Tree	Megaphanerophyte	Microphyll	197.32
22	*Diospyros lotus*	Ebenaceae	Tree	Megaphanerophyte	Microphyll	188.45
23	*Ficus palmate*	Moraceae	Tree	Mesophanerophyte	Mesophyll	169.04
24	*Ficus racemosa*	Moraceae	Tree	Megaphanerophyte	Macrophyll	145.67
25	*Flacourtia indica*	Flacourtiaceae	Tree	Nanophanerophyte	Microphyll	143.30
26	*Grewia optiva*	Malvaceae	Tree	Mesophanerophyte	Microphyll	137.74
27	*Ilex dipyrena*	Aquifoliaceae	Tree	Phanerophyte	Nanophyll	129.05
28	*Juglans regia*	Juglandaceae	Tree	Megaphanerophyte	Macrophyll	116.51
29	*Lannea coromandelica*	Anacardiaceae	Tree	Phanerophyte	Mesophyll	115.26
30	*Melia azedarach*	Meliaceae	Tree	Megaphanerophyte	Microphyll	109.43
31	*Morus alba*	Moraceae	Tree	Megaphanerophyte	Macrophyll	107.34
32	*Morus nigra*	Moraceae	Tree	Megaphanerophyte	Macrophyll	104.48
33	*Nyctanthes arbor-tristis*	Oleaceae	Tree	Phanerophyte	Microphyll	96.54
34	*Olea paniculata*	Oleaceae	Tree	Mesophanerophyte	Microphyll	95.11
35	*Prunus cornuta*	Rosaceae	Tree	Mesophanerophyte	Microphyll	94.56
36	*Machilus duthiei*	Lauraceae	Tree	Mesophanerophyte	Nanophyll	94.02

37	*Chamaerops humilis*	Arecaceae	Tree	Phanerophyte	Mesophyll	89.14
38	*Phoenix sylvestris*	Euphorbiaceae	Tree	Phanerophyte	Leptophyll	87.90
39	*Phyllanthus emblica*	Arecaceae	Tree	Phanerophyte	Mesophyll	81.19
40	*Picea smithiana*	Pinaceae	Tree	Megaphanerophyte	Nanophyll	80.99
41	*Pinus roxburghii*	Pinaceae	Tree	Megaphanerophyte	Nanophyll	76.57
42	*Pinus wallichiana*	Pinaceae	Tree	Megaphanerophyte	Nanophyll	74.33
43	*Pistacia chinensis ssp. Integerrima*	Anacardiaceae	Tree	Microphanerophyte	Microphyll	74.31
44	*Platanus orientalis*	Salicaceae	Tree	Mesophanerophyte	Mesophyll	73.88
45	*Populus alba*	Salicaceae	Tree	Mesophanerophyte	Mesophyll	68.33
46	*Populus ciliate*	Rosaceae	Tree	Mesophanerophyte	Microphyll	65.63
47	*Prunus armeniaca*	Platanaceae	Tree	Megaphanerophyte	Macrophyll	60.97
48	*Pyrus calleryana*	Rosaceae	Tree	Microphanerophyte	Nanophyll	59.78
49	*Pyrus bourgaeana*	Rosaceae	Tree	Megaphanerophyte	Macrophyll	59.63
50	*Pyrus pashia*	Rosaceae	Tree	Microphanerophyte	Mesophyll	58.37
51	*Quercus baloot*	Fagaceae	Tree	Mesophanerophyte	Microphyll	57.51
52	*Quercus robur*	Fagaceae	Tree	Mesophanerophyte	Microphyll	53.33
53	*Quercus glauca*	Fagaceae	Tree	Mesophanerophyte	Microphyll	50.11
54	*Quercus incana*	Fagaceae	Tree	Mesophanerophyte	Microphyll	45.04
55	*Quercus semecarpifolia*	Fagaceae	Tree	Mesophanerophyte	Microphyll	44.89
56	*Rhamnus purpurea*	Rhamnaceae	Tree	Megaphanerophyte	Microphyll	44.38

57	*Rhamnus triquetra*	Rhamnaceae	Tree	Megaphanerophyte	Microphyll	44.27
58	*Rhus chinensis*	Anacardiaceae	Tree	Microphanerophyte	Mesophyll	42.76
59	*Rhus punjabensis*	Anacardiaceae	Tree	Microphanerophyte	Mesophyll	39.19
60	*Rhus succedanea var. himalaica*	Anacardiaceae	Tree	Microphanerophyte	Mesophyll	34.34
61	*Robinia pseudo-acacia*	Papilionaceae	Tree	Mesophanerophyte	Mesophyll	31.48
62	*Salix babylonica*	Salicaceae	Tree	Mesophanerophyte	Mesophyll	28.18
63	*Salix tetrasperma*	Salicaceae	Tree	Mesophanerophyte	Mesophyll	27.31
64	*Sapindus mukorossi*	Sapindaceae	Tree	Phanerophyte	Mesophyll	26.13
65	*Taxus wallichiana*	Taxaceae	Tree	Megaphanerophyte	Nanophyll	26.02
66	*Thuja orientalis*	Cupressaceae	Tree	Nanophanerophyte	Leptophyll	24.57
67	*Toona ciliate*	Meliaceae	Tree	Phanerophyte	Microphyll	21.76
68	*Ulmus wallichiana*	Ulmaceae	Tree	Phanerophyte	Microphyll	18.64
69	Wendlandia heynei	Rubiaceae	Tree	Phanerophyte	Nanophyll	15.88
70	Xylosma longifolium	Flacourtiaceae	Tree	Mesophanerophyte	Nanophyll	13.69
71	*Andrachne cordifolia*	Euphorbiaceae	Shrub	Nanophanerophyte	Microphyll	3766.23
72	*Aristolochia punjabensis*	Aristolochiaceae	Shrub	Microphanerophyte	Nanophyll	3431.00
73	*Artemisia vulgaris*	Asteraceae	Shrub	Chamaephyte	Microphyll	1658.40
74	*Barleria cristata*	Acanthaceae	Shrub	Chamaephyte	Microphyll	1309.83
75	*Berberis aristata*	Berberidaceae	Shrub	Nanophanerophyte	Nanophyll	1282.29
76	*Berberis calliobotrys*	Berberidaceae	Shrub	Nanophanerophyte	Nanophyll	1234.84

77	*Betula utilis*	Betulaceae	Shrub	Megaphanerophyte	Mesophyll	1071.61
78	*Buddleja crispa*	Buddlejaceae	Shrub	Nanophanerophyte	Microphyll	644.99
79	*Buxus papillosa*	Buxaceae	Shrub	Nanophanerophyte	Microphyll	625.72
80	*Buxus wallichiana*	Buxaceae	Shrub	Nanophanerophyte	Microphyll	605.19
81	*Caesalpinia decapetala*	Caesalpiniaceae	Shrub	Nanophanerophyte	Microphyll	503.93
82	*Calotropis procera*	Apocynaceae	Shrub	Chamaephyte	Mesophyll	480.39
83	*Carissa spinarum*	Apocynaceae	Shrub	Therophyte	Microphyll	455.11
84	*Colebrookea oppositifolia*	Lamiaceae	Shrub	Nanophanerophyte	Leptophyll	430.83
85	*Coriaria nepalensis*	Coriariaceae	Shrub	Hemicryptophyte	Microphyll	421.05
86	*Cotoneaster nummularia*	Rosaceae	Shrub	Nanophanerophyte	Nanophyll	409.39
87	*Cotinus coggygria*	Anacardiaceae	Shrub	Therophyte	Mesophyll	403.37
88	*Cryptolepis dubia*	Apocynaceae	Shrub	Microphanerophyte	Nanophyll	340.55
89	*Daphne mucronata*	Urticaceae	Shrub	Nanophanerophyte	Nanophyll	339.72
90	*Daphne papyracea*	Urticaceae	Shrub	Microphanerophyte	Nanophyll	325.42
91	*Debregeasia saeneb*	Papilionaceae	Shrub	Nanophanerophyte	Mesophyll	300.56
92	*Desmodium elegans*	Hydrangeaceae	Shrub	Nanophanerophyte	Microphyll	285.84
93	*Deutzia staminea*	Sapindaceae	Shrub	Nanophanerophyte	Nanophyll	283.67
94	*Dodonaea viscosa*	Boraginaceae	Shrub	Nanophanerophyte	Microphyll	276.21
95	*Ehretia obtusifolia*	Elaeagnaceae	Shrub	Nanophanerophyte	Microphyll	253.30
96	*Elaeagnus umbellata*	Ephedraceae	Shrub	Chamaephyte	Nanophyll	219.88

97	*Ephedra gerardiana*	Celastraceae	Shrub	Phanerophyte	Nanophyll	211.71
98	*Euonymus echinatus*	Moraceae	Shrub	Megaphanerophyte	Mesophyll	189.97
99	*Himalrandia tetrasperma*	Hypericaceae	Shrub	Phanerophyte	Nanophyll	170.05
100	*Hypericum dyeri*	Hypericaceae	Shrub	Nanophanerophyte	Nanophyll	168.00
101	*Hypericum oblongifolium*	Papilionaceae	Shrub	Nanophanerophyte	Microphyll	142.44
102	*Indigofera hebepetala*	Papilionaceae	Shrub	Nanophanerophyte	Leptophyll	138.07
103	*Indigofera heterantha*	Papilionaceae	Shrub	Nanophanerophyte	Leptophyll	129.47
104	*Indigofera himalayensis*	Papilionaceae	Shrub	Nanophanerophyte	Mesophyll	128.37
105	*Indigofera linifolia*	Lamiaceae	Shrub	Nanophanerophyte	Microphyll	123.57
106	*Isodon rugosus*	Oleaceae	Shrub	Nanophanerophyte	Microphyll	121.38
107	*Jasminum humile*	Oleaceae	Shrub	Nanophanerophyte	Microphyll	80.91
108	*Jasminum mesnyi*	Oleaceae	Shrub	Nanophanerophyte	Microphyll	80.32
109	*Jasminum officinale*	Acanthaceae	Shrub	Nanophanerophyte	Mesophyll	71.95
110	*Justicia adhatoda*	Verbenaceae	Shrub	Chamaephyte	Microphyll	70.61
111	*Lantana camara*	Papilionaceae	Shrub	Chamaephyte	Nanophyll	70.10
112	*Lespedeza floribunda*	Papilionaceae	Shrub	Therophyte	Nanophyll	69.41
113	*Lespedeza juncea*	Caprifoliaceae	Shrub	Nanophanerophyte	Nanophyll	65.54
114	*Lonicera quinquelocularis*	Caprifoliaceae	Shrub	Nanophanerophyte	Mesophyll	63.25
115	*Lonicera spp*	Euphorbiaceae	Shrub	Nanophanerophyte	Mesophyll	59.63
116	*Mallotus philippensis*	Celastraceae	Shrub	Nanophanerophyte	Mesophyll	57.67

117	*Gymnosporia royleana*	Celastraceae	Shrub	Nanophanerophyte	Mesophyll	55.09
118	*Maytenus rufa*	Mimosaceae	Shrub	Nanophanerophyte	Leptophyll	54.32
119	*Mimosa himalayana*	Myrsinaceae	Shrub	Nanophanerophyte	Nanophyll	53.68
120	*Myrsine africana*	Apocynaceae	Shrub	Nanophanerophyte	Mesophyll	53.17
121	*Nerium oleander*	Oleaceae	Shrub	Nanophanerophyte	Microphyll	51.78
122	*Olea ferruginea*	Lamiaceae	Shrub	Mesophanerophyte	Microphyll	50.44
123	*Rydingia limbata*	Punicaceae	Shrub	Nanophanerophyte	Mesophyll	48.99
124	*Punica granatum*	Linaceae	Shrub	Nanophanerophyte	Nanophyll	47.36
125	*Reinwardtia indica*	Euphorbiaceae	Shrub	Nanophanerophyte	Macrophyll	44.63
126	*Rhamnus pentapomica*	Rhamnaceae	Shrub	Microphanerophyte	Nanophyll	43.88
127	*Ricinus communis*	Rosaceae	Shrub	Nanophanerophyte	Nanophyll	41.61
128	*Rosa brunonii*	Rosaceae	Shrub	Nanophanerophyte	Nanophyll	41.00
129	*Rosa chinensis*	Rosaceae	Shrub	Nanophanerophyte	Nanophyll	40.17
130	*Rosa macrophylla*	Rosaceae	Shrub	Nanophanerophyte	Nanophyll	40.00
131	*Rosa moschata*	Rosaceae	Shrub	Nanophanerophyte	Nanophyll	37.14
132	*Rosa multiflora*	Rosaceae	Shrub	Microphanerophyte	Nanophyll	35.90
133	*Rosa webbiana*	Rosaceae	Shrub	Nanophanerophyte	Microphyll	35.87
134	*Rubus ellipticus*	Rosaceae	Shrub	Nanophanerophyte	Mesophyll	32.84
135	*Rubus fruticosus*	Rosaceae	Shrub	Microphanerophyte	Mesophyll	31.79
136	*Rubus sanctus*	Polygonaceae	Shrub	Chamaephyte	Mesophyll	30.87

137	*Rumex hastatus*	Rhamnaceae	Shrub	Nanophanerophyte	Microphyll	30.18
138	*Sageretia thea*	Salicaceae	Shrub	Megaphanerophyte	Mesophyll	27.88
139	*Salix acmophylla*	Buxaceae	Shrub	Nanophanerophyte	Microphyll	26.12
140	*Sarcococca saligna*	Rutaceae	Shrub	Nanophanerophyte	Mesophyll	25.45
141	*Skimmia laureola*	Rubiaceae	Shrub	Nanophanerophyte	Microphyll	24.38
142	*Spermadictyon suaveolens*	Rosaceae	Shrub	Nanophanerophyte	Microphyll	23.00
143	*Spiraea canescens*	Acanthaceae	Shrub	Therophyte	Nanophyll	22.36
144	*Strobilanthes glutinosus*	Acanthaceae	Shrub	Nanophanerophyte	Nanophyll	21.63
145	*Strobilanthes urticifolia*	Oleaceae	Shrub	Megaphanerophyte	Mesophyll	21.21
146	*Syringa emodi*	Caprifoliaceae	Shrub	Nanophanerophyte	Microphyll	19.97
147	*Viburnum cotinifolium*	Caprifoliaceae	Shrub	Nanophanerophyte	Mesophyll	19.61
148	*Viburnum grandiflorum*	Verbenaceae	Shrub	Megaphanerophyte	Microphyll	18.59
149	*Vitex negundo*	Thymelaeaceae	Shrub	Nanophanerophyte	Nanophyll	17.88
150	*Wikstroemia canescens*	Lythraceae	Shrub	Nanophanerophyte	Microphyll	17.78
151	*Woodfordia fruticosa*	Rutaceae	Shrub	Microphanerophyte	Mesophyll	16.48
152	*Zanthoxylum armatum*	Rhamnaceae	Shrub	Megaphanerophyte	Nanophyll	12.44
153	*Ziziphus jujube*	Rhamnaceae	Shrub	Nanophanerophyte	Nanophyll	10.85
154	*Ziziphus nummularia*	Rhamnaceae	Shrub	Nanophanerophyte	Nanophyll	7.24
155	*Ziziphus oxyphylla*	Rhamnaceae	Shrub	Nanophanerophyte	Nanophyll	5.90
156	*Achillea*	Asteraceae	Herb	Hemicryptophyte	Leptophyll	2442.05

	millefolium subsp. millefolium					
157	*Achyranthes aspera*	Amaranthaceae	Herb	Therophyte	Nanophyll	851.15
158	*Aconitum heterophyllum*	Ranunculaceae	Herb	Hemicryptophyte	Mesophyll	801.18
159	*Ageratum conyzoides*	Asteraceae	Herb	Nanophanerophyte	Nanophyll	790.32
160	*Agrostis gigantea*	Poaceae	Herb	Geophyte	Nanophyll	696.22
161	*Agrostis stolonifera*	Poaceae	Herb	Geophyte	Nanophyll	658.82
162	*Agrostis viridis*	Poaceae	Herb	Hemicryptophyte	Nanophyll	565.97
163	*Ainsliaea aptera*	Asteraceae	Herb	Nanophanerophyte	Nanophyll	485.01
164	*Ajuga bracteosa*	Lamiaceae	Herb	Hemicryptophyte	Microphyll	383.00
165	*Ajuga parviflora*	Lamiaceae	Herb	Hemicryptophyte	Mesophyll	372.64
166	*Alternanthera pungens*	Amaranthaceae	Herb	Nanophanerophyte	Nanophyll	358.38
167	*Amaranthus viridis*	Amaranthaceae	Herb	Therophyte	Mesophyll	333.41
168	*Anaphalis busua*	Asteraceae	Herb	Hemicryptophyte	Nanophyll	319.88
169	*Anagallis arvensis*	Primulaceae	Herb	Therophyte	Nanophyll	314.32
170	*Androsace rotundifolia*	Primulaceae	Herb	Hemicryptophyte	Nanophyll	304.28
171	*Anisomeles indica*	Lamiaceae	Herb	Chamaephyte	Mesophyll	289.57
172	*Anthemis cotula*	Asteraceae	Herb	Nanophanerophyte	Nanophyll	275.46
173	*Apluda mutica*	Poaceae	Herb	Hemicryptophyte	Nanophyll	265.92
174	*Aralia cachemirica*	Araliaceae	Herb	Microphanerophyte	Nanophyll	258.68
175	*Argemone mexicana*	Papaveraceae	Herb	Nanophanerophyte	Nanophyll	237.41

176	*Argyrolobium roseum*	Papilionaceae	Herb	Nanophanerophyte	Nanophyll	217.21
177	*Aristida cynantha*	Poaceae	Herb	Hemicryptophyte	Nanophyll	210.20
178	*Aristida mutabilis*	Poaceae	Herb	Therophyte	Nanophyll	194.81
179	*Artemisia scoparia*	Asteraceae	Herb	Hemicryptophyte	Nanophyll	191.34
180	*Arthraxon prionodes*	Poaceae	Herb	Hemicryptophyte	Microphyll	188.14
181	*Asclepias curassavica*	Apocynaceae	Herb	Nanophanerophyte	Nanophyll	186.01
182	*Asparagus adscendens*	Asparagaceae	Herb	Hemicryptophyte	Leptophyll	184.06
183	*Asparagus capitatus subsp. gracilis*	Asparagaceae	Herb	Chamaephyte	Leptophyll	182.77
184	*Asparagus racemosus*	Asparagaceae	Herb	Chamaephyte	Leptophyll	176.43
185	*Atropa acuminata*	Solanaceae	Herb	Therophyte	Mesophyll	169.68
186	*Bellis perennis*	Asteraceae	Herb	Hemicryptophyte	Leptophyll	169.33
187	*Bergenia ciliata f. ciliata*	Saxifragaceae	Herb	Geophyte	Microphyll	168.27
188	*Bergenia ciliata f. ligulata*	Saxifragaceae	Herb	Geophyte	Microphyll	166.69
189	*Bergenia stracheyi*	Saxifragaceae	Herb	Hemicryptophyte	Mesophyll	164.12
190	*Bidens cernua*	Asteraceae	Herb	Therophyte	Microphyll	163.27
191	*Bidens tripartita*	Asteraceae	Herb	Hemicryptophyte	Nanophyll	162.82
192	*Persicaria amplexicaulis*	Polygonaceae	Herb	Hemicryptophyte	Mesophyll	162.18
193	*Boerhavia procumbens*	Nyctaginaceae	Herb	Hemicryptophyte	Nanophyll	161.59
194	*Bothriochloa bladhii*	Poaceae	Herb	Hemicryptophyte	Leptophyll	160.24
195	*Bothriochloa ischaemum*	Poaceae	Herb	Hemicryptophyte	Microphyll	157.62

196	*Brachiaria eruciformis*	Poaceae	Herb	Hemicryptophyte	Leptophyll	156.63
197	*Brachiaria ramosa*	Poaceae	Herb	Hemicryptophyte	Nanophyll	153.06
198	*Bromus catharticus*	Poaceae	Herb	Hemicryptophyte	Microphyll	151.72
199	*Bromus japonicus*	Poaceae	Herb	Hemicryptophyte	Microphyll	151.09
200	*Bromus ramosus*	Poaceae	Herb	Hemicryptophyte	Microphyll	148.62
201	*Bupleurum lanceolatum*	Apiaceae	Herb	Therophyte	Microphyll	145.08
202	*Bupleurum longicaule*	Apiaceae	Herb	Therophyte	Microphyll	144.14
203	*Calamagrostis emodensis*	Poaceae	Herb	Therophyte	Leptophyll	141.99
204	*Calamagrostis epigejos*	Poaceae	Herb	Therophyte	Leptophyll	141.32
205	*Cannabis sativa*	Canabinaceae	Herb	Therophyte	Nanophyll	139.09
206	*Cardiospermum halicacabum*	Sapindaceae	Herb	Hemicryptophyte	Nanophyll	136.90
207	*Carex cruciate*	Cyperaceae	Herb	Geophyte	Leptophyll	126.20
208	*Carex filicina*	Cyperaceae	Herb	Geophyte	Leptophyll	119.48
209	*Carex psychrophila*	Cyperaceae	Herb	Therophyte	Mesophyll	114.27
210	*Carex schlagintweitiana*	Cyperaceae	Herb	Therophyte	Mesophyll	111.32
211	*Carex sanguinea*	Cyperaceae	Herb	Therophyte	Leptophyll	110.58
212	*Carpesium abrotanoides*	Asteraceae	Herb	Therophyte	Nanophyll	109.39
213	*Carpesium nepalense*	Asteraceae	Herb	Therophyte	Nanophyll	103.84
214	*Ceropegia macrantha*	Apocynaceae	Herb	Chamaephyte	Leptophyll	103.67
215	*Chenopodium album*	Chenopodiaceae	Herb	Therophyte	Nanophyll	103.30

216	*Chenopodium ambrosioides*	Chenopodiaceae	Herb	Therophyte	Leptophyll	101.70
217	*Chrysopogon gryllus*	Poaceae	Herb	Hemicryptophyte	Nanophyll	99.99
218	*Cichorium intybus*	Asteraceae	Herb	Therophyte	Nanophyll	97.73
219	*Cirsium arvense*	Asteraceae	Herb	Therophyte	Nanophyll	95.02
220	*Cissampelos pareira*	Menispermaceae	Herb	Microphanerophyte	Macrophyll	94.20
221	*Cissus carnosa*	Vitaceae	Herb	Microphanerophyte	Microphyll	92.41
222	*Clematis connata*	Ranunculaceae	Herb	Hemicryptophyte	Mesophyll	91.68
223	*Clematis gouriana*	Ranunculaceae	Herb	Hemicryptophyte	Microphyll	87.40
224	*Clematis grata*	Ranunculaceae	Herb	Nanophanerophyte	Nanophyll	86.85
225	*Clematis graveolens*	Ranunculaceae	Herb	Nanophanerophyte	Nanophyll	84.96
226	*Clematis montana*	Ranunculaceae	Herb	Therophyte	Nanophyll	83.77
227	*Clinopodium umbrosum*	Lamiaceae	Herb	Therophyte	Microphyll	81.68
228	*Colchicum luteum*	Colchicaceae	Herb	Geophyte	Nanophyll	81.55
229	*Convolvulus arvensis*	Convolvulaceae	Herb	Therophyte	Mesophyll	81.07
230	*Corchorus tridens*	Malvaceae	Herb	Therophyte	Microphyll	79.39
231	*Crotalaria medicaginea*	Papilionaceae	Herb	Therophyte	Nanophyll	79.05
232	*Cuscuta capitata*	Cuscutaceae	Herb	Phanerophyte	Aphyllous	78.87
233	*Cuscuta reflexa*	Cuscutaceae	Herb	Phanerophyte	Aphyllous	77.87
234	*Cymbopogon distans*	Poaceae	Herb	Hemicryptophyte	Leptophyll	76.69
235	*Cymbopogon jwarancusa*	Poaceae	Herb	Hemicryptophyte	Leptophyll	76.47

236	*Cymbopogon martini*	Poaceae	Herb	Hemicryptophyte	Leptophyll	74.83
237	*Cynanchum auriculatum*	Apocynaceae	Herb	Therophyte	Microphyll	74.41
238	*Cynodon dactylon*	Poaceae	Herb	Hemicryptophyte	Nanophyll	72.40
239	*Cynoglossum lanceolatum*	Boraginaceae	Herb	Hemicryptophyte	Microphyll	70.99
240	*Cyperus cyperoides*	Cypraceae	Herb	Geophyte	Microphyll	70.70
241	*Cyperus niveus*	Cypraceae	Herb	Geophyte	Nanophyll	68.96
242	*Cyperus rotundus*	Cypraceae	Herb	Geophyte	Nanophyll	68.72
243	*Datura metel*	Solanaceae	Herb	Therophyte	Mesophyll	68.15
244	*Dichanthium annulatum*	Poaceae	Herb	Hemicryptophyte	Nanophyll	68.04
245	*Dichanthium foveolatum*	Poaceae	Herb	Therophyte	Nanophyll	67.89
246	*Dicliptera bupleuroides*	Acanthaceae	Herb	Hemicryptophyte	Mesophyll	66.96
247	*Digitaria ciliaris*	Poaceae	Herb	Therophyte	Nanophyll	66.48
248	*Dioscorea deltoidea*	Dioscoreaceae	Herb	Geophyte	Mesophyll	65.85
249	*Duchesnea indica*	Rosaceae	Herb	Hemicryptophyte	Microphyll	65.58
250	*Echinops echinatus*	Asteraceae	Herb	Therophyte	Macrophyll	65.01
251	*Eleusine indica*	Poaceae	Herb	Therophyte	Nanophyll	61.59
252	*Eragrostis minor*	Poaceae	Herb	Therophyte	Nanophyll	61.56
253	*Erigeron bonariensis*	Asteraceae	Herb	Therophyte	Nanophyll	60.55
254	*Erigeron canadensis*	Asteraceae	Herb	Therophyte	Nanophyll	60.47
255	*Erigeron Spp*	Asteraceae	Herb	Therophyte	Microphyll	58.49

256	*Eriophorum comosum*	Cyperaceae	Herb	Hemicryptophyte	Leptophyll	57.12
257	*Eruca sativa*	Brassicaceae	Herb	Hemicryptophyte	Leptophyll	55.35
258	*Eryngium coeruleum*	Apiaceae	Herb	Therophyte	Nanophyll	53.92
259	*Eulaliopsis binata*	Poaceae	Herb	Hemicryptophyte	Microphyll	53.05
260	*Euphorbia cornigera*	Euphorbiaceae	Herb	Therophyte	Leptophyll	52.67
261	*Euphorbia indica*	Euphorbiaceae	Herb	Therophyte	Nanophyll	52.37
262	*Euphorbia prostrata*	Euphorbiaceae	Herb	Therophyte	Nanophyll	52.32
263	*Euphorbia wallichii*	Euphorbiaceae	Herb	Therophyte	Nanophyll	52.31
264	*Evolvulus alsinoides*	Convolvulaceae	Herb	Therophyte	Microphyll	52.04
265	*Festuca hartmannii*	Poaceae	Herb	Therophyte	Nanophyll	51.45
266	*Ficus pumila*	Moraceae	Herb	Nanophanerophyte	Mesophyll	51.37
267	*Filipendula ulmaria*	Rosaceae	Herb	Hemicryptophyte	Microphyll	51.00
268	*Fimbristylis squarrosa*	Cyperaceae	Herb	Hemicryptophyte	Microphyll	50.87
269	*Fragaria nubicola*	Rosaceae	Herb	Hemicryptophyte	Nanophyll	50.74
270	*Fumaria indica*	Fumariaceae	Herb	Therophyte	Leptophyll	48.97
271	*Galium aparine*	Rubiaceae	Herb	Therophyte	Nanophyll	47.59
272	*Galium asperifolium var. asperifolium*	Rubiaceae	Herb	Therophyte	Nanophyll	47.58
273	*Galium asperifolium var. obovatum*	Rubiaceae	Herb	Therophyte	Nanophyll	47.27

274	*Galium asperuloides*	Rubiaceae	Herb	Therophyte	Leptophyll	46.73
275	*Galium borale*	Rubiaceae	Herb	Therophyte	Leptophyll	45.71
276	*Galium eleganse*	Rubiaceae	Herb	Therophyte	Nanophyll	45.49
277	*Gentiana argentea*	Gentianaceae	Herb	Geophyte	Nanophyll	44.27
278	*Gentiana kurroo*	Gentianaceae	Herb	Therophyte	Leptophyll	43.91
279	*Gentiana olivieri*	Gentianaceae	Herb	Therophyte	Leptophyll	42.82
280	*Geranium collinum*	Geraniaceae	Herb	Therophyte	Microphyll	42.74
281	*Geranium himalayense*	Geraniaceae	Herb	Chamaephyte	Microphyll	42.38
282	*Geranium lucidum*	Geraniaceae	Herb	Therophyte	Mesophyll	41.30
283	*Geranium nepalense*	Geraniaceae	Herb	Chamaephyte	Microphyll	40.81
284	*Geranium rotundifolium*	Geraniaceae	Herb	Therophyte	Nanophyll	40.46
285	*Geranium wallichianum*	Geraniaceae	Herb	Therophyte	Mesophyll	40.42
286	*Gerbera gossypina*	Asteraceae	Herb	Hemicryptophyte	Microphyll	40.28
287	*Gloriosa superba*	Colchicaceae	Herb	Microphanerophyte	Nanophyll	39.85
288	*Goodyera repens*	Orchidaceae	Herb	Hemicryptophyte	Nanophyll	39.60
289	*Hedera nepalensis*	Araliaceae	Herb	Nanophanerophyte	Mesophyll	39.48
290	*Helictotrichon junghuhnii*	Poaceae	Herb	Hemicryptophyte	Leptophyll	39.45
291	*Heracleum candicans*	Apiaceae	Herb	Hemicryptophyte	Leptophyll	38.54
292	*Heteropogon contortus*	Poaceae	Herb	Hemicryptophyte	Microphyll	37.63
293	*Hiptage benghalensis*	Malpighiaceae	Herb	Phanerophyte	Nanophyll	37.03

294	*Hypericum perforatum*	Hypericaceae	Herb	Phanerophyte	Mesophyll	36.67
295	*Impatiens bicolor*	Balsaminaceae	Herb	Therophyte	Mesophyll	36.27
296	*Impatiens brachycentra*	Balsaminaceae	Herb	Therophyte	Microphyll	36.13
297	*Impatiens edgeworthii*	Balsaminaceae	Herb	Therophyte	Mesophyll	35.67
298	*Imperata cylindrica*	Poaceae	Herb	Geophyte	Leptophyll	34.24
299	*Ipomoea nil*	Convolvulaceae	Herb	Therophyte	Microphyll	33.56
300	*Ipomoea purpurea*	Convolvulaceae	Herb	Therophyte	Mesophyll	33.54
301	*Juncus articulatus*	Juncaceae	Herb	Hemicryptophyte	Microphyll	33.51
302	*Juncus maritimus*	Juncaceae	Herb	Chamaephyte	Microphyll	33.50
303	*Kobresia laxa*	Cyperaceae	Herb	Geophyte	Nanophyll	33.46
304	*Lactuca dissecta*	Asteraceae	Herb	Hemicryptophyte	Nanophyll	32.91
305	*Launaea capitata*	Asteraceae	Herb	Therophyte	Microphyll	32.78
306	*Launaea procumbens*	Asteraceae	Herb	Therophyte	Nanophyll	32.51
307	*Lepidium sativum*	Brassicaceae	Herb	Geophyte	Nanophyll	31.90
308	*Leucanthemum vulgare*	Asteraceae	Herb	Hemicryptophyte	Leptophyll	31.86
309	*Leucas cephalotes*	Lamiaceae	Herb	Therophyte	Microphyll	30.75
310	*Lolium perenne*	Poaceae	Herb	Therophyte	Nanophyll	30.25
311	*Lolium persicum*	Poaceae	Herb	Therophyte	Nanophyll	30.12
312	*Lolium temulentum*	Poaceae	Herb	Therophyte	Nanophyll	30.02
313	*Lotus corniculatus*	Papilionaceae	Herb	Hemicryptophyte	Leptophyll	29.64

314	*Malvastrum coromandelianum*	Malvaceae	Herb	Hemicryptophyte	Nanophyll	29.30
315	*Medicago laciniata*	Papilionaceae	Herb	Therophyte	Nanophyll	28.68
316	*Medicago lupulina*	Papilionaceae	Herb	Therophyte	Nanophyll	28.07
317	*Medicago minima*	Papilionaceae	Herb	Therophyte	Nanophyll	27.94
318	*Medicago polymorpha*	Papilionaceae	Herb	Therophyte	Nanophyll	27.93
319	*Melilotus indicus*	Papilionaceae	Herb	Therophyte	Nanophyll	27.54
320	*Mentha arvensis*	Lamiaceae	Herb	Geophyte	Nanophyll	27.52
321	*Mentha longifolia*	Lamiaceae	Herb	Geophyte	Mesophyll	27.44
322	*Mentha spicata*	Lamiaceae	Herb	Geophyte	Mesophyll	27.36
323	*Micromeria biflora*	Lamiaceae	Herb	Therophyte	Leptophyll	26.86
324	*Microstegium ciliatum*	Poaceae	Herb	Therophyte	Microphyll	26.85
325	*Microstegium nudum*	Poaceae	Herb	Therophyte	Microphyll	26.76
326	*Nasturtium officinale*	Brassicaceae	Herb	Geophyte	Nanophyll	26.62
327	*Nepeta hindostana*	Lamiaceae	Herb	Therophyte	Microphyll	26.41
328	*Ocimum basilicum*	Lamiaceae	Herb	Chamaephyte	Nanophyll	26.41
329	*Oenothera rosea*	Onagraceae	Herb	Hemicryptophyte	Microphyll	25.99
330	*Onosma hypoleucum*	Boraginaceae	Herb	Nanophanerophyte	Nanophyll	25.16
331	*Oplismenus compositus*	Poaceae	Herb	Nanophanerophyte	Nanophyll	25.08
332	*Oplismenus undulatifolius*	Poaceae	Herb	Nanophanerophyte	Nanophyll	24.91
333	*Origanum vulgare*	Lamiaceae	Herb	Therophyte	Nanophyll	24.83

334	*Oxalis corniculata*	Oxalidaceae	Herb	Therophyte	Nanophyll	24.67
335	*Paeonia emodi*	Paeoniaceae	Herb	Geophyte	Nanophyll	24.51
336	*Papaver somniferum*	Papaveraceae	Herb	Nanophanerophyte	Mesophyll	24.40
337	*Parthenium hysterophorus*	Asteraceae	Herb	Hemicryptophyte	Nanophyll	24.30
338	*Parthenocissus semicordata*	Vitaceae	Herb	Nanophanerophyte	Nanophyll	23.95
339	*Pergularia daemia*	Apocynaceae	Herb	Hemicryptophyte	Microphyll	23.95
340	*Persicaria barbata*	Polygonaceae	Herb	Therophyte	Nanophyll	23.58
341	*Persicaria nepalensis*	Polygonaceae	Herb	Therophyte	Nanophyll	22.78
342	*Phalaris minor*	Poaceae	Herb	Therophyte	Nanophyll	22.59
343	*Phyla nodiflora*	Verbenaceae	Herb	Nanophanerophyte	Nanophyll	22.25
344	*Phyllanthus fraternus*	Euphorbiaceae	Herb	Therophyte	Leptophyll	22.09
345	*Pimpinella acuminata*	Apiaceae	Herb	Therophyte	Mesophyll	21.72
346	*Pimpinella diversifolia*	Apiaceae	Herb	Therophyte	Mesophyll	21.51
347	*Piptatherum laterale*	Poaceae	Herb	Hemicryptophyte	Nanophyll	21.44
348	*Plantago amplexicaulis*	Plantaginaceae	Herb	Therophyte	Nanophyll	20.70
349	*Plantago lanceolata*	Plantaginaceae	Herb	Therophyte	Microphyll	20.54
350	*Plantago major*	Plantaginaceae	Herb	Geophyte	Macrophyll	20.54
351	*Plantago ovate*	Plantaginaceae	Herb	Therophyte	Nanophyll	20.50
352	*Poa annua*	Poaceae	Herb	Hemicryptophyte	Leptophyll	20.30
353	*Poa attenuate*	Poaceae	Herb	Hemicryptophyte	Leptophyll	19.85

354	*Poa pratensis*	Poaceae	Herb	Nanophanerophyte	Microphyll	19.53
355	*Poa stewartiana*	Poaceae	Herb	Nanophanerophyte	Microphyll	19.43
356	*Sinopodophyllum hexandrum*	Berberidaceae	Herb	Hemicryptophyte	Microphyll	19.38
357	*Polygala abyssinica*	Polygalaceae	Herb	Chamaephyte	Nanophyll	19.36
358	*Polygala erioptera*	Polygalaceae	Herb	Therophyte	Microphyll	19.29
359	*Polygonum aviculare*	Polygonaceae	Herb	Therophyte	Leptophyll	19.16
360	*Polygonatum multiflorum*	Asparagaceae	Herb	Therophyte	Nanophyll	18.96
361	*Polygonatum verticillatum*	Asparagaceae	Herb	Therophyte	Nanophyll	18.92
362	*Polypogon fugax*	Poaceae	Herb	Hemicryptophyte	Nanophyll	18.88
363	*Polypogon monspeliensis*	Poaceae	Herb	Therophyte	Microphyll	18.33
364	*Porana paniculata*	Convolvulaceae	Herb	Hemicryptophyte	Nanophyll	18.27
365	*Potentilla reptans*	Rosaceae	Herb	Therophyte	Mesophyll	18.18
366	*Potentilla supina*	Rosaceae	Herb	Chamaephyte	Leptophyll	17.87
367	*Lactuca brunoniana*	Asteraceae	Herb	Hemicryptophyte	Nanophyll	17.49
368	*Prunella vulgaris*	Lamiaceae	Herb	Hemicryptophyte	Mesophyll	17.43
369	*Ranunculus arvensis*	Ranunculaceae	Herb	Therophyte	Nanophyll	17.36
370	*Ranunculus hirtellus*	Ranunculaceae	Herb	Chamaephyte	Nanophyll	17.09
371	*Ranunculus laetus*	Ranunculaceae	Herb	Geophyte	Nanophyll	16.81
372	*Ranunculus repens*	Ranunculaceae	Herb	Geophyte	Nanophyll	16.75
373	*Ranunculus sceleratus*	Ranunculaceae	Herb	Geophyte	Nanophyll	16.56

374	*Rhynchosia minima*	Papilionaceae	Herb	Nanophanerophyte	Microphyll	16.48
375	*Ribes alpestre*	Grossulariaceae	Herb	Nanophanerophyte	Nanophyll	16.46
376	*Rubia cordifolia*	Rubiaceae	Herb	Hemicryptophyte	Microphyll	16.44
377	*Rubia himalayensis*	Rubiaceae	Herb	Geophyte	Microphyll	16.05
378	*Rumex dentatus*	Polygonaceae	Herb	Therophyte	Mesophyll	15.74
379	*Rumex nepalensis*	Polygonaceae	Herb	Hemicryptophyte	Mesophyll	15.72
380	*Saccharum bengalense*	Poaceae	Herb	Chamaephyte	Nanophyll	15.64
381	*Saccharum spontaneum*	Poaceae	Herb	Chamaephyte	Macrophyll	15.39
382	*Salvia moocroftiana*	Lamiaceae	Herb	Therophyte	Macrophyll	15.30
383	*Himalaiella heteromalla*	Asteraceae	Herb	Therophyte	Microphyll	15.21
384	*Saussurea costus*	Asteraceae	Herb	Chamaephyte	Mesophyll	15.07
385	*Schoenoplectus spp*	Cyperaceae	Herb	Hemicryptophyte	Nanophyll	14.96
386	*Scutellaria linearis*	Lamiaceae	Herb	Hemicryptophyte	Leptophyll	14.82
387	*Senecio analogus*	Asteraceae	Herb	Therophyte	Microphyll	14.74
388	*Setaria pumila*	Poaceae	Herb	Therophyte	Nanophyll	14.49
389	*Setaria viridis*	Poaceae	Herb	Therophyte	Nanophyll	14.49
390	*Sida cordata var. cordata*	Malvaceae	Herb	Hemicryptophyte	Nanophyll	14.44
391	*Sida cordifolia*	Malvaceae	Herb	Therophyte	Nanophyll	14.27
392	*Sigesbeckia orientalis*	Asteraceae	Herb	Nanophanerophyte	Leptophyll	13.87
393	*Silybum marianum*	Asteraceae	Herb	Chamaephyte	Mesophyll	13.83

394	*Smilax aspera*	Smilacaceae	Herb	Nanophanerophyte	Microphyll	13.66
395	*Smilax vaginata*	Smilacaceae	Herb	Nanophanerophyte	Microphyll	13.48
396	*Solanum nigrum var. nigrum*	Solanaceae	Herb	Therophyte	Microphyll	13.37
397	*Solanum nigrum var. villosum*	Solanaceae	Herb	Therophyte	Microphyll	13.21
398	*Solanum surattense*	Solanaceae	Herb	Hemicryptophyte	Nanophyll	12.81
399	*Sonchus arvensis*	Asteraceae	Herb	Therophyte	Mesophyll	12.57
400	*Sonchus asper*	Asteraceae	Herb	Therophyte	Mesophyll	12.45
401	*Sonchus oleraceous*	Asteraceae	Herb	Therophyte	Microphyll	12.36
402	*Stachys melissifolia*	Lamiaceae	Herb	Hemicryptophyte	Nanophyll	11.25
403	*Swertia angustifolia*	Gentianaceae	Herb	Chamaephyte	Nanophyll	11.01
404	*Swertia alata*	Gentianaceae	Herb	Chamaephyte	Nanophyll	10.92
405	*Swertia ciliate*	Gentianaceae	Herb	Therophyte	Mesophyll	10.59
406	*Swertia cordata*	Gentianaceae	Herb	Therophyte	Mesophyll	10.55
407	*Swertia paniculata*	Gentianaceae	Herb	Therophyte	Microphyll	10.38
408	*Swertia petiolata*	Gentianaceae	Herb	Therophyte	Microphyll	10.22
409	*Tagetes minuta*	Asteraceae	Herb	Therophyte	Microphyll	10.16
410	*Taraxacum officinale*	Asteraceae	Herb	Geophyte	Mesophyll	10.11
411	*Teucrium royleanum*	Lamiaceae	Herb	Nanophanerophyte	Nanophyll	9.98
412	*Thalictrum foliolosum*	Ranunculaceae	Herb	Nanophanerophyte	Nanophyll	9.61
413	*Themeda anathera*	Poaceae	Herb	Hemicryptophyte	Nanophyll	9.59

414	*Thymus linearis*	Lamiaceae	Herb	Hemicryptophyte	Nanophyll	9.40
415	*Tinospora sinensis*	Menispermaceae	Herb	Nanophanerophyte	Nanophyll	9.39
416	*Torilis leptophylla*	Apiaceae	Herb	Therophyte	Nanophyll	9.34
417	*Tribulus terrestris*	Zygophyllaceae	Herb	Therophyte	Leptophyll	9.24
418	*Trichodesma indicum*	Boraginaceae	Herb	Therophyte	Microphyll	9.20
419	*Trifolium repens*	Papilionaceae	Herb	Geophyte	Nanophyll	8.60
420	*Trifolium spp*	Papilionaceae	Herb	Therophyte	Nanophyll	8.60
421	*Trigonella spp*	Papilionaceae	Herb	Nanophanerophyte	Nanophyll	8.32
422	*Trillium govanianum*	Trilliaceae	Herb	Chamaephyte	Mesophyll	8.06
423	*Tussilago farfara*	Asteraceae	Herb	Geophyte	Macrophyll	7.83
424	*Tylophora hirsuta*	Apocynaceae	Herb	Nanophanerophyte	Nanophyll	7.80
425	*Urochloa panicoides*	Poaceae	Herb	Nanophanerophyte	Nanophyll	7.80
426	*Urtica dioica*	Urticaceae	Herb	Therophyte	Microphyll	7.46
427	*Urtica pilulifera*	Urticaceae	Herb	Phanerophyte	Microphyll	7.41
428	*Valeriana jatamansi*	Valerianaceae	Herb	Geophyte	Microphyll	7.39
429	*Verbascum thapsus*	Scrophulariaceae	Herb	Geophyte	Macrophyll	7.25
430	*Verbena officinalis*	Verbenaceae	Herb	Therophyte	Microphyll	7.20
431	*Glandularia aristigera*	Verbenaceae	Herb	Nanophanerophyte	Nanophyll	7.12
432	*Veronica persica*	Scrophulariaceae	Herb	Geophyte	Nanophyll	7.12
433	*Veronica polita*	Scrophulariaceae	Herb	Therophyte	Nanophyll	7.03

434	*Veronica spp*	Scrophulariaceae	Herb	Therophyte	Nanophyll	7.00
435	*Chrysopogon zizanioides*	Poaceae	Herb	Microphanerophyte	Nanophyll	6.97
436	*Vinca major*	Apocynaceae	Herb	Geophyte	Nanophyll	6.55
437	*Vincetoxicum arnottianum*	Apocynaceae	Herb	Chamaephyte	Mesophyll	6.39
438	*Viola canescense*	Violaceae	Herb	Therophyte	Microphyll	6.09
439	*Viola odorata*	Violaceae	Herb	Therophyte	Microphyll	5.70
440	*Xanthium strumarium*	Asteraceae	Herb	Therophyte	Mesophyll	5.31
441	*Zeuxine strateumatica*	Orchidaceae	Herb	Therophyte	Microphyll	5.13
442	*Adiantum caudatum*	Pteridaceae	Herb	Geophyte	Macrophyll	4.85
443	*Adiantum capillus-veneris*	Pteridaceae	Herb	Geophyte	Nanophyll	4.47
444	*Adiantum incisum*	Pteridaceae	Herb	Geophyte	Nanophyll	4.36
445	*Adiantum venustum*	Pteridaceae	Herb	Geophyte	Nanophyll	4.30
446	*Dryopteris ramosa*	Dryopteridaceae	Herb	Hemicryptophyte	Macrophyll	4.15
447	*Dryopteris sieboldii*	Dryopteridaceae	Herb	Hemicryptophyte	Macrophyll	4.04
448	*Dryopteris stewartii*	Dryopteridaceae	Herb	Hemicryptophyte	Macrophyll	4.01
449	*Dryopteris spp*	Dryopteridaceae	Herb	Hemicryptophyte	Macrophyll	3.58
450	*Dryopteris wallichiana*	Dryopteridaceae	Herb	Geophyte	Mesophyll	3.42
451	*Pteris Vittata*	Pteridaceae	Herb	Geophyte	Mesophyll	2.82
452	*Pteris cretica*	Pteridaceae	Herb	Geophyte	Microphyll	2.81
453	*Equisetum debile*	Equisetaceae	Herb	Geophyte	Aphyllous	2.57

454	*Equisetum ramosissimum*	Equisetaceae	Herb	Geophyte	Aphyllous	2.41

7.2 Appendix 2: Five plant communities in the MFD

S.NO	***Plant Name***	**Community-01 defined by value of Regeneration**			**Community-02 defined by value of OM**			**Community-03 defined by value of CaCO3**			**Community-04 defined by value of EC**			**Community-05 defined by value of Clay**		
		Max Group	**IV**	**p ***	**Max Group**	**IV**	**p ***	**Max Group**	**IV**	**p ***	**Max Group**	**IV**	**p ***	**Max Group**	**IV**	**p ***
1	*Abies pindrow*	4	18.9	0.0274	1	14.5	0.2464	9	17.6	0.1516	6	9.1	0.3277	19	9.8	0.3781
2	*Acacia catechu*	3	1.9	0.7233	0	1.2	1	6	3.4	0.757	6	1.4	0.7862	6	12.3	0.3705
3	*Acacia modesta*	3	12.4	0.0888	0	14.7	0.082	13	20.2	0.1134	4	5.8	0.5769	14	12.6	0.2645
4	*Acacia nilotica*	3	6.8	0.3067	0	5.2	0.6191	22	16.4	0.1908	5	3	0.9002	18	13.2	0.2835
5	*Acer caesium*	3	6.2	0.1004	0	5.6	0.0976	8	7.7	0.5913	1	3.5	0.4273	25	5.3	0.8222
6	*Acer cappadocicum*	1	3.6	0.2749	0	3.2	0.7247	15	21.6	0.1742	7	3.7	0.3739	9	4.4	0.8152
7	*Aesculus indica*	4	24.6	0.011	0	11.4	0.6491	18	31.6	0.0248	6	22.8	0.001	15	19.1	0.1234
8	*Ailanthus altissima*	2	7.1	0.3337	0	7	0.4575	13	28.2	0.0566	1	2.6	0.9836	15	10	0.4135
9	*Albizia julibrissin*	3	2.6	0.8286	0	5.3	0.1698	15	18.7	0.2286	4	2.7	0.6679	9	9.6	0.4085
10	*Albizia lebbeck*	2	1.3	0.867	0	1.2	1	7	5.6	0.5609	6	2.7	0.3701	11	3.7	0.8642
11	*Albizia chinensis*	1	3.4	0.3883	0	3.2	0.7147	11	10	0.4665	6	4	0.2515	6	10.1	0.4243
12	*Albizia odoratissima*	3	3.1	0.4873	0	1.6	1	8	7.7	0.3489	1	1.7	1	25	12.7	0.2951
13	*Alstonia scholaris*	2	4.3	0.2505	0	3.2	0.7313	13	32.4	0.0684	5	1.1	0.7283	14	17.3	0.1252
14	*Bauhinia variegate*	3	1.4	0.9124	0	4	0.2893	6	2.9	0.8314	6	2	0.5551	6	7.9	0.6131
15	*Broussonetia papyrifera*	4	1.7	0.9592	1	2.5	0.8388	22	42.3	0.0072	7	2.5	0.7191	6	12.1	0.3181

16	*Cassia fistula*	2	7.7	0.1944	1	4.1	0.81	13	25.8	0.084	4	3.3	0.818	14	13.6	0.2456
17	*Cedrus deodara*	4	19.8	0.1032	1	18	0.4465	14	15.4	0.2715	6	11.3	0.4721	15	9.6	0.5483
18	*Celtis australis*	3	1.5	1	0	2.3	0.3651	7	5.6	0.5609	1	3.4	0.82	10	4.3	1
19	*Cornus macrophylla*	2	3.8	0.8112	1	5	0.6129	9	7.7	0.6861	7	4.9	0.4261	15	4.9	0.7902
20	*Cupressus sempervirens*	2	1.8	1	2	9	0.0556	2	11.7	0.4181	5	2.2	0.8376	18	28	0.0334
21	*Dalbergia sissoo*	3	1.7	0.8666	1	3.8	0.4273	2	4.6	0.7443	4	6	0.1234	19	15.8	0.181
22	*Diospyros lotus*	4	15	0.1498	1	12.1	0.5979	18	26.9	0.0592	6	9.8	0.3561	6	7.8	0.6987
23	*Ficus palmate*	1	4.4	0.5405	1	4.4	0.6699	9	10.4	0.4759	1	3.1	0.7261	18	14.7	0.21
24	*Ficus racemosa*	3	2.3	0.9606	2	11.1	0.074	11	16.2	0.2611	4	5.6	0.2677	8	14.5	0.1858
25	*Flacourtia indica*	2	1.8	0.6149	1	0.9	1	13	50	0.027	4	3.4	0.8122	15	25	0.0958
26	*Grewia optiva*	3	3.1	0.4691	0	1.6	1	3	3.8	1	5	8	0.0198	9	6.1	0.6237
27	*Ilex dipyrena*	1	5	0.12	1	1.9	0.6541	9	33.3	0.0712	5	2.1	0.3333	15	20.2	0.1186
28	*Juglans regia*	3	3.7	0.5119	2	2.8	0.872	15	12.2	0.3943	4	6.8	0.0964	19	6	0.7023
29	*Lannea coromandelica*	3	2.9	0.5513	0	11.4	0.0084	8	16.8	0.2733	2	2.1	0.8644	25	42.3	0.0016
30	*Melia azedarach*	3	1.4	0.9508	0	3.2	0.3683	14	14.4	0.2773	6	2	0.5623	9	11.5	0.3449
31	*Morus alba*	3	1.5	1	0	2.3	0.3611	10	5.3	0.6905	4	3.4	0.8194	7	5.9	0.5991
32	*Morus nigra*	2	2.6	0.5515	0	1.2	1	15	25.7	0.1066	6	5.4	0.1	9	6.1	0.6037
33	*Nyctanthes arbor-tristis*	2	1	1	0	4.5	0.2509	10	10.5	0.3869	4	6.9	0.1332	7	11.8	0.4163
34	*Olea paniculata*	3	15.2	0.0992	0	22.7	0.0262	13	48.3	0.003	4	7.3	0.6373	25	7.8	0.6851
35	*Prunus cornuta*	1	5	0.1174	1	1.9	0.6571	4	2.3	1	7	1.9	0.8232	12	9.3	0.5031
36	*Machilus duthiei*	1	4.9	0.13	1	1.9	0.6671	2	4.2	0.6227	2	2.1	0.97	15	25	0.0992
37	*Chamaerops humilis*	2	3.6	0.3071	1	1.9	0.6415	13	47.5	0.0138	1	2.2	0.9132	14	22.4	0.0718
38	*Phoenix sylvestris*	2	2.2	0.8296	0	2.2	1	2	5	0.8464	1	2	0.8696	18	34.2	0.0194
39	*Phyllanthus emblica*	3	6.8	0.2026	0	9.6	0.0916	8	18.2	0.1704	4	2.8	0.822	25	12.3	0.2446
40	*Picea smithiana*	1	13.5	0.01	1	5.1	0.3755	5	11.2	0.4389	7	2.6	0.756	15	7.4	0.5413
41	*Pinus roxburghii*	4	28.3	0.1036	2	55.4	0.0002	18	17.7	0.072	5	19.7	0.1426	29	16	0.089
42	*Pinus wallichiana*	1	27.8	0.0994	1	38.6	0.0354	5	27	0.061	6	15.3	0.6249	10	14	0.3897

43	*Pistacia chinensis ssp. Integerrima*	2	1.7	0.9682	0	3.6	0.6605	13	39.3	0.0138	1	2.2	0.857	15	10.2	0.4089
44	*Platanus orientalis*	2	4.3	0.2494	0	3.2	0.7243	8	2.3	0.955	7	3.6	0.3931	8	13.2	0.2673
45	*Populus alba*	3	4.6	0.2661	0	1.5	0.897	18	19.7	0.1796	5	7.2	0.0408	9	7.9	0.5141
46	*Populus ciliate*	4	9.2	0.0378	2	2.7	0.7189	22	96.3	0.0002	1	3.2	0.6025	6	30.1	0.0404
47	*Prunus armeniaca*	4	3.3	0.2821	1	0.9	1	22	50	0.0232	1	3.4	0.815	6	16.7	0.2468
48	*Pyrus calleryana*	3	2.8	0.9682	1	4.5	0.7584	7	6.9	0.7393	7	4.8	0.4369	10	11.3	0.2789
49	*Pyrus bourgaeana*	4	14.6	0.0356	1	7.2	0.6325	5	10	0.5347	6	8.7	0.1278	19	8.4	0.5555
50	*Pyrus pashia*	4	6.4	0.6903	2	22.4	0.0102	15	7.7	0.6917	6	3.6	0.9856	15	6.6	0.7181
51	*Quercus baloot*	4	5.1	0.132	1	3.8	0.4017	9	27.6	0.1046	1	3.4	0.4591	15	43.5	0.003
52	*Quercus robur*	4	12.8	0.0516	2	24.2	0.0036	3	11.4	0.4449	1	4.8	0.6235	11	8.5	0.5191
53	*Quercus glauca*	1	4.5	0.2593	1	2.8	0.6667	4	8.7	0.4057	7	1.6	0.7964	12	7.5	0.6127
54	*Quercus incana*	4	13.6	0.3189	1	13.1	0.7179	7	5.3	0.9756	6	14	0.0622	10	7.5	0.6847
55	*Quercus semecarpifolia*	3	3.1	0.5417	2	7.9	0.078	9	25	0.114	2	5.5	0.166	15	10.8	0.3167
56	*Rhamnus purpurea*	3	4.9	0.2517	2	2.3	0.8962	2	7.6	0.6183	4	3	0.6355	18	33.4	0.02
57	*Rhamnus triquetra*	1	2.2	0.8164	0	4.8	0.2893	11	5.3	0.779	6	3.1	0.5233	6	17.2	0.1288
58	*Rhus chinensis*	2	2.9	0.5735	1	2.4	1	2	6.8	0.6585	2	2.5	0.9038	7	5.4	0.826
59	*Rhus punjabensis*	2	1.3	1	0	2.8	0.7782	9	16.4	0.2575	5	3.4	0.3183	15	14.1	0.1856
60	*Rhus succedanea var. himalaica*	4	2.2	0.7393	1	1.9	0.6537	9	19	0.2122	1	1.8	0.944	15	21.3	0.0622
61	*Robinia pseudo-acacia*	4	2.2	0.7055	0	2.5	0.7169	22	43.3	0.0198	6	2	0.769	6	9.8	0.4129
62	*Salix babylonica*	4	3.3	0.2821	1	0.9	1	22	50	0.0232	1	3.4	0.815	6	16.7	0.2468
63	*Salix tetrasperma*	1	3.5	0.3843	1	2.8	0.6779	3	4.9	0.6185	5	1.5	0.5305	12	6.7	0.7107
64	*Sapindus mukorossi*	2	1	1	0	1.6	1	15	33.3	0.0604	6	2.1	0.4329	9	5.8	0.6311
65	*Taxus wallichiana*	1	4.4	0.6785	2	6.1	0.3807	9	11	0.4549	4	6.4	0.1712	15	6.4	0.5769
66	*Thuja orientalis*	4	2.5	0.7411	0	3.1	0.7051	2	8.7	0.5867	1	2.2	0.8426	18	28.1	0.0414
67	*Toona ciliate*	3	3.3	0.4209	0	7.5	0.148	15	18.7	0.2276	1	2.2	0.8316	15	9.6	0.3503
68	*Ulmus wallichiana*	4	1.4	1	0	3.2	0.7217	11	9.1	0.5247	5	1.1	0.8242	9	4.3	0.8302
69	*Wendlandia heynei*	3	1.2	1	1	4.7	0.2803	6	9.8	0.4807	1	3.3	0.4665	6	26.1	0.0642

70	*Xylosma longifolium*	3	3.3	0.4187	0	3.1	0.7113	15	18.8	0.2172	7	2.5	0.6943	25	4.9	0.87
71	*Andrachne cordifolia*	1	2.8	0.5751	1	1.8	0.929	2	5.5	0.6843	1	1.4	0.875	15	14.3	0.231
72	*Aristolochia punjabensis*	4	2.2	0.8698	1	5.2	0.3775	15	15.5	0.2745	7	3.4	0.5669	8	4	0.9292
73	*Artemisia vulgaris*	3	4.8	0.2008	0	2.8	0.7714	9	19.8	0.2166	4	2.7	0.7602	15	18.5	0.0688
74	*Barleria cristata*	2	10.7	0.4013	0	11.4	0.5509	8	15.1	0.238	4	6	0.8956	25	14.4	0.1536
75	*Berberis aristata*	4	6.4	0.8186	1	12.4	0.2246	14	13.2	0.3327	6	11.7	0.0604	19	7.3	0.6583
76	*Berberis calliobotrys*	4	30.5	0.021	2	31.9	0.07	18	27.4	0.0626	6	13.6	0.5825	15	17.4	0.1642
77	*Betula utilis*	4	5.2	0.1302	1	2.8	0.6753	3	4.6	0.6451	6	5.2	0.1254	12	7.1	0.6721
78	*Buddleja crispa*	4	10.7	0.0212	1	5.7	0.2178	22	95	0.0002	6	4	0.4243	6	28.9	0.0384
79	*Buxus papillosa*	2	3.6	0.3021	1	1.9	0.6597	13	47.3	0.0108	4	2	0.7964	15	25	0.0958
80	*Buxus wallichiana*	2	3.6	0.2312	1	1.9	0.8244	13	48.6	0.0108	4	2.5	0.7964	15	25	0.0958
81	*Caesalpinia decapetala*	4	10	0.0272	2	4.5	0.1908	10	7	0.5629	6	1.8	0.5483	11	5.3	0.8448
82	*Calotropis procera*	3	4.5	0.4679	0	6.3	0.2763	15	15.3	0.3061	2	3.2	0.7606	25	15.9	0.1796
83	*Carissa spinarum*	3	28.9	0.075	0	40.5	0.0244	11	12.9	0.4729	4	23.2	0.0168	29	13.6	0.2833
84	*Colebrookea oppositifolia*	3	10.6	0.1096	2	6	0.6663	14	7.7	0.6977	5	10.9	0.0546	12	10.9	0.3459
85	*Coriaria nepalensis*	2	2.6	0.5485	1	2.8	0.6803	10	6.9	0.5727	6	5.1	0.1488	7	2.2	0.9736
86	*Cotoneaster nummularia*	3	1.5	1	1	0.9	1	3	3.8	1	4	3.4	0.8166	10	4.3	1
87	*Cotinus coggygria*	4	1.7	1	2	4.8	0.169	2	10.3	0.4493	5	1.4	0.7489	13	2	1
88	*Cryptolepis dubia*	3	4.8	0.3263	1	2.8	0.7459	13	23.8	0.121	1	7.3	0.0724	6	15.6	0.1668
89	*Daphne mucronata*	2	2.7	0.763	0	4.3	0.4539	13	23.1	0.1154	1	3.3	0.7037	15	5.6	0.7435
90	*Daphne papyracea*	4	16.1	0.046	1	12	0.3479	15	10.6	0.4365	4	5.7	0.8492	15	6.7	0.7994
91	*Debregeasia saeneb*	4	2.8	0.6077	2	17	0.0042	9	15.3	0.2955	4	6.2	0.1074	15	12.4	0.2192
92	*Desmodium elegans*	1	5.4	0.3113	0	3.1	0.826	11	5	0.8662	2	3.7	0.5329	29	14.5	0.1966
93	*Deutzia staminea*	4	1.7	1	1	2.8	0.6705	10	7.7	0.5453	6	1.4	0.8096	12	9.3	0.5073
94	*Dodonaea viscosa*	3	19.1	0.0608	0	16	0.3089	13	42.1	0.0132	4	12.5	0.1712	14	16.3	0.217
95	*Ehretia obtusifolia*	4	1.7	1	0	6.8	0.0454	15	24.8	0.1246	7	1.3	0.933	25	8.7	0.5491
96	*Elaeagnus umbellate*	1	7.6	0.24	1	5.3	0.6737	5	6	0.838	4	4.8	0.4901	15	7.4	0.5561

97	*Ephedra gerardiana*	3	1.9	0.7075	2	4.1	0.2611	8	4.9	0.5471	6	1.4	0.8194	25	12.3	0.3677
98	*Euonymus echinatus*	4	4.7	0.1346	2	18.7	0.0004	2	12.2	0.3483	5	1.9	0.5171	13	6.5	0.6853
99	*Himalrandia tetrasperma*	1	6.2	0.0976	2	6.2	0.0998	4	4.3	0.8348	7	3.7	0.4711	13	5.6	0.7187
100	*Hypericum dyeri*	4	4.4	0.1728	1	1.6	1	5	15	0.3149	6	8.7	0.0246	12	7.4	0.6435
101	*Hypericum oblongifolium*	1	5.7	0.1742	1	2.1	1	7	4	0.8852	1	2.5	0.7828	15	13.8	0.2028
102	*Indigofera hebepetala*	2	1	1	1	1.9	0.6559	8	4.5	0.6117	1	1.8	0.9406	17	3.7	0.7175
103	*Indigofera heterantha*	1	8.7	0.3819	1	7.9	0.5881	5	31.1	0.0542	5	4.4	0.8812	11	7.9	0.6661
104	*Indigofera himalayensis*	1	6.2	0.3075	1	11.3	0.0706	22	42.2	0.0108	6	4.5	0.4961	6	7	0.6233
105	*Indigofera linifolia*	3	3.1	0.7852	1	7.7	0.1808	22	31.6	0.0448	4	3.5	0.6439	15	5.5	0.7882
106	*Isodon rugosus*	4	6.7	0.0352	1	1.9	0.6571	2	3.6	0.775	4	2.1	0.6891	13	3.4	0.8474
107	*Jasminum humile*	1	5.8	0.826	1	8.1	0.6001	3	5.2	0.9174	1	4.8	0.8384	11	7.9	0.6457
108	*Jasminum mesnyi*	1	3.8	0.7904	1	6.1	0.4465	15	7.5	0.6921	1	2.8	0.9166	18	24.8	0.023
109	*Jasminum officinale*	1	1.7	0.9758	0	6.8	0.1718	22	22.6	0.1412	7	5.8	0.1382	18	25.3	0.0588
110	*Justicia adhatoda*	3	7.1	0.2803	0	7.9	0.2967	6	6.1	0.8136	1	4.4	0.6387	6	15.3	0.184
111	*Lantana camara*	2	11.8	0.0982	1	10.3	0.2591	13	45.1	0.0076	4	12.4	0.038	18	9	0.5263
112	*Lespedeza floribunda*	2	1.8	0.7868	1	3.8	0.4193	8	4.9	0.5383	4	1.1	0.9056	19	8.8	0.4741
113	*Lespedeza juncea*	3	13.2	0.1922	1	13	0.3335	13	6	0.9082	4	7.1	0.6969	15	6	0.8864
114	*Lonicera quinquelocularis*	4	11.6	0.1718	1	9.1	0.5809	14	8.8	0.6023	6	10.1	0.1124	19	10.5	0.3585
115	*Lonicera spp*	1	2.9	0.6523	0	6	0.24	9	9.5	0.5387	2	4.2	0.4031	15	11.1	0.2741
116	*Mallotus philippensis*	2	13.6	0.1798	0	19.9	0.0654	13	13.8	0.3351	5	10.4	0.2208	29	21.7	0.0524
117	*Gymnosporia royleana*	2	3.3	0.5829	0	8	0.0936	15	15.3	0.2811	6	4	0.3803	25	5.5	0.772
118	*Maytenus rufa*	3	4.8	0.3593	2	3.5	0.6317	6	6.5	0.7381	2	4.7	0.3231	25	11	0.2979
119	*Mimosa himalayana*	3	2.7	0.6943	0	11.4	0.0084	8	16.5	0.2404	2	1.5	0.8934	25	41	0.0028
120	*Myrsine africana*	4	23.6	0.5335	1	34.5	0.1762	5	17.2	0.15	6	17.7	0.4481	29	21.8	0.0132
121	*Nerium oleander*	2	5.8	0.3327	0	4.4	0.7762	13	27.1	0.0424	1	4.1	0.5803	18	15.8	0.1612
122	*Olea ferruginea*	3	10.3	0.188	1	9	0.3881	13	15.9	0.2649	4	7.1	0.3951	18	8.6	0.5539
123	*Rydingia limbata*	1	2.2	0.8564	2	2.7	0.8528	11	7	0.7077	5	2.5	0.5833	29	10.1	0.2875

124	*Punica granatum*	4	11.4	0.6015	0	13.5	0.6191	18	21.4	0.1176	6	9.3	0.5659	6	11.2	0.3767
125	*Reinwardtia indica*	4	6.8	0.3955	1	5.9	0.6397	14	16.4	0.163	6	14.4	0.0054	8	7	0.6227
126	*Rhamnus pentapomica*	2	4	0.2879	0	2.4	0.9154	13	39.6	0.0178	1	6.2	0.1244	18	21.3	0.0902
127	*Ricinus communis*	1	2.6	0.6483	0	4.8	0.3063	15	16.7	0.2505	6	6	0.0984	6	6.8	0.6857
128	*Rosa brunonii*	2	4.1	0.2376	1	1.4	1	14	13.6	0.3191	7	4.2	0.2352	17	7.8	0.6123
129	*Rosa chinensis*	1	2.8	0.5877	1	3.8	0.4109	9	28.8	0.094	5	3.5	0.4497	15	19.4	0.0876
130	*Rosa macrophylla*	4	17.7	0.0184	2	15.7	0.027	22	46.4	0.0134	6	3.2	0.935	18	14.6	0.2268
131	*Rosa moschata*	3	2.2	0.7237	1	2.8	0.6787	7	6.6	0.5767	6	2	0.5857	10	6.2	0.7093
132	*Rosa multiflora*	4	4.9	0.1314	1	2.8	0.6709	10	7.1	0.5489	6	1.6	0.7323	12	9.3	0.5073
133	*Rosa webbiana*	4	2.2	0.7548	1	2.8	0.6721	22	41.7	0.0302	1	5	0.2294	6	12.9	0.2559
134	*Rubus ellipticus*	1	10.9	0.878	2	37.7	0.0034	14	9.7	0.6189	5	20.8	0.004	29	30	0.0058
135	*Rubus fruticosus*	3	3.4	0.8814	1	3.8	0.893	18	44	0.014	5	6.1	0.3147	9	5.8	0.7868
136	*Rubus sanctus*	4	2.3	0.6127	1	1.9	0.6627	9	27.1	0.1244	6	2	0.6037	15	12.5	0.3553
137	*Rumex hastatus*	4	2.2	0.7325	0	1.6	1	2	3.6	0.7842	7	1.9	0.8028	8	12.5	0.3547
138	*Sageretia thea*	4	2	0.9788	0	3.8	0.7506	18	34.2	0.0524	1	4.9	0.4567	6	8.2	0.5723
139	*Salix acmophylla*	1	2.4	0.5417	1	2.8	0.6681	8	3.6	0.7958	6	1.7	0.6359	15	21.3	0.0652
140	*Sarcococca saligna*	4	20.6	0.0762	0	16.2	0.5853	18	27.3	0.0464	6	15.1	0.0974	9	11.3	0.4257
141	*Skimmia laureola*	4	2.3	0.6163	1	1.9	0.6481	10	10.5	0.3853	6	2.1	0.4301	19	12.2	0.2845
142	*Spermadictyon suaveolens*	3	3.1	0.4793	0	1.6	1	8	3.8	0.7253	1	1.7	1	9	5.5	0.6741
143	*Spiraea canescens*	3	2.8	0.4965	1	2.8	0.5997	5	8.6	0.4435	1	1.8	0.7574	10	3.8	0.7908
144	*Strobilanthes glutinosus*	4	4.6	0.1204	1	3.8	0.3675	14	12	0.3965	1	3.4	0.5061	19	11.6	0.3001
145	*Strobilanthes urticifolia*	4	9.5	0.5809	2	13.6	0.3095	5	33.8	0.0278	6	6	0.8806	18	10.6	0.4515
146	*Syringa emodi*	4	3.3	0.2803	2	6.2	0.0972	3	3.8	1	1	3.4	0.8216	13	5.6	0.7103
147	*Viburnum cotinifolium*	1	5.8	0.5877	2	9.5	0.2328	9	10.6	0.4827	2	3.9	0.8436	14	13.1	0.2284
148	*Viburnum grandiflorum*	4	30.6	0.0046	1	20.3	0.2472	18	14.5	0.3213	6	17.7	0.0264	19	12.2	0.2845
149	*Vitex negundo*	2	6.4	0.1302	2	9.1	0.0534	6	3.8	0.7487	2	5.3	0.183	12	4.7	0.852
150	*Wikstroemia canescens*	4	11.8	0.1524	1	14.5	0.1168	22	45.1	0.004	6	13	0.0276	6	7.1	0.6865

151	*Woodfordia fruticosa*	3	12.6	0.1496	0	11	0.4385	8	8.3	0.6627	2	5.5	0.8412	25	8.3	0.5945
152	*Zanthoxylum armatum*	1	11.3	0.2873	1	10.1	0.6751	9	11.5	0.3787	1	5.6	0.9052	15	5.9	0.8478
153	*Ziziphus jujube*	3	1.5	1	0	2.3	0.3665	4	4.3	0.8344	1	3.4	0.8302	29	25	0.0912
154	*Ziziphus nummularia*	2	1	1	2	12.5	0.0062	3	7.7	0.4367	6	2	0.5913	13	11.1	0.4197
155	*Ziziphus oxyphylla*	2	5.1	0.5125	1	7.4	0.2697	15	5.8	0.8408	7	2.5	0.9752	19	17	0.1486
156	*Achillea millefolium subsp. millefolium*	1	5.2	0.3547	1	7.3	0.1914	15	11.1	0.4547	7	1.9	0.9594	15	5	0.7994
157	*Achyranthes aspera*	3	2.8	0.6607	0	13.6	0.0122	8	24.2	0.1196	7	6.4	0.1078	25	58	0.0004
158	*Aconitum heterophyllum*	3	1.9	0.7039	1	2.8	0.6741	15	28.6	0.0984	7	1.3	0.9294	17	8.7	0.5715
159	*Ageratum conyzoides*	2	1.8	0.5983	1	0.9	1	15	5.8	0.8408	6	3.8	0.3001	11	5.3	0.8506
160	*Agrostis gigantean*	1	16.4	0.0064	0	5.3	0.5445	9	11.4	0.4353	7	3.3	0.7229	18	17.5	0.1458
161	*Agrostis stolonifera*	1	6.2	0.162	1	2.1	1	9	22.3	0.1512	1	2.5	0.7393	14	12.6	0.2332
162	*Agrostis viridis*	4	7.5	0.168	1	3.4	0.8706	22	26.1	0.0476	1	5.2	0.3149	29	15.8	0.1696
163	*Ainsliaea aptera*	1	4.6	0.2366	1	2.8	0.6791	5	17.4	0.2178	7	1.7	0.6201	12	8.3	0.5823
164	*Ajuga bracteosa*	4	7	0.2434	1	6.9	0.3311	2	16.1	0.2505	5	5.4	0.3439	11	7.5	0.5679
165	*Ajuga parviflora*	1	9.9	0.2414	2	23	0.0072	6	7.7	0.6843	2	9.8	0.1308	25	9.3	0.4989
166	*Alternanthera pungens*	2	6.1	0.236	0	7.5	0.1704	13	15.4	0.2691	1	4.5	0.4083	18	17.2	0.1532
167	*Amaranthus viridis*	4	1.7	0.856	1	2.8	0.6587	3	5.7	0.5919	5	2.1	0.5219	10	5.4	0.7706
168	*Anaphalis busua*	4	2.5	0.827	1	3.5	0.6745	9	12.4	0.3937	1	1.8	0.976	15	10.1	0.3177
169	*Anagallis arvensis*	4	12.7	0.1334	1	8.2	0.8228	7	6.6	0.8358	6	12.5	0.0378	18	8.4	0.5787
170	*Androsace rotundifolia*	4	18.6	0.0548	1	16	0.2891	7	8.9	0.6183	6	11.2	0.194	19	12.3	0.24
171	*Anisomeles indica*	2	2	0.7826	1	1.9	0.8576	2	2.9	0.9076	4	4.5	0.1684	17	12.5	0.3571
172	*Anthemis cotula*	3	5.6	0.4121	1	7.5	0.2513	9	8.2	0.6485	6	7.7	0.1126	18	19	0.11
173	*Apluda mutica*	1	9.1	0.1288	1	3.6	0.961	9	6.3	0.7862	4	5.9	0.3341	15	5.2	0.8034
174	*Aralia cachemirica*	4	2.3	0.6127	1	1.9	0.6627	9	27.1	0.1244	6	2	0.6037	15	12.5	0.3553
175	*Argemone Mexicana*	2	6.8	0.2022	2	6.1	0.4101	13	21.1	0.1272	4	3.5	0.7069	25	7.7	0.5141
176	*Argyrolobium roseum*	2	1.8	0.6079	1	0.9	1	7	5.6	0.5647	6	3.8	0.3053	10	4.3	1

177	*Aristida cynantha*	3	6.7	0.2957	2	7.5	0.3147	18	28	0.055	4	4.9	0.5147	6	6.5	0.6803
178	*Aristida mutabilis*	4	8.2	0.0662	2	14.8	0.0118	18	6.8	0.7217	4	3.6	0.5321	29	8	0.4963
179	*Artemisia scoparia*	2	2.6	0.6243	1	1.9	0.8626	8	9	0.5311	7	1.3	0.888	25	9.3	0.4631
180	*Arthraxon prionodes*	4	24.9	0.1016	2	33.4	0.0514	5	30.1	0.0274	5	12.3	0.862	10	10.5	0.6191
181	*Asclepias curassavica*	3	1.9	0.7007	1	2.8	0.6789	8	3.4	0.769	5	1.5	0.4911	12	9.3	0.5041
182	*Asparagus adscendens*	3	2.9	0.5291	0	9.1	0.0484	8	8.1	0.5743	7	5.1	0.1332	25	24.4	0.0742
183	*Asparagus capitatus subsp. gracilis*	3	3.3	0.5011	0	9.1	0.0496	8	8.8	0.5395	5	1.1	0.7708	25	24.4	0.0844
184	*Asparagus racemosus*	2	4.8	0.3563	1	3.1	0.6919	15	13.5	0.3593	6	4.3	0.3351	12	3.3	0.9852
185	*Atropa acuminate*	2	1.3	1	1	2.4	1	15	21.7	0.1812	7	3.1	0.4907	8	6.9	0.6841
186	*Bellis perennis*	4	11.3	0.1076	2	5.9	0.8252	9	34.1	0.0276	4	8	0.1926	15	27	0.0246
187	*Bergenia ciliata f. ciliata*	1	2.5	0.5967	1	1.9	0.8248	9	20.4	0.1654	2	2.7	1	17	5.3	0.6597
188	*Bergenia ciliata f. ligulata*	3	1.5	1	1	0.9	1	9	33.3	0.0712	4	3.4	0.8168	15	25	0.0934
189	*Bergenia stracheyi*	1	4.2	0.239	1	2.8	0.6713	15	28.6	0.0984	5	1.4	0.6107	17	2.2	0.966
190	*Bidens cernua*	3	3.1	0.5177	0	2.2	0.3979	10	4.5	0.7906	4	3.1	0.6895	7	4.5	0.8548
191	*Bidens tripartite*	4	3.3	0.2715	1	0.9	1	2	6.7	0.4507	1	3.4	0.8162	11	5.3	0.8498
192	*Persicaria amplexicaulis*	4	3	0.6203	1	1.6	1	9	20.4	0.1654	5	4.2	0.1716	15	13.6	0.2024
193	*Boerhavia procumbens*	2	7	0.4933	0	16.6	0.0464	13	15.7	0.1996	5	8.5	0.1524	29	10.1	0.3853
194	*Bothriochloa bladhii*	4	2	0.8652	0	5.5	0.2583	6	6.8	0.6519	4	1.6	0.9396	19	7.1	0.6119
195	*Bothriochloa ischaemum*	3	8.3	0.12	1	5.7	0.4615	8	8.4	0.6185	4	15.1	0.0046	18	6.1	0.7045
196	*Brachiaria eruciformis*	4	6.7	0.2701	1	6.2	0.4285	15	10.3	0.5141	7	6.5	0.2046	12	5.2	0.8136
197	*Brachiaria ramose*	2	3	0.9462	1	4.6	0.7538	2	5.1	0.904	1	13.5	0.0046	18	16.7	0.1548
198	*Bromus catharticus*	4	2.9	0.6117	1	3.5	0.5267	6	6.6	0.6845	1	2.6	0.6839	19	29.3	0.042
199	*Bromus japonicas*	2	1.3	0.8674	1	1.9	0.6501	4	2.7	0.9344	6	2.7	0.3271	18	47.1	0.0094
200	*Bromus ramosus*	4	2.6	0.7143	1	2.7	0.896	9	12.9	0.3661	5	2	0.938	15	8.8	0.4183
201	*Bupleurum lanceolatum*	4	7.5	0.0882	1	2.6	0.8216	9	9.7	0.5079	1	2.5	0.7059	15	8.6	0.4469
202	*Bupleurum longicaule*	3	4.6	0.221	1	2.8	0.6897	9	21.1	0.174	4	5.1	0.2036	15	20.2	0.09
203	*Calamagrostis emodensis*	3	1.5	1	1	0.9	1	4	4.3	0.8336	1	3.4	0.8176	12	12.5	0.2985

204	*Calamagrostis epigejos*	4	6.7	0.0352	1	1.9	0.8244	2	2.7	0.9212	4	2.5	0.6891	13	4	0.8134
205	*Cannabis sativa*	1	3.8	0.3377	0	3.2	0.5975	6	15.4	0.2478	1	2.3	0.6609	7	11.8	0.3463
206	*Cardiospermum halicacabum*	3	4.2	0.2965	1	5.7	0.1918	10	3.1	0.9092	1	2.9	0.5821	12	4.4	0.893
207	*Carex cruciate*	4	13.8	0.0904	1	7.2	0.9076	5	8.2	0.6717	6	12.7	0.031	9	9.4	0.4669
208	*Carex filicina*	4	30.1	0.011	2	35.5	0.0066	2	11.2	0.6793	6	17.6	0.134	11	13.2	0.5617
209	*Carex psychrophila*	3	1	1	1	1.9	0.6645	7	11.1	0.3449	7	2.5	0.5103	11	3.7	0.8444
210	*Carex schlagintweitiana*	4	16.2	0.065	1	9.3	0.8136	11	6	0.9066	6	14.5	0.0254	9	10.1	0.4451
211	*Carex sanguinea*	3	3.1	0.4793	0	1.6	1	8	3.8	0.7253	1	1.7	1	9	5.5	0.6741
212	*Carpesium abrotanoides*	4	2.7	0.5791	1	1.8	0.9408	9	27.1	0.096	2	1.9	0.9524	17	10.9	0.3505
213	*Carpesium nepalense*	4	5.9	0.058	2	18.7	0.0004	2	9.6	0.4681	1	1.3	1	13	6.8	0.6945
214	*Ceropegia macrantha*	4	13	0.0194	2	5.9	0.4385	10	4.2	0.9516	1	7	0.1228	19	19.4	0.1074
215	*Chenopodium album*	4	5.7	0.4123	1	4.6	0.9166	22	12.9	0.3783	1	3.5	0.8232	19	9.9	0.3677
216	*Chenopodium ambrosioides*	2	5.8	0.1908	2	2.4	0.7912	6	5.7	0.7241	2	1.5	0.9788	29	12.1	0.2997
217	*Chrysopogon gryllus*	4	6.4	0.1908	1	6.6	0.195	2	21.8	0.1664	6	2.5	0.801	10	6.8	0.6885
218	*Cichorium intybus*	4	2.2	0.9642	0	12.4	0.0258	18	21.1	0.1196	6	2.4	0.865	18	9.2	0.4973
219	*Cirsium arvense*	4	12.7	0.0098	2	13.9	0.0062	9	24.6	0.1174	1	4.9	0.2156	15	20.5	0.093
220	*Cissampelos pareira*	2	6.8	0.3805	0	7.6	0.4115	8	5.9	0.8428	4	10.1	0.0504	18	8.7	0.4691
221	*Cissus carnosa*	2	1.3	0.8646	1	1.9	0.6637	2	3.1	0.8606	4	6.9	0.1336	29	12.1	0.2997
222	*Clematis connate*	4	7	0.1236	1	5.7	0.2066	22	79.9	0.0012	6	2.8	0.6563	6	21.1	0.089
223	*Clematis gouriana*	4	7.8	0.1258	2	25.7	0.0004	14	7.7	0.6765	1	5.5	0.2561	19	20.1	0.1
224	*Clematis grata*	3	7.8	0.8438	2	9.7	0.7926	15	12.2	0.3261	7	12.2	0.066	13	6.4	0.8446
225	*Clematis graveolens*	1	5	0.3799	0	3.7	0.6371	7	3.4	0.958	1	3.4	0.6463	15	8.3	0.4763
226	*Clematis montana*	4	3.3	0.2775	0	2.3	0.3553	3	3.8	1	4	3.4	0.8178	17	6.2	0.4863
227	*Clinopodium umbrosum*	4	19.7	0.1658	1	17.4	0.6241	14	8.7	0.7872	6	10.9	0.7085	10	12.1	0.4255
228	*Colchicum luteum*	1	2.8	0.6219	1	2.4	1	15	14.6	0.3063	6	3.2	0.4153	12	5.5	0.8098
229	*Convolvulus arvensis*	1	4.3	0.7009	1	4.4	0.8154	14	5.2	0.8894	1	4.1	0.5289	19	13.2	0.246
230	*Corchorus tridens*	4	4.1	0.2645	0	2.9	0.6119	22	83	0.0004	1	1.9	0.8578	6	17.1	0.1142

231	*Crotalaria medicaginea*	2	8.5	0.3449	2	7.2	0.7147	13	75.1	0.0002	5	7.2	0.3653	14	7.3	0.6603
232	*Cuscuta capitata*	3	4.8	0.1936	1	4.7	0.2727	9	13.6	0.3555	7	3	0.5291	15	13.1	0.1832
233	*Cuscuta reflexa*	3	3.1	0.4597	1	1.9	0.6655	10	10.5	0.3809	4	1.9	0.8268	12	9.4	0.5029
234	*Cymbopogon distans*	4	8.9	0.0508	2	18.7	0.003	18	7.8	0.6357	6	9.5	0.0278	29	12.4	0.23
235	*Cymbopogon jwarancusa*	2	1.8	0.6155	1	0.9	1	14	20	0.1422	6	3.8	0.2961	11	5.3	0.8456
236	*Cymbopogon martini*	3	2.5	0.6323	2	3.3	0.5777	14	12	0.3967	4	3.9	0.2935	19	11.5	0.3049
237	*Cynanchum auriculatum*	4	4.2	0.5161	2	7.8	0.1486	2	6.6	0.7524	5	11.9	0.009	8	15.3	0.1892
238	*Cynodon dactylon*	4	30.1	0.0126	2	26.6	0.0768	18	33.7	0.0554	6	11.7	0.5625	9	14.2	0.3377
239	*Cynoglossum lanceolatum*	2	5	0.8202	0	6.8	0.6469	22	9.7	0.5285	5	10.1	0.0666	29	4.7	0.8834
240	*Cyperus cyperoides*	4	3.1	0.9576	2	21.2	0.0044	18	4.7	0.9232	5	7.8	0.1038	29	26.2	0.0178
241	*Cyperus niveus*	2	3.2	0.5237	2	11.1	0.0114	6	13.8	0.2941	2	3.3	0.4813	7	9	0.5057
242	*Cyperus rotundus*	4	2.6	0.5833	0	6.6	0.0632	18	73.7	0.001	6	2.4	0.6171	9	11.5	0.3519
243	*Datura metel*	3	4	0.5777	0	6	0.3515	15	13.8	0.3391	6	1.8	0.9496	29	7.4	0.5639
244	*Dichanthium annulatum*	1	10.5	0.3573	1	15.7	0.1462	6	5.9	0.9182	6	10	0.2913	7	4.3	0.9766
245	*Dichanthium foveolatum*	4	4.8	0.8758	0	8.4	0.3923	22	12.9	0.2945	1	5.6	0.5005	18	7	0.6529
246	*Dicliptera bupleuroides*	3	10.5	0.6315	0	19.7	0.1146	11	8.5	0.7011	4	8.6	0.6011	29	13.2	0.2549
247	*Digitaria ciliaris*	2	9.6	0.237	0	14.7	0.0796	2	10.4	0.5115	1	5.5	0.6613	18	10.7	0.3721
248	*Dioscorea deltoidea*	4	18.2	0.0614	0	13.8	0.4569	9	9.8	0.5165	4	11	0.2284	15	7.2	0.7337
249	*Duchesnea indica*	2	7.5	0.4735	2	6.8	0.7704	5	4.7	0.9468	6	5	0.7536	18	19.5	0.065
250	*Echinops echinatus*	2	4.5	0.6515	0	12.3	0.0392	8	7.3	0.7191	1	6.9	0.137	25	7.3	0.4775
251	*Eleusine indica*	4	1.8	0.8432	0	9.1	0.0458	10	4.9	0.7153	4	7.9	0.048	17	7.8	0.5675
252	*Eragrostis minor*	4	7.9	0.3027	2	6.5	0.6967	15	15.2	0.2294	6	11.3	0.0288	29	6.4	0.6759
253	*Erigeron bonariensis*	3	9.7	0.2412	0	21.3	0.0138	11	7.6	0.7299	7	5.9	0.5911	29	16.2	0.1506
254	*Erigeron Canadensis*	1	3.8	0.3631	1	1.3	1	6	13.2	0.3327	4	1.1	0.9704	19	10.7	0.3769
255	*Erigeron Spp*	3	8	0.0832	0	3.9	0.5103	11	4.6	0.8828	5	3.6	0.4359	29	19.4	0.1186
256	*Eriophorum comosum*	2	1.2	0.9116	0	4.1	0.2114	10	7.7	0.5163	4	5.5	0.1898	6	6.9	0.6377
257	*Eruca sativa*	2	2	0.789	0	3.2	0.7185	18	16.3	0.2533	5	4.3	0.1154	29	14.1	0.1836

258	*Eryngium coeruleum*	4	5.2	0.2112	1	3.2	0.5455	14	8.9	0.5643	1	2.3	0.7912	15	10.2	0.3365
259	*Eulaliopsis binata*	1	4.2	0.3309	2	8.6	0.0592	10	5.2	0.7664	5	2.2	0.7165	8	16.6	0.157
260	*Euphorbia cornigera*	4	3	0.5529	2	7.9	0.1216	18	10.9	0.4743	5	2.6	0.5237	29	12.6	0.2198
261	*Euphorbia indica*	4	5.5	0.2156	0	4.8	0.2759	3	10.3	0.4659	4	9.1	0.0334	11	4.7	0.8654
262	*Euphorbia prostrate*	2	7.8	0.3217	2	6.8	0.6539	13	11.8	0.3681	1	4.1	0.8638	29	4.8	0.8828
263	*Euphorbia wallichii*	4	10.6	0.1532	1	5.6	0.9204	11	5.9	0.8622	6	8.1	0.195	9	10.6	0.3585
264	*Evolvulus alsinoides*	2	2.4	0.8068	2	8.3	0.0892	13	30.2	0.0574	4	3	0.6427	8	13.6	0.198
265	*Festuca hartmannii*	4	10.4	0.0462	2	7.3	0.2136	9	9.6	0.5543	6	13.1	0.0052	15	5.5	0.7604
266	*Ficus pumila*	1	5.4	0.0766	1	1.9	0.6541	9	33.3	0.0712	5	2.5	0.2498	15	18.5	0.1396
267	*Filipendula ulmaria*	3	2.7	0.6901	2	3.8	0.4895	10	12.7	0.3715	2	3.1	0.6801	29	20.5	0.1008
268	*Fimbristylis squarrosa*	3	1.9	0.7055	0	1.2	1	13	41.3	0.0272	4	4.4	0.3919	15	20	0.1348
269	*Fragaria nubicola*	4	25.2	0.0426	2	50.1	0.0006	2	12.6	0.4673	5	12	0.5783	29	14.4	0.2705
270	*Fumaria indica*	2	3.6	0.4511	1	3.8	0.4365	8	9.8	0.4721	7	3.9	0.3559	19	10	0.4019
271	*Galium aparine*	1	13.6	0.1266	0	11.3	0.4139	5	28.1	0.0524	1	8.6	0.3641	6	4.1	0.9856
272	*Galium asperifolium var. asperifolium*	2	3.3	0.7437	1	4.7	0.5473	9	9.2	0.5735	7	5.8	0.1988	15	8	0.4115
273	*Galium asperifolium var. obovatum*	1	9.1	0.0176	1	2.4	1	3	3.4	0.8022	5	0.9	0.9658	12	5.8	0.7726
274	*Galium asperuloides*	4	17.1	0.0132	2	5	0.869	5	9.3	0.5773	6	12.4	0.0162	9	10.1	0.3775
275	*Galium borale*	1	4.6	0.6683	1	5.1	0.7099	7	11.6	0.4265	7	5.1	0.4367	19	4	0.912
276	*Galium elegance*	2	6.8	0.1496	2	13.9	0.0162	4	9.9	0.5361	2	5.1	0.2875	18	20.8	0.1068
277	*Gentiana argentea*	4	6.6	0.1584	2	3.2	0.6731	11	7.3	0.6675	6	5.9	0.117	12	3.7	0.964
278	*Gentiana kurroo*	3	2.8	0.5337	1	3.8	0.4169	5	12.9	0.3325	4	1.4	0.9184	10	5.9	0.7233
279	*Gentiana olivieri*	4	10.4	0.0548	2	5.6	0.5489	11	7.4	0.7177	6	10.3	0.032	9	14.6	0.2218
280	*Geranium collinum*	1	4.2	0.1696	1	1.9	0.6541	9	33.3	0.0712	4	2.2	0.914	15	22.4	0.0742
281	*Geranium himalayense*	3	2.5	0.7956	1	4.9	0.3705	15	16.9	0.2448	7	4.2	0.3849	17	3.5	0.965
282	*Geranium lucidum*	1	2	0.9546	1	4.9	0.3703	9	11.5	0.4291	7	1.9	0.9178	15	11	0.2482
283	*Geranium nepalense*	4	3.6	0.7177	1	4.2	0.6119	15	10.4	0.4915	7	5.5	0.2392	13	4.7	0.8598

284	*Geranium rotundifolium*	4	8.5	0.1482	1	3.7	0.7888	10	4.2	0.9062	6	6.1	0.4803	19	23	0.0794
285	*Geranium wallichianum*	1	6.2	0.1954	0	5.7	0.2723	18	49.4	0.0048	6	2	0.9308	15	10.6	0.3123
286	*Gerbera gossypina*	4	12.8	0.2635	1	18.6	0.1162	5	14.2	0.2817	6	12.7	0.092	15	16	0.1382
287	*Gloriosa superba*	3	1.5	1	1	0.9	1	2	6.7	0.4375	4	3.4	0.8178			
288	*Goodyera repens*	4	9.2	0.1098	2	5.6	0.5301	11	14	0.3291	6	4.8	0.4709	9	15.7	0.1596
289	*Hedera nepalensis*	3	8.2	0.9596	2	34.1	0.0034	18	32.1	0.0152	5	6.9	0.8924	11	7.9	0.6751
290	*Helictotrichon junghuhnii*	3	2.4	0.9454	1	4.9	0.5493	9	9.6	0.5583	6	4.9	0.3883	18	20.4	0.0816
291	*Heracleum candicans*	4	2.5	0.7924	1	3.2	0.5275	9	17.5	0.248	5	2.8	0.5059	15	10	0.3065
292	*Heteropogon contortus*	3	5.6	0.139	0	7.1	0.0834	15	16.3	0.246	2	1.5	0.9158	9	11.6	0.3097
293	*Hiptage benghalensis*	2	2.9	0.5787	2	3.9	0.3347	14	9.2	0.5515	6	3.2	0.4295	11	8.1	0.5139
294	*Hypericum perforatum*	3	5.2	0.3977	0	2.4	1	9	9.7	0.5459	7	3.1	0.779	15	8.2	0.4557
295	*Impatiens bicolor*	1	4	0.197	1	1.9	0.6523	5	50	0.0016	2	2.1	0.9472	10	2.7	0.948
296	*Impatiens brachycentra*	1	6.4	0.1744	2	9.1	0.058	4	2.2	0.9802	6	2.3	0.7325	12	12.3	0.2006
297	*Impatiens edgeworthii*	1	2.2	0.6725	0	1.3	1	3	4.6	0.7267	6	1.5	0.764	12	3.1	0.9452
298	*Imperata cylindrical*	2	7.1	0.4279	2	17.8	0.0264	6	8.8	0.5919	2	9.7	0.0812	18	7.1	0.6701
299	*Ipomoea nil*	3	2.4	0.8806	1	5.2	0.3549	15	19	0.1984	7	4.6	0.3351	13	2.8	0.9934
300	*Ipomoea purpurea*	4	9.4	0.0334	2	7.1	0.1376	18	12.1	0.4099	2	2.3	0.8296	25	3.8	0.955
301	*Juncus articulates*	3	2.1	0.9834	1	4.7	0.6099	9	10.3	0.4853	7	2.3	0.9556	18	21.6	0.074
302	*Juncus maritimus*	2	1.8	0.6097	1	0.9	1	7	5.6	0.5605	4	3.4	0.8224	10	4.3	1
303	*Kobresia laxa*	4	1.4	1	1	1.6	1	9	19.1	0.2058	4	3.2	0.6155	15	14.1	0.1886
304	*Lactuca dissecta*	4	4.4	0.1594	1	3.8	0.4425	2	16.4	0.245	5	1.2	0.7592	10	9.6	0.4105
305	*Launaea capitata*	1	8.4	0.1442	2	5.2	0.5975	2	12.2	0.4043	2	4.2	0.5933	29	5.7	0.6601
306	*Launaea procumbens*	1	2.4	0.7161	0	4.1	0.3423	9	10.7	0.4111	1	4.8	0.4539	15	5.9	0.6841
307	*Lepidium sativum*	1	6.5	0.161	1	4.9	0.3709	9	17.4	0.2448	7	4.1	0.4137	15	9.1	0.3491
308	*Leucanthemum vulgare*	4	17.9	0.0398	1	10.4	0.6905	14	9.1	0.6323	6	13.3	0.0484	19	20.4	0.0554
309	*Leucas cephalotes*	3	1.9	0.8682	0	6.5	0.067	10	7.4	0.5409	4	9.1	0.048	7	6.8	0.6199
310	*Lolium perenne*	4	15.1	0.0764	1	10.9	0.5303	14	4.8	0.963	6	11.6	0.076	19	7.5	0.7065

311	*Lolium persicum*	1	6.3	0.1714	0	3.2	0.6981	7	5.7	0.8114	1	3.6	0.5155	18	17	0.1478
312	*Lolium temulentum*	4	2.5	0.766	1	2.1	0.969	9	18	0.229	1	1.6	0.968	15	10	0.3637
313	*Lotus corniculatus*	4	13.9	0.2979	2	17.3	0.2785	18	7.2	0.829	6	7.7	0.8726	18	5.5	0.9538
314	*Malvastrum coromandelianum*	3	10.5	0.1094	0	6.5	0.5929	11	4.7	0.9294	4	4.8	0.6463	29	24.1	0.0516
315	*Medicago laciniata*	4	6.7	0.0424	1	1.9	0.6697	2	4.8	0.5581	6	2.4	0.3697	10	8.7	0.5507
316	*Medicago lupulina*	4	14.3	0.0916	1	11.4	0.4233	7	8.3	0.6775	6	9.5	0.2072	9	6	0.8436
317	*Medicago minima*	4	6.2	0.2597	1	6.4	0.3353	6	9.7	0.5307	1	5.7	0.2671	19	20.5	0.0948
318	*Medicago polymorpha*	1	4.2	0.7251	1	4.6	0.9142	9	9.7	0.5237	2	3.3	0.8702	15	5.3	0.7161
319	*Melilotus indicus*	2	6.3	0.5001	2	9.4	0.2184	11	10.4	0.5225	5	4.9	0.6071	18	15.4	0.1442
320	*Mentha arvensis*	1	5	0.1088	1	1.9	0.6539	3	3.8	1	5	2.1	0.3247	7	3.4	0.7878
321	*Mentha longifolia*	4	4.5	0.2344	0	2.8	0.6387	22	86.7	0.0004	1	2.1	0.7654	6	20	0.0884
322	*Mentha spicata*	1	2.7	0.5637	1	5.7	0.2128	10	8.3	0.6077	5	2.9	0.4575	12	5.5	0.8052
323	*Micromeria biflora*	3	21	0.3469	2	26.5	0.3105	10	10.8	0.5969	5	16.7	0.2002	9	9	0.7578
324	*Microstegium ciliatum*	4	0.9	1	0	6.8	0.0364	10	9.2	0.4611	4	10.3	0.0222	7	9.7	0.4533
325	*Microstegium nudum*	3	1	1	0	4.5	0.2274	10	10.5	0.3689	4	6.9	0.1332	7	11.8	0.3431
326	*Nasturtium officinale*	2	1.8	0.6069	1	0.9	1	4	4.3	0.836	6	3.8	0.3019	18	50	0.0144
327	*Nepeta hindostana*	2	1.3	1	1	2.4	1	9	20	0.2086	7	2.9	0.5849	15	13.5	0.2004
328	*Ocimum basilicum*	4	3.3	0.2775	0	2.3	0.3553	3	3.8	1	4	3.4	0.8178	17	6.2	0.4863
329	*Oenothera rosea*	4	20.7	0.0678	2	38.1	0.0018	18	14.7	0.2807	5	15.1	0.0664	9	8.2	0.6811
330	*Onosma hypoleucum*	4	2.3	0.6229	2	5.4	0.126	8	15.4	0.2695	6	7.7	0.0492	15	18.3	0.157
331	*Oplismenus compositus*	3	1.2	1	0	4.5	0.1656	10	10.5	0.3409	4	6.9	0.1332	7	11.8	0.3259
332	*Oplismenus undulatifolius*	2	1.9	0.9786	0	7.1	0.1834	3	5.5	0.8028	4	4.5	0.3635	17	4.3	0.9048
333	*Origanum vulgare*	3	2.5	0.6613	0	1.8	0.8406	10	4.2	0.8444	4	2.6	0.8956	7	4.8	0.7317
334	*Oxalis corniculata*	4	17	0.5315	1	20.2	0.6073	22	11.8	0.5451	4	16.3	0.1324	6	9.3	0.6603
335	*Paeonia emodi*	3	1.5	1	1	0.9	1	10	5.3	0.6805	2	3.3	1	15	13.5	0.2004
336	*Papaver somniferum*	3	5.9	0.2462	0	5.3	0.5759	13	22	0.0892	4	7.8	0.061	18	15.8	0.2002
337	*Parthenium hysterophorus*	3	12.1	0.2208	0	19.7	0.0518	13	36.1	0.0208	4	10.1	0.1936	25	6.7	0.758

338	*Parthenocissus semicordata*	1	3.1	0.3735	1	2.8	0.6639	3	6	0.5897	6	1.6	0.7057	12	5.2	0.7616
339	*Pergularia daemia*	4	3.4	0.3827	1	3.2	0.5269	22	24.6	0.1236	1	5.1	0.22	14	8.1	0.5099
340	*Persicaria barbata*	4	6.7	0.0386	2	5.4	0.1292	2	3.7	0.7369	6	2	0.5909	11	5.3	0.8448
341	*Persicaria nepalensis*	1	3	0.6079	2	10.9	0.025	3	3.2	0.8032	2	3.2	0.6425	14	13.2	0.2472
342	*Phalaris minor*	2	4.5	0.1898	2	4.7	0.149	11	11.4	0.4133	5	9.7	0.0094	29	8.3	0.5223
343	*Phyla nodiflora*	1	1.8	0.9252	0	7.1	0.1202	2	4.6	0.8436	7	4.7	0.2847	18	34.4	0.0154
344	*Phyllanthus fraternus*	2	1.9	0.9414	0	6.4	0.2208	11	4.7	0.8552	1	2.1	0.8712	18	30.9	0.0296
345	*Pimpinella acuminate*	4	2	0.7149	1	2.8	0.6687	2	3.6	0.783	6	1.5	0.7996	10	4.8	0.8064
346	*Pimpinella diversifolia*	1	4.8	0.4889	2	12.7	0.0354	11	4.4	0.922	6	3.3	0.6731	15	5.7	0.7069
347	*Piptatherum laterale*	4	3	0.4609	2	6	0.0692	3	7.7	0.4041	1	2.7	0.8528	13	4.7	0.7439
348	*Plantago amplexicaulis*	3	3.7	0.4803	2	2.4	0.8386	7	3.8	0.9296	4	1.3	0.9786	8	4.3	0.8878
349	*Plantago lanceolata*	4	11	0.1754	1	10.2	0.3959	18	14.9	0.2911	1	5.7	0.6931	15	7.5	0.6269
350	*Plantago major*	2	3.8	0.4087	2	16.7	0.0032	11	7.1	0.6913	5	10.5	0.0144	8	24.3	0.066
351	*Plantago ovate*	1	3	0.4611	1	1.9	0.6671	8	5.4	0.5485	6	2.7	0.3207	15	25	0.0992
352	*Poa annua*	4	19	0.0448	2	24.2	0.0228	15	6.8	0.8448	4	8.2	0.5713	13	14.4	0.2466
353	*Poa attenuate*	1	4.4	0.5569	1	5.9	0.3893	5	7.1	0.7299	6	3.7	0.6307	10	3.2	0.9814
354	*Poa pratensis*	4	21.9	0.014	1	11	0.6787	14	7.2	0.7874	6	10.7	0.198	19	14.5	0.156
355	*Poa stewartiana*	1	3	0.6207	1	1.6	1	6	12.3	0.3739	5	1.1	0.7315	19	12.7	0.2847
356	*Sinopodophyllum hexandrum*	2	3.5	0.3995	1	4.7	0.2655	15	23.9	0.122	6	3.3	0.3853	17	5.8	0.7686
357	*Polygala abyssinica*	3	3.1	0.4623	0	4.5	0.2573	15	33.3	0.0604	5	2.2	0.2306	9	18.2	0.166
358	*Polygala erioptera*	2	3.6	0.3075	2	12.5	0.0102	11	11.3	0.3473	5	8	0.0218	8	33.3	0.0352
359	*Polygonum aviculare*	3	3.3	0.9992	0	8	0.4437	13	10.4	0.4639	1	4	0.8342	18	12.1	0.2691
360	*Polygonatum multiflorum*	1	8.7	0.0436	0	2.2	0.919	7	4.9	0.7916	1	2.9	0.6105	25	6.8	0.6953
361	*Polygonatum verticillatum*	2	5.1	0.2424	1	5.7	0.2054	15	21.2	0.158	6	2.7	0.5599	17	4.7	0.8814
362	*Polypogon fugax*	1	3.3	0.3741	2	5.4	0.084	8	2.7	0.8604	2	3	0.4399	10	3.8	0.8326
363	*Polypogon monspeliensis*	1	13.9	0.0262	1	6.6	0.4039	7	11.1	0.4255	5	3	0.903	18	15.3	0.1866
364	*Porana paniculata*	2	7.7	0.094	2	13	0.0362	11	4.8	0.9076	5	7.7	0.0506	29	6.5	0.6139

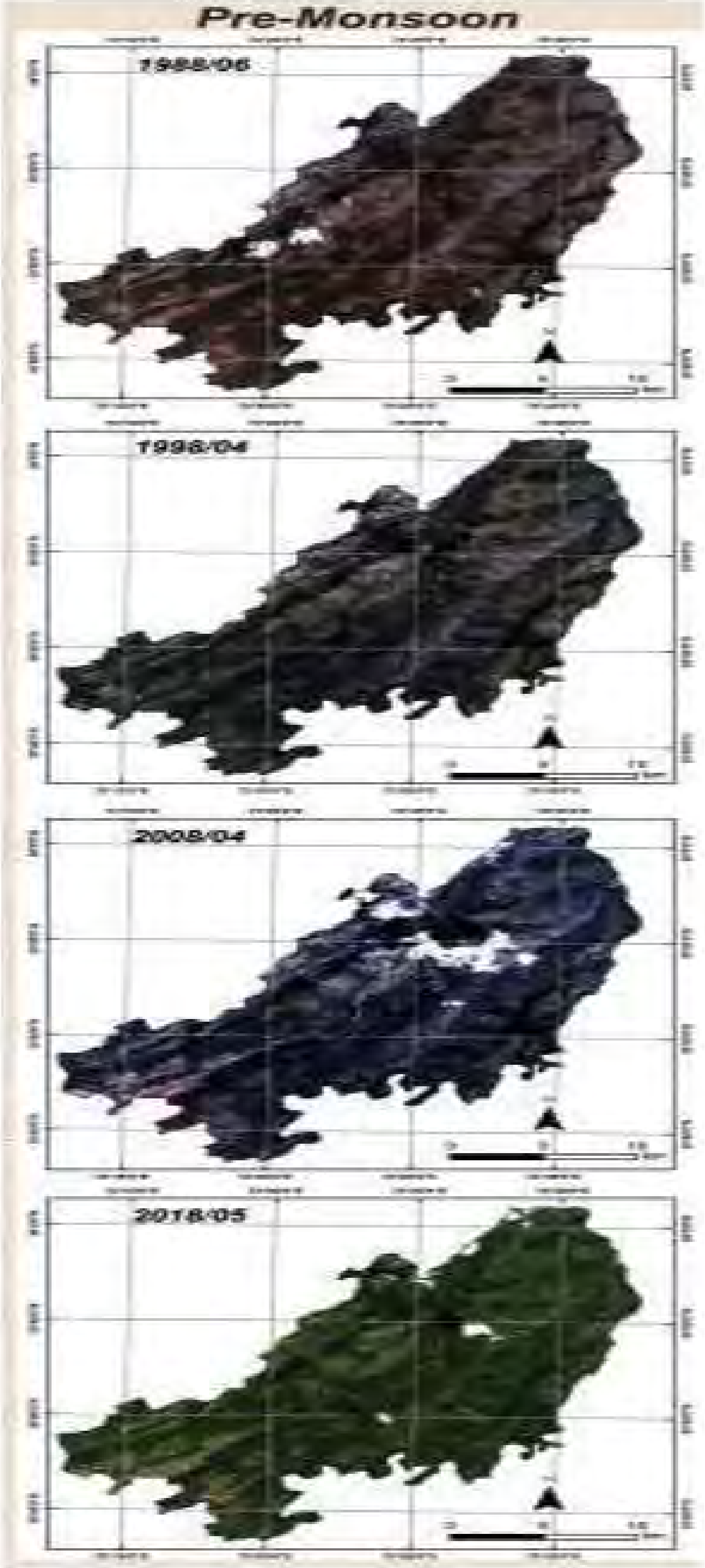
365	*Potentilla reptans*	2	5.8	0.2575	2	20.1	0.0034	6	9.2	0.5395	2	5.6	0.2158	29	18.8	0.1128
366	*Potentilla supine*	1	11.1	0.1184	2	13.1	0.1152	6	15.2	0.2553	2	12.4	0.0254	18	15.4	0.1298
367	*Lactuca brunoniana*	2	2.4	0.7706	0	8.2	0.0794	10	6	0.7363	4	6.5	0.1242	6	5.6	0.7704
368	*Prunella vulgaris*	4	15.2	0.0382	2	8.3	0.5629	5	10.5	0.4785	6	14.8	0.006	9	9.6	0.4603
369	*Ranunculus arvensis*	2	1.8	0.5983	1	0.9	1	9	33.3	0.0668	6	3.8	0.3001	11	5.3	0.8506
370	*Ranunculus hirtellus*	1	3.5	0.3365	1	3.8	0.3529	10	2.1	0.9882	6	3.9	0.2701	18	41.5	0.009
371	*Ranunculus laetus*	4	18.8	0.0312	1	11.3	0.5815	15	10	0.5227	6	15.1	0.0162	9	7.3	0.7189
372	*Ranunculus repens*	1	9.2	0.2561	0	5.4	0.9672	3	7.1	0.7385	1	9.5	0.1146	17	8.3	0.5679
373	*Ranunculus sceleratus*	1	10.4	0.2915	2	17	0.0714	5	8.4	0.6107	2	10.2	0.1132	18	8	0.5617
374	*Rhynchosia minima*	4	1.7	0.6823	2	4.8	0.1608	3	7.7	0.4331	5	2.8	0.2384	10	2.7	0.968
375	*Ribes alpestre*	2	3	0.6607	1	3.3	0.7033	22	64.6	0.0012	1	3	0.6821	6	12.1	0.2535
376	*Rubia cordifolia*	1	10	0.1118	2	24.3	0.0028	18	5.7	0.851	5	9	0.0748	13	6.6	0.6447
377	*Rubia himalayensis*	4	3.3	0.2717	1	0.9	1	22	50	0.02	6	3.8	0.3125	6	16.7	0.2446
378	*Rumex dentatus*	1	2.4	0.6513	0	5.8	0.1008	2	2.5	0.9472	7	4.3	0.2276	17	16.4	0.1154
379	*Rumex nepalensis*	4	3.3	0.2819	1	0.9	1	9	33.3	0.0668	1	3.4	0.824	15	25	0.0986
380	*Saccharum bengalense*	2	2.7	0.4591	2	4.9	0.1156	4	8.7	0.4129	5	5.9	0.0968	29	38.1	0.0246
381	*Saccharum spontaneum*	2	1.2	0.8646	1	1.9	0.6637	2	3.2	0.8504	4	6.9	0.1336	17	8.3	0.5679
382	*Salvia moocroftiana*	4	1.7	1	0	1.2	1	11	9.7	0.4877	5	1.4	0.6739	6	8.8	0.5487
383	*Himalaiella heteromalla*	2	3.6	0.3099	1	1.9	0.6665	14	20	0.1422	1	2	0.7984	10	2.4	1
384	*Saussurea costus*	3	0.9	1	2	5	0.168	2	13.3	0.3063	7	2.2	0.5647	10	2.5	1
385	*Schoenoplectus spp*	3	0.9	1	0	4.5	0.2274	10	10.5	0.3763	4	6.9	0.1332	7	11.8	0.3653
386	*Scutellaria linearis*	4	3.8	0.3311	1	2.6	0.8296	3	4.3	0.8226	1	6.4	0.0918	19	8.7	0.4637
387	*Senecio analogus*	3	5.2	0.2783	2	3	0.6399	2	4.9	0.8512	1	2	0.9042	18	27.4	0.0608
388	*Setaria pumila*	3	1.2	0.9252	1	1.9	0.8256	4	8.7	0.3599	4	2.8	0.803	17	16.4	0.1154
389	*Setaria viridis*	4	8	0.2899	0	8	0.3899	18	45.3	0.0128	4	4.9	0.6533	29	19	0.1144
390	*Sida cordata var. cordata*	3	3.5	0.7876	0	7.6	0.1766	13	23.8	0.0748	7	2.8	0.8712	25	10.2	0.3331
391	*Sida cordifolia*	2	7.4	0.4693	0	15.4	0.0666	8	6.4	0.827	2	6.5	0.4263	18	11.4	0.3167

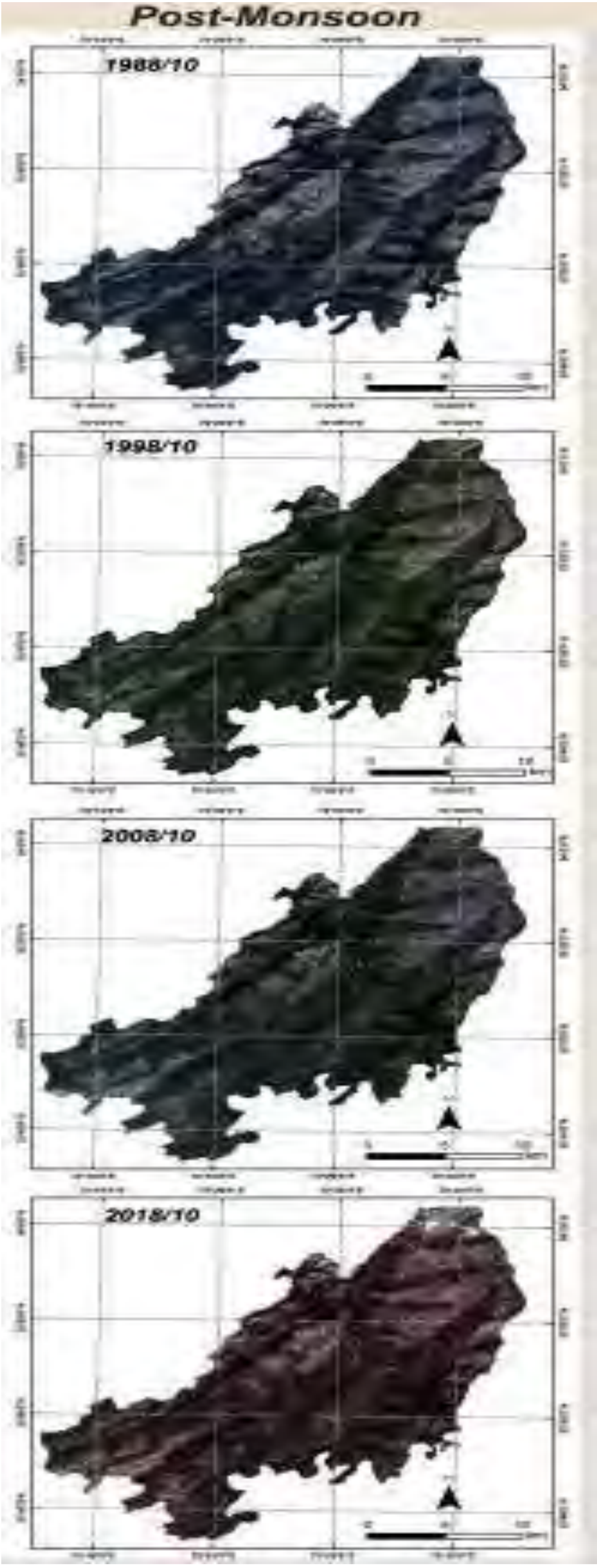
392	*Sigesbeckia orientalis*	3	2.2	0.8084	0	8	0.097	6	5.4	0.779	4	5.7	0.1694	17	5	0.8352
393	*Silybum marianum*	2	7	0.2893	0	4.9	0.8298	8	7.7	0.6815	2	5.2	0.4183	25	18.6	0.0584
394	*Smilax aspera*	4	11.7	0.7087	2	39.7	0.0006	10	5	0.9938	5	7.5	0.9632	11	6.1	0.8784
395	*Smilax vaginata*	1	5.6	0.0748	1	1.9	0.6593	5	23.2	0.1146	7	2.4	0.5357	11	3.7	0.8602
396	*Solanum nigrum var. nigrum*	1	5.3	0.3329	0	3.7	0.6977	6	5.2	0.8568	1	3.3	0.7229	15	6.9	0.5863
397	*Solanum nigrum var. villosum*	3	4.4	0.5949	0	6.8	0.2611	11	3.4	0.9894	1	2.3	0.9692	18	23	0.0484
398	*Solanum surattense*	3	8.3	0.0448	0	12.6	0.0208	15	16.5	0.2621	2	2.1	0.9118	9	6.9	0.5963
399	*Sonchus arvensis*	2	1	1	1	1.9	0.6637	2	4.2	0.6501	4	6.9	0.1336	11	6.1	0.8784
400	*Sonchus asper*	1	3.9	0.2725	0	2.9	0.6713	18	39	0.0324	5	4.8	0.1248	6	6	0.7429
401	*Sonchus oleraceous*	4	2.2	0.7325	0	1.6	1	2	3.6	0.7842	7	1.9	0.8028	8	12.5	0.3547
402	*Stachys melissifolia*	4	3.3	0.2825	1	0.9	1	10	5.3	0.6829	1	3.4	0.8186	6	18.8	0.123
403	*Swertia angustifolia*	3	1.5	1	1	0.9	1	7	5.6	0.5527	1	3.4	0.8144	17	6.2	0.4839
404	*Swertia alata*	4	3.3	0.2783	1	0.9	1	2	6.7	0.4405	6	3.8	0.3059	10	4.3	1
405	*Swertia ciliate*	4	2.9	0.6435	2	3.3	0.5937	22	60.1	0.0018	6	3.4	0.4455	6	15.4	0.1604
406	*Swertia cordata*	4	3.7	0.3327	0	2.7	0.757	22	81	0.0004	7	1.9	0.9168	6	16.2	0.1428
407	*Swertia paniculata*	3	3.7	0.5097	1	3.1	0.6895	15	14.2	0.3311	5	2.2	0.7407	9	2.3	0.998
408	*Swertia petiolata*	2	1	1	1	1.9	0.6633	5	21.3	0.1414	1	1.8	0.943	11	2.9	0.9688
409	*Tagetes minuta*	4	6.2	0.2044	2	13.8	0.0196	3	6.2	0.7744	1	4.4	0.3819	19	25.2	0.0562
410	*Taraxacum officinale*	4	6	0.1928	1	5.7	0.1976	22	77.6	0.0014	6	3	0.4713	6	18.8	0.123
411	*Teucrium royleanum*	1	3	0.6207	1	1.6	1	6	12.3	0.3739	5	1.1	0.7315	19	12.7	0.2847
412	*Thalictrum foliolosum*	4	2.2	0.7325	0	1.6	1	2	3.6	0.7842	7	1.9	0.8028	8	12.5	0.3547
413	*Themeda anathera*	2	23.3	0.2805	2	30.5	0.2114	22	14.6	0.2873	1	12.5	0.9782	6	13	0.2713
414	*Thymus linearis*	4	26.3	0.003	1	11.9	0.5385	9	7.8	0.7321	6	12.4	0.0676	19	9.2	0.4193
415	*Tinospora sinensis*	2	3.6	0.5251	1	5.3	0.3397	13	33.7	0.034	4	2.4	0.7716	6	12.2	0.245
416	*Torilis leptophylla*	4	7.3	0.3045	2	4.9	0.805	11	6.1	0.841	6	10.9	0.0252	9	10.2	0.4283
417	*Tribulus terrestris*	2	6.6	0.3307	0	12.2	0.056	13	18.7	0.1658	1	6.2	0.2635	18	15.1	0.197
418	*Trichodesma indicum*	3	3.4	0.9088	2	9.5	0.1456	10	9.8	0.5051	4	12	0.041	29	14.7	0.2248

419	*Trifolium repens*	4	19.4	0.0586	2	15.5	0.3981	18	6.9	0.8636	6	18.5	0.0074	18	6.4	0.8766
420	*Trifolium spp*	1	6.8	0.1514	1	3.7	0.5393	5	13.3	0.3639	1	5.5	0.1896	19	9.9	0.3581
421	*Trigonella spp*	4	1.4	1	1	1.6	1	5	14.8	0.3253	6	8.7	0.0212	13	2	1
422	*Trillium govanianum*	4	5.8	0.2024	0	2.2	1	11	16.6	0.2484	2	2.7	0.6671	9	7.1	0.6291
423	*Tussilago farfara*	1	5.8	0.2374	1	3.3	0.6533	9	17.4	0.2278	4	2	0.8912	15	8.7	0.4371
424	*Tylophora hirsute*	4	3.2	0.8752	2	18	0.0084	11	5	0.89	4	3.8	0.6265	29	7.7	0.5367
425	*Urochloa panicoides*	4	7.2	0.2915	0	11.8	0.0808	6	8.5	0.6125	4	7.7	0.1764	19	9.8	0.4295
426	*Urtica dioica*	4	2.2	0.6389	1	2.8	0.6673	9	66.7	0.0008	1	1.7	0.7355	15	46.2	0.0028
427	*Urtica pilulifera*	1	5.7	0.2498	0	3.2	0.7299	9	16.3	0.2527	1	1.8	0.9716	15	10.8	0.3361
428	*Valeriana jatamansi*	4	20.9	0.0026	1	4.2	0.9654	11	6	0.818	6	7	0.2124	9	5.9	0.7528
429	*Verbascum Thapsus*	2	3.6	0.3069	1	1.9	0.6665	14	20	0.1422	6	2.7	0.3675	11	3.7	0.858
430	*Verbena officinalis*	3	1.5	1	1	0.9	1	4	4.3	0.8396	4	3.4	0.826	19	9.8	0.4295
431	*Glandularia aristigera*	3	4	0.4561	1	6	0.2885	2	4.2	0.865	4	10.5	0.0316	11	7.5	0.5883
432	*Veronica persica*	3	1.5	1	1	0.9	1	7	5.6	0.5527	1	3.4	0.8144	17	6.2	0.4839
433	*Veronica polita*	4	11.5	0.1082	1	7.3	0.6603	14	8.3	0.6335	6	7.7	0.2382	9	7.4	0.6107
434	*Veronica spp*	4	2.5	0.5229	0	4.2	0.172	18	48.2	0.0018	6	2.5	0.5323	6	6.3	0.6843
435	*Chrysopogon zizanioides*	2	2.9	0.6463	2	16.5	0.003	6	2.9	0.9218	2	1.9	0.921	29	8.7	0.4737
436	*Vinca major*	4	4.4	0.1728	1	1.6	1	5	15	0.3149	6	8.7	0.0246	12	7.4	0.6435
437	*Vincetoxicum arnottianum*	1	12.5	0.007	1	1.9	0.6563	10	3.4	0.7946	2	2.1	0.944	10	2.7	0.948
438	*Viola canescense*	1	4.2	0.1696	1	1.9	0.6541	9	33.3	0.0712	4	2.2	0.914	15	22.4	0.0742
439	*Viola odorata*	4	2	0.6569	0	1.2	0.8916	9	62.1	0.0012	1	1.4	0.7159	15	34.1	0.0374
440	*Xanthium strumarium*	3	1.5	1	1	0.9	1	2	6.7	0.4375	4	3.4	0.8178	29	8.7	0.4737
441	*Zeuxine strateumatica*	4	5.2	0.1414	2	11.6	0.0168	2	2.8	0.8964	1	1.2	1	13	8	0.6035
442	*Adiantum caudatum*	1	18	0.0278	1	12.3	0.3661	22	30	0.0386	5	6.9	0.6607	7	10.6	0.3085
443	*Adiantum capillus-veneris*	3	8.5	0.8682	2	13.5	0.4253	9	9.6	0.5525	5	11.1	0.1788	12	11.1	0.3701
444	*Adiantum incisum*	4	4.6	0.9772	0	19.8	0.026	10	10.9	0.4615	7	5.3	0.7816	29	7.5	0.6491
445	*Adiantum venustum*	4	10.1	0.3681	2	12.8	0.2737	9	51	0.0044	4	5.1	0.9232	15	35.9	0.008

446	*Dryopteris ramose*	1	4.8	0.7548	1	9.4	0.223	22	11.2	0.4779	1	6	0.3585	18	12.7	0.2266
447	*Dryopteris sieboldii*	1	16.5	0.0152	2	13.4	0.0924	18	5.9	0.872	7	5.9	0.4863	15	5.5	0.8292
448	*Dryopteris stewartii*	3	6.4	0.4645	2	9.6	0.1994	15	6.9	0.7445	4	8.7	0.0844	13	4.6	0.8334
449	*Dryopteris spp*	1	10.7	0.4135	1	14.9	0.2336	9	29.3	0.0396	1	10.4	0.2304	15	32	0.0108
450	*Dryopteris wallichiana*	1	4.1	0.6659	2	20.2	0.003	15	11.3	0.4359	1	2.9	0.8174	18	17.2	0.1182
451	*Equisetum ramosissimum*	1	1.7	0.9714	2	10.1	0.0258	9	14.4	0.3107	2	3.3	0.5123	18	22.4	0.075
452	*Equisetum debile*	1	5.7	0.2773	2	7	0.2166	7	8.7	0.5951	7	5.5	0.2492	18	27.5	0.022
453	*Pteris Vittata*	4	15.6	0.08	1	16.9	0.129	22	15.1	0.2382	6	11.4	0.1118	15	14	0.1822
454	*Pteris cretica*	2	7.5	0.4911	1	9.6	0.3647	9	5.2	0.9278	4	2.9	0.9996	8	5.3	0.8594

Appendix 3: Real color Pre and Post-monsoon maps of MFD




Post-Monsoon
1988/10
1998/10
2008/10
2018/10

7.3 Appendix 3: Details of Landsat maps of MFD used during analysis

1988	LANDSAT/LT05/C01/T1_SR/LT05_150036_19880605	***Pre- Monsoon Period***
	LANDSAT/LT05/C01/T1_SR/LT05_150037_19880605	
1998	LANDSAT/LT05/C01/T1_SR/LT05_150036_19980414	
	LANDSAT/LT05/C01/T1_SR/LT05_150037_19980414	
2008	LANDSAT/LT05/C01/T1_SR/LT05_150036_20080425	
	LANDSAT/LT05/C01/T1_SR/LT05_150037_20080425	
2018	LANDSAT/LC08/C01/T1_SR/LC08_150036_20180523	
1988	LANDSAT/LT05/C01/T1_SR/LT05_150036_19881027	***Post- Monsoon Period***
	LANDSAT/LT05/C01/T1_SR/LT05_150037_19881027	
1998	LANDSAT/LT05/C01/T1_SR/LT05_150036_19981007	
	LANDSAT/LT05/C01/T1_SR/LT05_150037_19981007	
2008	LANDSAT/LT05/C01/T1_SR/LT05_150036_20081002	
	LANDSAT/LT05/C01/T1_SR/LT05_150037_20081002	
2018	LANDSAT/LC08/C01/T1_SR/LC08_150036_20181014	

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DIVERSITY AND ABUNDANCE OF CLIMBERS IN RELATION TO THEIR HOSTS AND ELEVATION IN THE MONSOON FORESTS OF MURREE IN THE HIMALAYAS

AMJAD UR RAHMAN[1,2], SHUJAUL MULK KHAN[1,*], ZAFEER SAQIB[3], ZAHID ULLAH[4], ZEESHAN AHMAD[1], SEMIH EKERCIN[5], ABDUL SAMAD MUMTAZ[1] AND HABIB AHMAD[6]

[1]*Department of Plant Sciences, Quaid-i-Azam University, Islamabad, Pakistan*
[2]*Department of Botany, University of Swabi, Khyber Pakhtunkhwa, Pakistan*
[3]*Department of Environmental sciences, International Islamic University, Islamabad, Pakistan*
[4]*Center for Plant Sciences and Biodiversity, University of Swat, Pakistan.*
[5]*Department of Geomatics, Aksaray University, Aksaray, Turkey*
[6]*Islamia College University, Peshawar, Pakistan*
**Corresponding author's email: shuja60@gmail.com*

Abstract

Climbers play diverse roles in the biology of forests. Climber species due to its fragile nature are sustible to any change in the forests. Knowledge about climber species in the forests is relatively inadequate and this is the first effort to report the climber plant species in Pakistan. Ecological methods were used to find out climbers abundance, distribution and their relationship with trees/ shrubs in five 1-ha plot range of 735 m to 1754 m elevation at sea level at five localities viz., Baroha, Ghoragali, Numbal, Patriata and Salgaran in the Murree Forests in Western Himalaya, Pakistan during the year of 2016-2017. An overall 3400 climbing plants belonging to 23 species, 19 genera and 13 families were identified and described. Apocynaceae (22%) was the most leading family followed by Ranunculaceae (13%) Rosaceae (13%) and Menispermaceae (9%). Based on our findings the climber species are classified into four classes based on their habit/ form as well. The dominant class was represented by twining climbing mode (43%) followed by woody (30.4%) and hook mode (22%) while tendrils (4.3%) were rare. The abundance and distribution of climber plants were affected by parameters like biotic factors (collection pressure, grazing pressure and No. of hosts) and abiotic factors (topographic and edaphic). Canonical Corresponding Analysis (CCA) indicated that grazing and collection pressures along with elevation were the most important factors influencing the distribution and abundances of climbers. Documentation of the climbers is imperative in the context of increasing forest disturbances, deforestation and fragmentation of forest habitat. Current study will lead towards many other detail studies on climbers in near future.

Key words: Climbers; Diversity; Abundance; Climbing mode; Ordination; Monsoon Forests; Himalaya.

Introduction

Plants having distinct structure to climb on hosts are termed as climbers. Climbers are mostly fixed in the soil but need support for their weak stem. They compete strongly with large trees and shrubs for light, space as well as nutrients (Richards, 1952). Climber plants play significant ecological role in nutrients cycling, forests dynamics and hence establish an essential tropic level within an ecosystem very few studies have been done on climbers. Kokou *et al.*, (2002) divided the climbers in to three categories namely climbing vines, climbing shrubs and woody climbing plants (lianas). Climbing vines are generally herbaceous type in sprawling growth habit like runners. Vines are not able to reach the mature forest canopy due to weak nature. Climbing shrubs climb without clingy tendrils or roots. Cracks in the bark of fibrous barked trees support these shrub climbers to climb. Lianas are mostly woody and may reach to the crown of forest trees (Jongkind & Hawthorne, 2005). Specific structure, dynamics and functions of vegetation and ecosystem is influenced by Lianas (Burns & Dawson, 2005), the occurrence and abundance of which is more important in moist tropical forest (Hegarty, 1991).

A considerable number of vascular plant families comprise climbing species. Vitaceae and Hippocrateaceae families' are almost climbers: their axes have condensed groups of subsidiary tissue which are extremely light demanding (Hegarty, 1991; Schnitzer & Carson, 2001). There is another group of climbers called Lianas beside the soft tissues. They possess a considerable amount of supporting tissues allowing them to climb over the large trees. Woody climbers (Lianas) are intact structural parasites (Stevens, 1987), defending on other plants for support. Differences in climbing approaches, dispersal and phenological approaches help in distribution gaps and allow effective resource dividing between the climber species (Oldeman, 1990). Four major characteristics i.e., high growth rates, roots lateral growth, propagation through seed and production of branches play vital role in the colonization of climbers in forest and boundaries of forest clearing. In the diversity of tropical forest 25 % of woody plants total diversity is contributed by Lianas (Schnitzer & Carson, 2001) and yet are frequently unnoticed in many forest records and in forest ecological practices (Phillips *et al.*, 2005). The overall low care to lianas is most possibly owing to problems in restricting individuals whole lower minimum size of populations and general absence of taxonomic studies that possibly led to in the elimination of liana in many records. The climbers will be the first to reduce in the silviculturally managed forests therefore, they are the most threatened group of plants, and need to be documented both qualitatively and quantitatively.

Climbers show great variety in their mechanism of climbing (Bongers *et al.*, 2005; Jongkind & Hawthorne, 2005). These include root climbers, branch twiner, stem twiner, scramblers, tendril climber and hook/thorn climbers. The most common in the forest edges are the tendril climbers, where the common support is through smaller thread like structures called tendrils, than in forest