CHAPTER ONE: INTRODUCTION

1.1 Plant Diversity

Biodiversity is an important attribute of an ecosystem (Shiekh *et al*. 2002; Quijas *et al*. 2011). The term biodiversity has been local people synonym in some cases with species richness (Begon *et al*. 2009). Biological diversity encompasses the complete range of species, the genetic variation within species and all biological communities, including their ecosystem interactions (Whitakker 1972; Woodward 1988). In the ecological and floristic study, biodiversity is measured in terms of alpha, beta and gamma diversity (Whitakker 1972). Species richness is a measure of the number of different species found in a sample or in an ecological community, landscape or region. In general, patterns of species richness is defined by consequence of many interacting factors, such as plant productivity, competition, geographical area, historical and evolutional development, regional species pool and dynamics, environmental variables, and anthropogenic activities (Woodward 1988; Palmer 1991; Eriksson 1996; Zobel 1997; Criddle *et al*. 2003).

At global scale, general pattern of species richness revealed a decreasing pattern with increasing latitude or elevation (Rapoport 1982; Willig *et al*. 2003 and Hillebrand 2004). Himalayan region harbors high degree of taxonomic richness due to high topographic and climatic variations,strong micro-habitat differentiations, and a varied history of migration and evolution (Körner 2003; Bhattarai and Vetaas 2003; Shaheen and Shinwari 2012). In line with this, many studies have documented unimodal pattern of species richness along the Himalayan elevation gradient (Bhattarai and Vetaas 2003; Carpenter 2005).

Temperature, solar radiation and moisture are some of the prominent environmental factors that define microclimate and influence ecological processes such as photosynthesis, evapo-transpiration and nutrient cycling (Woodward 1988). The microclimate encompasses a suite of climatic conditions in a localized area which directly influences germination, growth and reproduction of plant species (Geiger *et al*. 1995; Chen *et al.* 1999). Moreover, microclimate determines the resource availability, the variability of which causes great impacts on pattern of species diversity along environmental gradient in alpine Himalaya (Pausas *et al*. 2001; Korner 2003; Salick *et al*. 2007).

The alpine-nival niche harbor distinct vegetation type and flora where plant life is constrained particularly by low temperature and short growing season (Korner 2003; Nagy and Grabherr 2009). Evolutionary adaptation, ontogenetic modification and reversible adjustments are the important determinants of plant species to cope with such harsh environmental conditions (Körner 1999). The alpine-nival life zone, therefore, is characterized by prostrate shrubs, forbs, sedges and grasses with great phenotypic plasticity in response to the variation in local environmental conditions. Such plants exhibit characteristically short stature, high investment to the below ground biomass, fast growth in specific season and tolerance to low temperature (Körner 1999).

Despite the environmental stresses, the alpine-nival life zone of the Himalaya supports high proportions of endemics and rare species due to strong geographical isolation created by mountain barriers (Körner 2003; Salick *et al*. 2007). Most of the rare and endemic species show high habitat specificity and narrow range of distribution, and are thus important from ecological and evolutionary perspectives (Shrestha and Joshi 1996; Körner 2003). Besides natural rarity, a number of species are threatened by anthropogenic activities, such as overgrazing, overexploitation and forest fires. The environmental harshness together with increasing anthropogenic pressure accelerates the chance of species extinction in the Himalayan mountains (Ghimire *et al.* 2006).

High altitude areas in the mountains are one of the most vulnerable ecosystems due to climate change. Mountains are often referred to as "thermometer of the world" (Salick *et al*. 2009). Researches from different mountain regions of the world revealed that species extinction mostly occur on mountain tops (Thuiller *et al.* 2008) in comparison to lower elevation areas. Mountain top (or summit) acts as a trap for the upward migrating species in response to climate change. Therefore, mountain tops are considered to be ideal site for the study of change in plant species distribution pattern for tracing and understanding the response of alpine biota to climate change, and for assessing regional to large scale risks of biodiversity loss and the vulnerability of mountain ecosystem under changing environmental pressure (Nilsoon and Pitt 1991; Gottfried *et al*. 1998). According to Pauli *et al*. (2003), vegetation of higher mountain areas can be used as an ecological indicator for climate change. Rare and endemic species particularly are more susceptible to the climate change and altering plants life history, phenological events and species composition (Root *et al*. 2005; Walther *et al*. 2005; Pounds *et al*. 2006; Foden *et al.* 2007; Salick *et al*. 2009; Felde *et al*. 2012; Jump *et al*. 2012; Telwala *et al*. 2013).

1.2 Transhumance Practice

Biodiversity boosts ecosystem productivity and provides a number of natural services for humankind. Snow accumulation as water reservoirs for downstream people, wetlands for biodiversity support, higher number of medicinal plants and NTFPs, source of minerals, and pasture land for transhumance practices are some of the important mountain ecosystem services at alpine Himalaya (Ilyas *et al*. 2012). Among the ecosystem services provided by alpine Himalaya, pasture land is considered to be deeply integrated to the livelihood activities. The Himalayan pastures have been grazed for centuries (Miller 1999). Alpine meadows exhibit remarkable number of herbaceous and graminoid species supporting large number of domestic animals and wild ungulates. Such meadows also support basic human needs of food, medicine, water, and space (Baily *et al*. 2011).

In the Himalayan Nepal, mountain people, for centuries, are intricately engaged in the livestock rearing as a major economic source (Karki *et al.* 2011). Transhumance is a traditional practice of mountain people to utilize seasonal availability of grazing resources. This practice involves the movement of people with their livestock between summer and winter pastures over a year (Nyssen *et al*. 2009). Mountain people who utilize alpine pastures have developed strategies to cope with climatic variability, inaccessibility, shortages of fodder and low productivity (Moktan *et al*. 2008). However, the contribution of grasslands is severely affected by livestock losses as a result of poisonous plants, ensuring direct negative impact on the herders' quality of life and subsequent downstream economic status (Wang and Yang 2003). Livestock rotation systems are herders' rational approach for livestock production by utilizing seasonal production of pasture at different mountain elevations (Chetri *et al*. 2011). Pasture management strategies by herders, including rotational grazing and burning, are used to promote desired palatable species growth (Karki *et al*. 1999).

Palatability is a plant characteristic in which plants or plant parts are consumed by grazing animals as stimulated by the sensory desire (Heath *et al*. 1985; Hussain and Durani

2009). Preference is the selection of plant species by animals for feed. Many factors affect palatability, such as animal, plant, season and climate. The animal factors are related to age, stage of pregnancy, general health and hunger of animal; while plant factors include seasonal availability, degree of maturity, growth stage, phenology, morphological and chemical nature, relative abundance and accessibility to the area (Nyamangara and Ndlovu, 1995; Hussain and Durani, 2009). Usually, wildlife species are selective consumers and they select plant species according to their physiological and morphological adaptation (Hofmann 1989).

From an ecological perspective, grazing has marked effects on biodiversity, ecosystem function, plant biomass and soil stability (Van der Wal *et al*. 2011). High intensity grazing can reduce diversity and can alter species composition of grassland. For example, high livestock density leads to increase in the abundance of unpalatable (or less palatable) species, such as weeds and exotic invasive species (Pakeman 2004; Fosaa and Olsen 2007). Exotic species are more competitive and have different growth responses compared with native species. Moderate grazing to some extent promote biodiversity by creating high habitat heterogeneity leading to rich in diversity of plant species (Mulder *et al*. 2001; Pucheta *et al*. 2004 and Zou *et al*. 2015). For sustainable grazing, the status of palatable resources is important, as livestock farming can be sensitive to change in pasture quality and productivity, which ultimately affects economic conditions of the herders (Skonhoft *et al*. 2010). Thus, there remains always a trade-off between managing grassland for high forage production, biodiversity, and sustainability.

1.3 Rationale

The Himalayan ecosystem supports high species richness providing great ecosystem services. Alpine vegetations are the main sources for cultural, spiritual and economic aspects of the mountain people in the Himalaya (Salick *et al.* 2003). However, at present, due to rapid globalization and economic growth, the cultural and spiritual value being deteriorated and substituted by the monetary aspects. This issue has posing serious threat to the stability of ecologically important habitats such as alpine ecosystems.

Api-Nampa Conservation Area (ANCA) in the Far-Western region of Nepal is rich in terms of biodiversity (Tiwari 2013). ANCA was established by the Government of Nepal in 2010 for the conservation and management of unique biodiversity of northern region of Far-

Western Nepal as well as to uplift the socio-economic status of the local people. Beside this, different organization including International Centre for Integrated Mountain Development (ICIMOD) and Research Center for Applied Science and Technology (RECAST) has been working in both social and ecological aspects since the establishment of the ANCA. Consequently, the area is in high priority for research and development in recent years.

ANCA encompasses extensive areas of alpine pastures, which are traditionally being used for grazing livestock and extracting medicinal and other resources. However, the status of these pastures in terms of species composition and diversity and their contribution to the local livelihood are poorly understood. Thus, this study was envisaged to assess plant species composition and richness with particular focus on the richness and abundance of palatable and unpalatable species in pastoral habitats along an elevation gradient in Upper Chamelia valley.

1.4 Objectives and Hypothesis

The general objective of this research was to assess the status of transhumance practice and evaluate the pastoral plant communities in terms of richness, composition and abundance along the alpine-nivale gradient of Upper Chamelia valley in Api-Nampa Conservation Area (ANCA). The main hypotheses put forwarded in this study were (i) alpine pastures greatly support people's livelihood by providing quality forage for their domestic animal; (ii) alpine-nival gradient differently support palatable and unpalatable plant species; thus diversity, compostion and abundane of such species vary along the elevation gradient, and (ii) along the elevation gradient, mountain summits in the pastoral habitat enhances diversity of range restricted species with lifeform better adaptive to harsh ecological conditions. The specific objectives were:

- to study the system of livestock movement, and assess the pattern of pasture resource utilization in terms of forage provided by alpine pasture and relate this with livelihood dependency of rural people
- to assess the pattern of richness, composition and abundance of palatable and unpalatable plant species along the elevation gradient.

- to analyze the life form pattern, elevation amplitudes and biogeographic elements of plant species along the alpine-nival gradient

1.5 Limitation of the Study

Our main objective was to access the transhumance system and to evaluate the pastoral plant communities with particular focus on richness, composition and abundance of palatable and unpalatable plant species rather than to find grazing effect in the area. Because of this reason, we selected different mountain peaks at different elevations for sampling. The direct grazing impact on the distribution of plant species considering the grazed and ungrazed habitats of rangeland was out of the scope of the present study. The time and resource constraints were the other factors limiting the documentation of detail information replicating the mountain summits at different elevations.

CHAPTER TWO: MATERIALS AND METHOD

2.1 Study Area

2.1.1 Physiography

The study was conducted in upper Chamelia Valley in Ghusa Village Development Committees (VDC) of Darchula district (29^0 36' to 30^0 15' N and 80^0 22' to 81^0 9' E) in the north-western Nepal (Fig. 1). Darchula, with a total area of 3122 km^2, is one of the mountainous districts, bordered by Bajhang in the East, Tibet Autonomous Region of China in the North, Uttrakhanda (India) in the West and Baitadi district of Nepal in the South. Elevation of Darchula district ranges from 518 m to 7132 m asl. About 1,903 km^2 area of the district was declared as conservation area in 2010, known as Api Nampa Conservation Area (ANCA).

2.1.2 Climate

The climate varies widely from subtropical to alpine-nival type. At the northern part of ANCA, most of the area is covered by snow and the climate is alpine. But in the southern part and valley bottoms, the climate is subtropical, and in the middle hill region the climate is temperate type. The average maximum temperature is 18.6^0C in June/July, the minimum temperature is 7.7^0C in November/December, and average annual rainfall is 2129 mm (DNPWC 2008).

2.1.3 People, ethnicity and Socio-economic status

Majority of people in Darchula are Indo-Aryans and they speak Nepali (Doteli) language. The major cast groups of Indo-Aryans are Brahmin, Chhetry, Thakuri, Dalit, Lohar, Kaine, Bandhe and Sanyasi. Among them, 85.19% of total population are represented by Chhetry/Thakuri/Brahmin cast group, 10% by Dalit, and the rests are from different occupational groups. Byansi (Saukas) are the only indigenous community belonging to Tibeto-Burman origin, but they represent only 0.12% of the total population. Agriculture is the main occupation of the local people supplemented by animal husbandry and commercial harvesting of medicinal plants. About 32% of people are employed in government and private organizations.

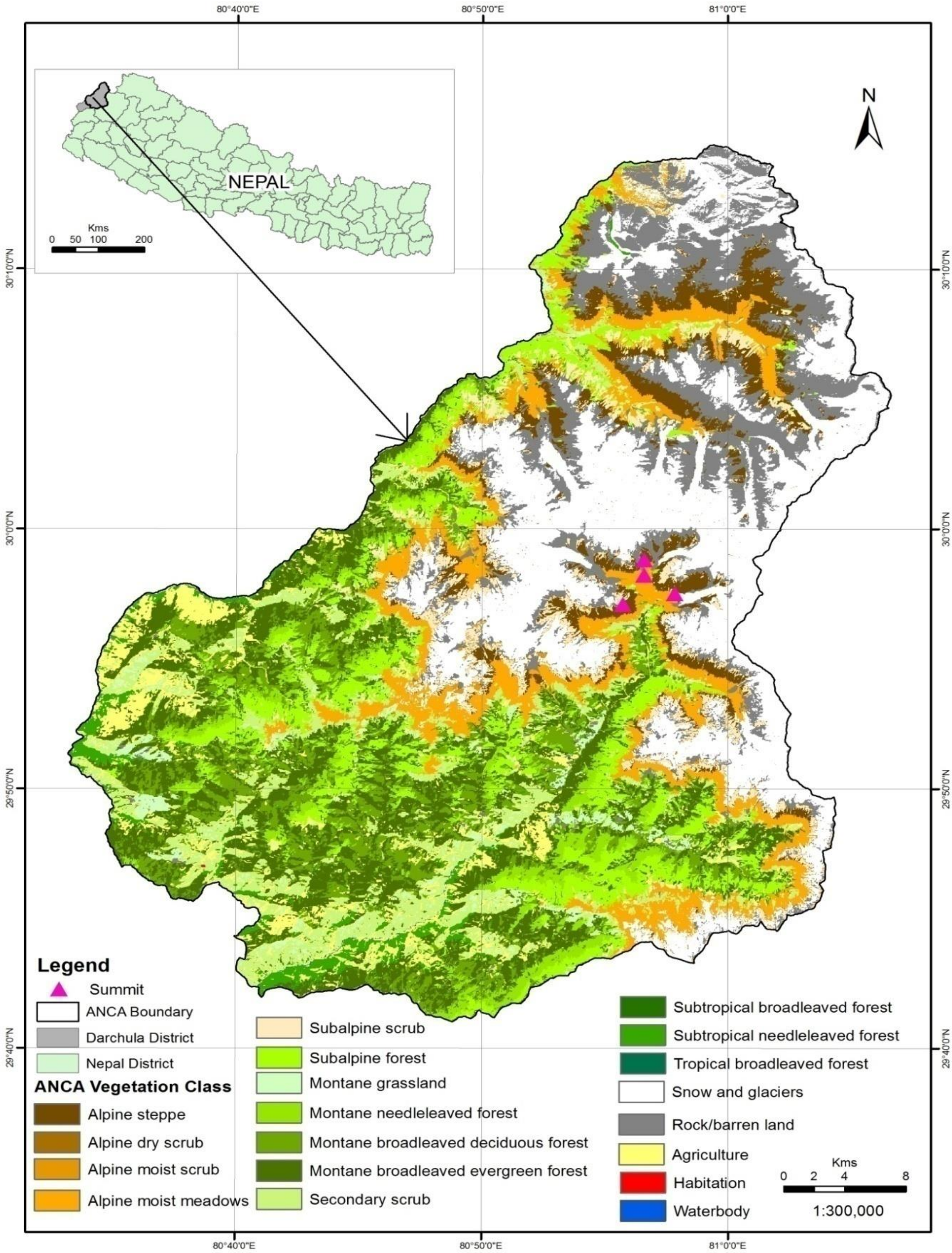

Figure 1. Map of the Darchula district showing the sample sites in red triangle (Source: ICIMOD)

Due to difficult topography and lack of modern technology, crop production in the study area is very low. Hardly two crops are grown per year. The major crops are rice, wheat, maize, barley, bean and potato. The crop yields are enough only for four to six months. This leads people to search for other livelihood options. Animal husbandry and commercial harvesting of medicinal plants are the alternative means of subsistence. In recent years, the socio-economic status of people is slowly becoming better because majority of them are engaged in harvesting and trade of *Ophiocordyceps sinensis* (kido) and other medicinal and aromatic plants (MAPs) such as *Neopicrorhiza scrophulariflora* (katuki), *Fritillaria cirrhosa* (ghande bish) and *Nardostachys grandiflora* (balaichan), which have high trade value in global market. Majority of households from Ghusa VDC participate in the harvesting of *Ophiocordyceps sinensis*.

2.1.4 Flora and fauna

Vegetation in Chamelia Valley below the treeline (3800 m) comprises stands of coniferous and broadleaved forests at various propersions. Vegetation above treeline consists of subalpine and lower-alpine shrublands and meadows. The dominant tree species in the forests at the temperate belt (*ca*. 2000-3000 m) are *Acer* spp., *Aesculus indica*, *Betula alnoides, Quercus leucotrichophora, Rhododendron arboreum*, *Sorbus cuspidata* and *Toona ciliata*. Forests in the subalpine belt (>3000-3800 m) comprise *Abies spectabilis, Betula utilis, Quercus semecarpifolia* and *Tsuga dumosa*. Treeline species are *Betula utilis, Rhododendron campanulatum* and *Sorbus microphylla*. Above treeline (>3800-<4300 m asl) shrub and sub-shrub elements like *Cotoneaster microphylla*, *Rhododendron anthopogon*, *Juniperus sqaumata, Juniperus recurva*, *Lonicera* sp. and *Salix* spp. form scattered vegetation. Chamaephytes like *Geum elatum, Gypsophila cerastioides*, *Hackelia uncinata, Heracleum wallichii, Koenigia nepalensis*, *Ligularia virgaurea*, *Pedicularis roylei*, *Rhodiola fastigiata*, *R. wallichi, Senecio chrysanthemoides, S. kunthianus, Silene gonosperma, S. setisperma, Swertia multicaulis, S. petiolata* and *Thalictrum cultratum*; and Cryptophytes, like *Allium prattii, Aconitum spicatum*, *Bistorta macrophylla, B. affinis, Cypripedium himalaicum, Dactylorhiza hatagirea*, *Delphinium brunonianum, D. vestitum, Herminium josephii, Nardostachys grandiflora* and *Polygonatum hookeri* are more common in the north and west slope. Hemicryptophytes, like *Carex atrata, Euphorbia stracheyi, Phleum alpinum, Potentilla microphylla, Primula macrophylla, Salix hylematica, Saussurea leontodontoides* and *Saxifraga mucronulata* are more dominant in eastern and southern aspects and also in upper mountain summits. Phytogeographically Chamelia valley is influenced by western Himalayan floristic elements.

Chamelia Valley provides suitable habitats for several rare, endangered and threatened species of animals such as snow leopard (*Uncia uncia*), musk deer (*Moschus moschiferous*), leopard cat (*Felis bengalensis*), Hanuman langur (*Semnopithecus entellus)*, Danphe (*Lophopherus impejanus*), Satyr pheasant (*Tragopan satyra*), snow cock (*Tetraogallus tibetanus*), blood pheasant (*Ithaginis cruentus*), red billed chough (*Pyrrhocorax pyrrhocorax*) and yellow-billed chough (*Pyrrhocorax graculus*) (Shrestha 1990).

2.2 Method

This research was conducted in the context of a long-term project related to the monitoring of alpine plants in response to climate change in North-West Nepal (Ghimire 2012; 2015) applying GLORIA (Global Research Initiative in Alpine Environment) methodology (Pauli *et al*. 2011). Here, I used baseline data collected from Darchula in 2014 and 2015 to analyze species diversity and distribution patterns of palatable and unpalatable species. A preliminary field visit was made in October 2014, during which period we identified sampling sites and interviewed some of the herders about the transhumance practice and uses of pastoral resources. Actual field sampling and detail interviews were made only in July 2015.

2.2.1 Transhumance practices

Participatory methods, including focus group discussions, key informant surveys and personal interviews with herders were adopted for the assessment the transhumance practice. This included the understanding of (i) the system of livestock movement into different pastures, (ii) the pattern of pasture resource utilization in terms of forage production and availability in the alpine pasture, and (iii) the livestock holdings and income generation. In addition, we also documented the herder's knowledge about the palatability of plant species, in terms of the availability of species preferred by the herbivore. Headers were interviewed *in situ* in the pastures of Dhauliodar (3200 m asl), Pilkanda (3800 m asl), Bhabhaya (3500 m asl) and base of Kalidhunga (3800 m asl). In total, thirty herders were interviewed and 4 focus group discussions (two each in 2015 and 2016) were held.

2.2.2 Herbivore choices

During each interview, herders were asked to enlist the species most or least preferred by their livestock. This list helped us to categorize plant species in to three palatability classes – palatable, unpalatable and poisonous – on the basis of the usage of the species as fodder and preference by the animals. In addition, we conducted extensive literature review to identify the palatability of plant species in high altitude region of the Himalaya (Hussain and Durrani 2009; Khan and Hussain 2012; Sheday *et al.* 2016). Periodic field visits and direct observations of the animal grazing in the pasture also helped us to figure it out whether a species in question is palatable. The species which were grazed by livestock were considered as palatable. The species which were not grazed at all by livestock at any stage were considered as unpalatable (NP). Unpalatable species causing illness or death of the animals were considered as poisonous (PP). The palatable species were further grouped in to four sub-classes: highly palatable (HP; i.e., the species mostly preferred and given first choice by the livestock in all times), moderately palatable (MP; i.e., the species usually, but not in all times, preferred by the livestock), less palatable (LP; i.e., the species not given first choice by the livestock), and rarely palatable (RP; i.e., the species rarely grazed often under compulsion when no other feed exist).

2.2.3 Plot design and data collection

Four mountain peaks were selected along an elevation gradient of 4000-4650 m representing the same macro-climate in the upper Chamelia Valley for the detail study. Each summit was divided into eight summit area section (SAS). Four upper SAS representing four compass directions (E, W, N and S) were laid from the highest summit point (HSP, top of the summit) to the 5 m downward vertical direction (**Fig. 2**). Further four lower SAS, representing four compass lines, were laid from the 5 m end point of upper SAS to the 5 m vertically down. At each 5 m end of vertical elevation from the HSP of upper SAS in each of the four cardinal compass direction, one 3 × 3 m plot (quadrat-cluster) was laid thus totaling four such plots per summit. Each plot was divided into nine 1 × 1 m quadrats, out of which four corner quadrads were selected for vegetation sampling. Altogether, sixteen 1 × 1 m quadrats were sampled per summit.

Elevation, slope and aspect were recorded in each plot. Presence of species was recorded in each 16 corner quadrats. Combining the species presence from all eight SAS and

16 quadrats gave the total summit flora (**Fig. 2**). In each of the 16 quadrats, top cover (%) of major surface types (vascular plant, lichen, bryophyte, scree, bare ground, and litter cover) were recorded based on visual observation.

2.2.4 Plant collection, identification and preservation

Most of the plant species were identified in the field. Digital photographs of plant species were taken. Voucher specimens were collected in respective sites outside the sampling plots for future reference. The collected samples were tagged, dried and brought to the laboratory for further identification. Voucher specimens were identified and confirmed through consulting expert and literature (Banerjii and Pradhan 1984; Banarjii 1982; Pollunin and Stainton 1984; Stainton 1987 and 1988; White and Sharma 2000; Pearce and Cribb 2002) as well as by comparing the specimens deposited in the national herbaria (TUCH and KATH). The collected specimens were deposited in TUCH.

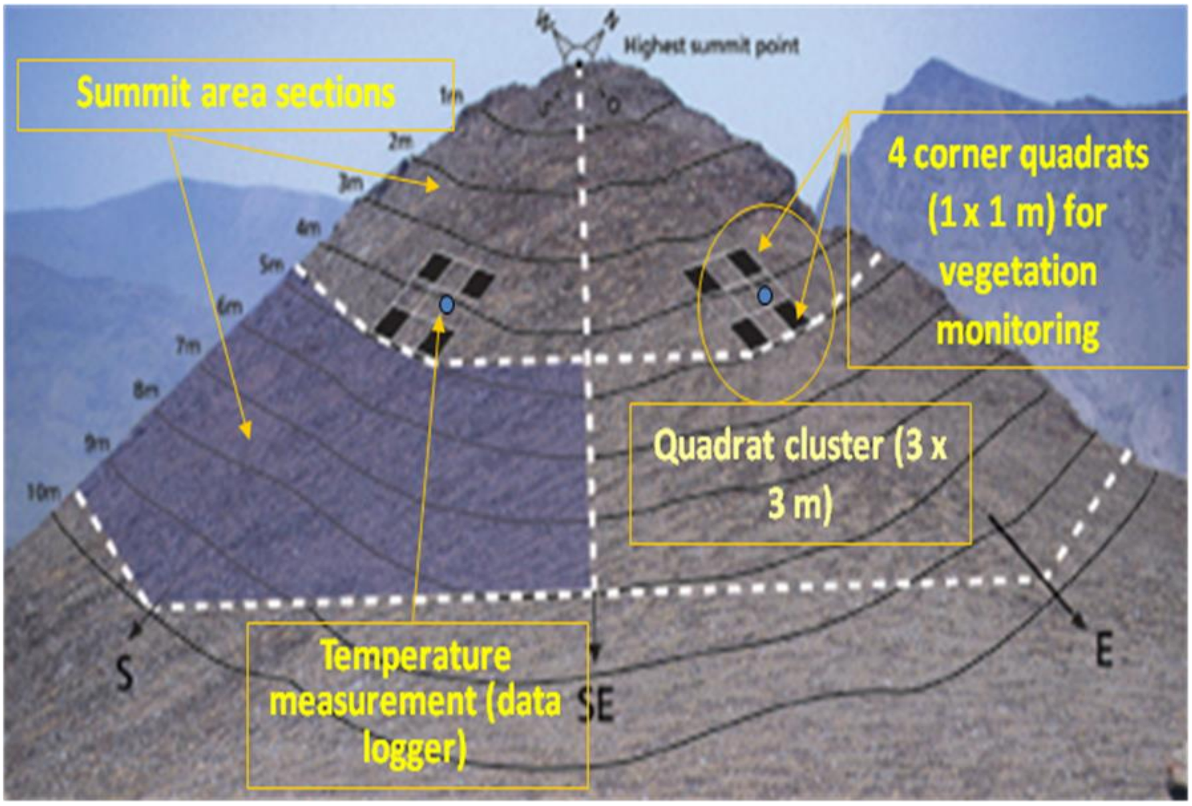

Figure 2. Field sampling technique showing the summit area sections and quadrats representing four compass directions (E, W, N and S) (source: GLORIA: www.gloria.org).

2.2.5 Geographical distribution patterns (chorotype)

Chorotype, which represents geographic distribution pattern of organisms (Baroni-Urbani *et al.* 1978; Olivero *et al.* 2011), was evaluated for each species based on literature and on-line databases related to the flora of Nepal (Shrestha *et al*. 1996; Zheng-Yi and Raven 1996-2003; Press *et al.* 2002; Ohbha *et al.* 2008; Rajbhandari *et al.* 2010, 2011, 2012; Watson *et al*. 2011; Rajbhandari *et al.* 2016). On the basis of biogeographical distribution range, following categories were made (adapted from Joshi 2013):

- **Himalayan endemics (HE)**: Himalaya is considered as the area from Pakistan to Myanmar, including Tibetan autonomous Region of China (TAR – now known as the Xizang Autonomous Region) and W. china (Sichuan and Yunnan). The floral elements belonging to these areas are considered as Himalayan endemics.
- **Pan-Himalayan distribution (PE)**: Including Himalaya as above, the areas lying adjoining to the Himalaya represent the biogeographical range of Pan-Himalaya. Those floral elements, which are restricted to the Pan-Himalaya but crossing the Himalayan range, are considered as Pan-Himalayan elements.
- **Broad range of distribution (BR):** Those floral elements, which are crossing the territory of pan-Himalayan range, are considered as broad range of distribution.

2.2.6 Plant life form classification (functional group)

Plant life form may be defined as the structural form of a plant, which assumes under the conditions of its habitat. Structural form reflects a plant's adaptation to its environment and indicates its response to disturbance such as grazing (Mueller-Dombois and Ellenberg 1974). There is a correlation between plant life form and climates, therefore, the life form spectra are said to be the indicators of micro- and macro-climate (Bouri and Mukherjee 2011). There are many life form classification proposed, among them, life form categorized based on system of Raunkiaer (1934) is considered to be more acceptable. According to Raunkiaer's system, the main life forms are Phanerophytes (PH), Chamaephytes (CH), Hemicryptophytes (HE), Cryptophytes (CR) and Therophytes (TH):

- **Phanerophytes (PH):** The perennating buds are situated higher up on the aerial shoot. The plants are woody trees, tall shrubs and lianas. There may be evergreen phanerophytes (with or without bud scales) or deciduous phanerophytes (with bud scales).

- **Chamaephytes (CH):** The perennating buds are situated close to the ground but are lower than 25 cm. According to the shoot, behavior four categories are recognized: (i) suffruticose chamaephytes: erect shoots die back at the onset of unfavorable condition and perennating buds occur on the lower portion of the stem (e.g., *Urticia dioica*); (ii) passive chamaephytes: weakened erect shoot fall over the ground at the onset of unfavorable seasons and perennating buds arise along the horizontal stem at ground level (e.g., *Stellaria holostea*); (iii) active chamaephytes: shoot is oriented along the ground such as creeping herbs (e.g., *Trifolium*), stoloniferous grasses (e.g., *Cynodon dactylon*) and trailing shrubs (e.g., *Cotoneaster*); (iv) cushion-chamaephytes: further reduced and compact form of the active chamaephyte (e.g., *Saxifraga*). Carpet mosses, fructicose lichen, bog mosses and leaf succulents, (e.g., *Sedum*) are also included in chamaephytes.

- **Hemicryptophytes (HC):** The perennating buds are located on the ground surface protected by the soil or dead plants parts; shoot die at the onset of unfavorable conditions. The plants are usually biennial and perennial herbs and also include mat forming algae, crustose lichens and thalloid bryophytes. Tussock forming plants (buds protected by old leaf sheaths, e.g., *Festuca, Poa, Dianthus*) and rosette plants (plants leaves arranged in a rosette protecting the buds and the aerial shoot leafless e.g., *Viola, Primula* are common examples.

- **Cryptophytes (CR):** The perennating buds are located below the ground surface or submerged in water. It includes (i) geophytes (plants with bulbs, corms, rhizomes, tubers and root tubers e.g., *Orobanche*), (ii) hydrophytes (except phytoplankton), (iii) halophytes (marsh plants in which perennating bud rooted in the soil beneath the water e.g., *Typha*).

- **Therophytes (TH):** The plants complete their life cycle (seed germination to seed maturation) within the favorable season of the year and remain dormant during unfavorable season in the form of seeds e.g., annual pteridophytes.

2.3 Data Analysis

2.3.1 Gradient analyses for species composition difference

Detrended Correspondence Analysis (DCA), an indirect gradient analysis (Hill and Gauch 1980) was used to analyze the species composition of four summits as well as to test the turnover rate or axis length. DCA is one of the most popular and robust indirect gradient analysis and computationally very efficient ordination method. The SD units of the first two ordination axes (axis I and axis II) together with the eigenvalues (total inertia) are used to evaluate the dispersion pattern with the species composition. Eigenvalues are the shrinkage values in weighted average (Oksanen 1996). The axes explain percentages of the variance in the species data and eigenvalues are good measurement of the main variation in samples and species along the ordination axes (Jongman 1995).

As the gradient length obtained from a preliminary DCA was greater than 2.0 *SD* units, canonical correspondence analysis (CCA) was followed for further analysis. CCA is a direct gradient analysis to relate the species composition to the environmental variables by permutation and regression (ter Braak 1986). Each environmental variable was tested up to 9999 times against full species composition model. CCA displays three pieces of information's simultaneously: sample as plot, species as symbols and environmental variable as arrows (or points) (Palmer 2007). The angle between arrows indicates correlation between individual environmental variables of imaginary axis running in the direction of the variables.

2.3.2 Species diversity measures

Most often species diversity is represented simply as number of species in an area. It is a kind of density (number of species per unit area), and is generally called species richness. Species richness (α-diversity) is the principle measure of diversity considered in this study. Species richness was obtained at the level of 1 × 1 m quadrat and 3 × 3 m quadrat-cluster. Total number of species from all SAS and quadrats per summit is defined as γ- diversity (Whittaker 1972). The effect of aspect (main compass directions) and summits on species richness was examined through two-way ANOVA. Species richness data were log transformed to achieve normality and homogeneity of variance prior to parametric tests. The richness values of life-form, cover percentage of environmental variables and physical parameters in all summits were skewed and did not follow normal distribution even after transformation, therefore those data were treated through non-parametric tests (Kruskal-Wallis test for K independent samples). The relationships among environmental variables of all data set were obtained by Spearman rank correlations.

All univariate analyses were performed in SPSS version 20 (Fowler *et al*. 2001) and multivariate analysis were performed through CANOCO version 4.5 based on the guidelines provided in McCune and Grace 2002.

CHAPTER THREE: RESULTS

3.1 Transhumance Practice

Pilkanda area of upper Chamelia valley is one of the major summer pasture for the people living in the Ghusa VDC. Variety of plant species start to sprout on early summer with the beginning of melting of snow in the summer pasture areas of Chamelia valley and these plants finally bloom on midsummer. At the mean time, local herders of lower temperate zone of Ghusa VDC migrate to supper pasture areas with their cattle (sheep and goats), and stay until early winter.

The local herders proceed in a definite spatio-temporal pattern to graze their sheep and goats (Fig. 3). Their movement starts from main permanent settlements (Ghusa VDC, 2000-2400 m asl) where they spent about six month (October first to April last). Herders depart from the village in last of April and reach to the summer pasture (>3800 m) on first week of July. On the way, they stay 2-3 days in Khayekot (2000 m asl), 3-5 days in Chechere (2400 m asl), 3-5 days in Simar (2600 m sal), 2-3 days in Domule (2900 m asl) and finally they reach Dhauleodar (3400 m sal). They stay from May to June in Dhaule odar and graze the sheep and goats in the surrounding pastures of Bhabhai (3600 m asl) and Nete (3800 m asl). In the first week of July, they move to Pilkanda (>3800 m asl) and stay there for up to the first week of September. In Pilkanda, Thadapani (3900-4500 m asl), Ringde (3600-4400 m), Gauchhaleghole (3800-4450 m), Dopakhe (3800-4400 m), Kalidhunga (3800-4300 m) and Bainsad (3800-4400 m) are the main grazing sub-pastures. Herders return to Dhauleodar in mid-September and stay for 2-3 days. On the way back, they stay 2-3 days in Domule, 3-5 days in Simar, 2-4 days in Chechere, 1-2 days in Khayekot and finally, in the first week of October, herders reach to their permanent settlement (Ghusa VDC) and graze their goats and sheeps in winter pastures near the settlement (Fig. 3).

The study area supports higher level of plant diversity, which is linked, with different levels of ecosystem services. Among the services provided by grassland, only the services related to domestic animal use of forage is evaluated here. On the basis of direct observation and interview with herders (n = 30), there were 4,350 number of sheep and goats in a total of seven sheds belonging to the people of Ghusa VDC. Additionally, there were a total of 60 cows and oxes and 95 mules together with horses found to be grazing in the same summer pasture.

Table 1. Number of grazing animals and income for each shed (value in *000 NRs, detail in Appendix 1).

Income source	No. of Shed							Overall income (million)
	1	2	3	4	5	6	7	
Number of sheep and goat	750	600	650	550	650	500	650	
Income from direct selling (NRs.)	1560	1824	1040	1056	728	640	1144	7.992
Income from load carrying (NRs)	135	144	175.8	109.2	136.8	96	129	0.926
Income from selling wool (NRs)	115	75	100	85	95	85	105	0.660
Total income of each shed	1810	2043	1315.8	1250.2	959.8	821	1378	9.618

People had traditional management system of rotation for the sufficient availability of palatable species and sustainability of grazing system (explained in Fig. 3). In our field site among the domestic grazing animals, the number of sheep and goats was found higher. The grassland was located far remote from the settlement and livestock had to cross a lot of difficult terrains. So, the herders here mostly prefer to rear sheep and goats because they can be graged in difficult and sloppy terrain. Thus, smaller herbivores were found to be more compatible for transhumance practice.

According to the interview information, the economic subsidies and cash income was mostly obtained from livestock rearing. The trend of livestock farming was found to be reducing in recent years due to increased market demand of *Ophiocordyces* and other highly valued medicinal plants. Thus, a significant number (>80%) of interviewed households were found to be engaged in harvesting of *Ophicordyceps* and other medicinal plants in study sites. The income from *Ophicordyceps* and medicinal plant harvesting was far beyond, in comparison to rearing livestock in the area. The income gained from the sheep and goats does not last for more than three months for their family. About 50 people and their family members were fully engaged in this occupation. From the quick review on total income of the seven sheds present in valley showed that NRs 9.6018 million per year was directly obtained from the transhumance practice (Table 1; Appendix 1).

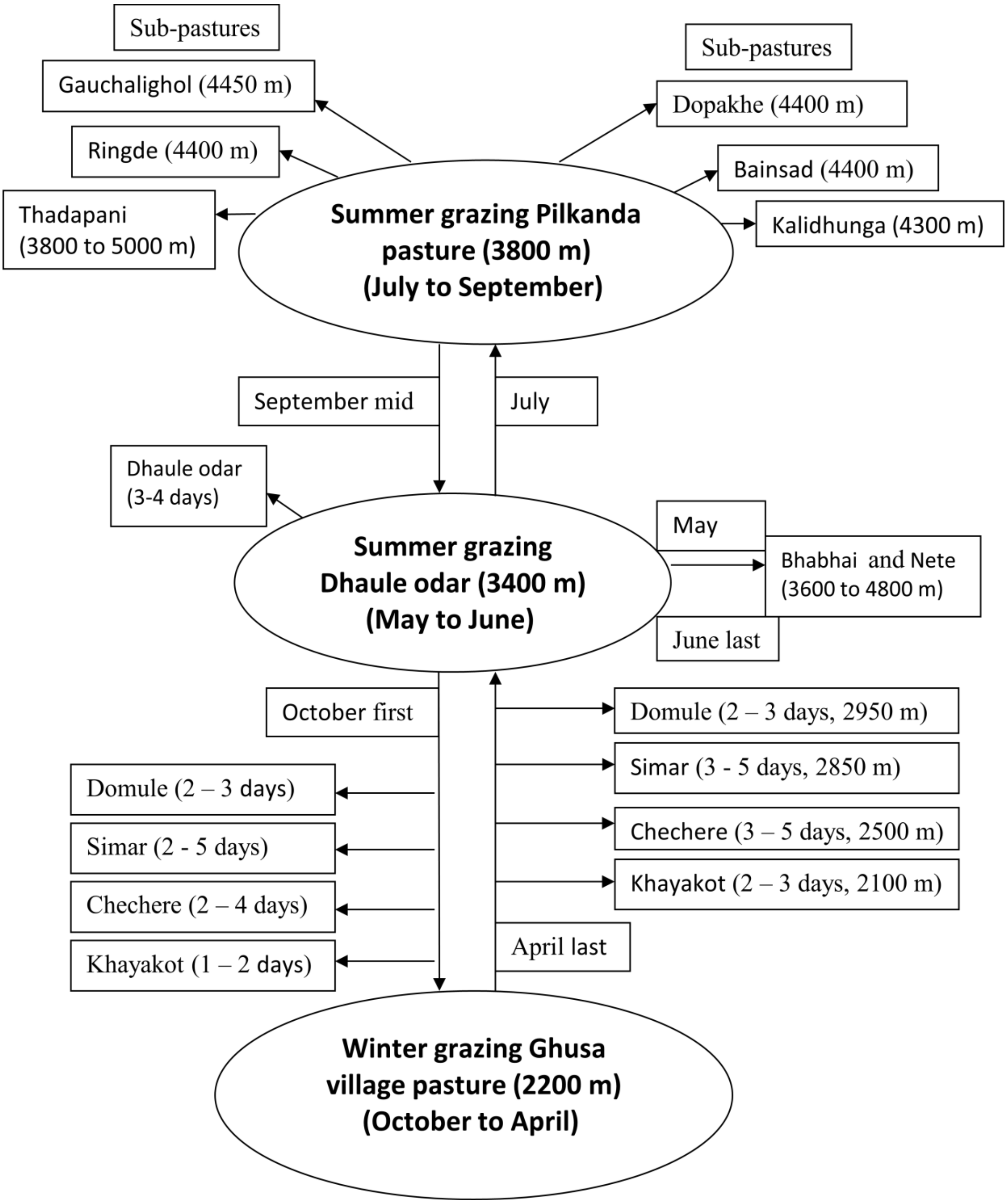

Figure 3. The transhumance practice followed by local herders in Chamelia valley.

Regarding the cash income generation, about NRs. 0.92 million was generated by the use of sheep/goat as a means of transportation, 0.66 million by wool production and 7.99 million were earned by direct selling. Sheep farming showed multi-functional income generating source compared to goat. Sheeps are used for wool production and transportation. Similarly, the local people utilize meat for their nutrient requirement as compared to people at lower elevation. The nutrient deficiency was directly subsidized by meat obtained from livestock and this service had been providing great asset in turn of low crop production in Himalayan terrain.

3.2 Species Composition

The environmental variables (mean ± SD) recorded in quadrats (1 ×1 m) among four summits are given in Appendix 2. There was significant difference in substrate and vegetation variables among summits. The vascular plant cover was highest in SMB and lowest in SMD. The cover percentage of vascular plants decreased significantly from SMB to SMD. Litter cover value also showed similar trend with respect to summits. The cover percentage of bryophyte and lichen were significantly highest in SMC. Similarly, rock cover percentage was highest in SMD and lowest in SMB.

The DCA ordination analysis of all four summits showed gradient length 4.5 SD unit and eigenvalue 0.69. The variance revealed by the first axis of DCA was 10.3 % of the total variance in the data set after combining all the four summits (Table 2). The percentage of variance were decreased towards the second, third and fourth axes. The value of gradient length (4.5) indicated that there was high composition turnover along the main gradient.

Canonical Correspondence Analysis (CCA) showed that the first axis to represent the strong elevation gradient. The eigenvalue of CCA first axis was 0.682, which indicated the effective separation of species along the main gradient (Table 3). CCA first axis explained 10.2% variance in species composition data and 27.1% variance in species-environmental data relationship. First axis separated the samples (Fig. 4a) and species (Fig. 4b) from the negative end (SMA) to the positive end (SMD). Here, elevation, a macro-environmental variable, explained 67% variance (p=0.0001) in total dataset (Appendix 3). Among the micro-environmental variables, cover of rock, bryophyte and lichen had significant effect for formation of heterogeneous species composition. The distance between the sample points in the diagram (Fig. 4) approximated the dissimilarity in species composition. CCA second axis explained 7.9% variance in species composition data. The eigenvalue of second axis (0.529) also specified the substantial separation of species along the gradient of unknown variable(s). However the positive relationship of bryophyte cover (Bry) and cattle grazing (Catt) and negative relationship of bare ground cover (Bgr) and sheep/goat grazing (SheGoa) indicated that the second axis represent a complex gradient related to disturbance and substrate type. The grazing factors (cattle effect and combined sheep and goats effect) were opposite to the elevational gradient (Fig. 4). The effect of grazing was closely associated with SMA and SMB at lower elevation.

Table 2. DCA summery of four summits.

Variables	Axes			
	1	2	3	4
Eigenvalues	0.694	0.392	0.28	0.22
Lengths of gradient	4.504	3.471	2.764	2.807
Species-environment correlations	0.985	0.528	0.263	0.664
Cumulative percentage variance				
of species data	10.3	16.2	20.4	23.6
of species-environment relation	39.4	44	0	0

Total inertia = 6.707.

Table 3. CCA summary of four summits.

Variables	Axes			
	1	2	3	4
Eigenvalues	0.684	0.529	0.5	0.199
Species-environment correlations	0.994	0.981	0.982	0.911
Cumulative percentage variance				
of species data	10.2	18.1	25.5	28.5
of species-environment relation	27.1	48.1	68	75.8

Sum of all canonical eigenvalues = 2.521

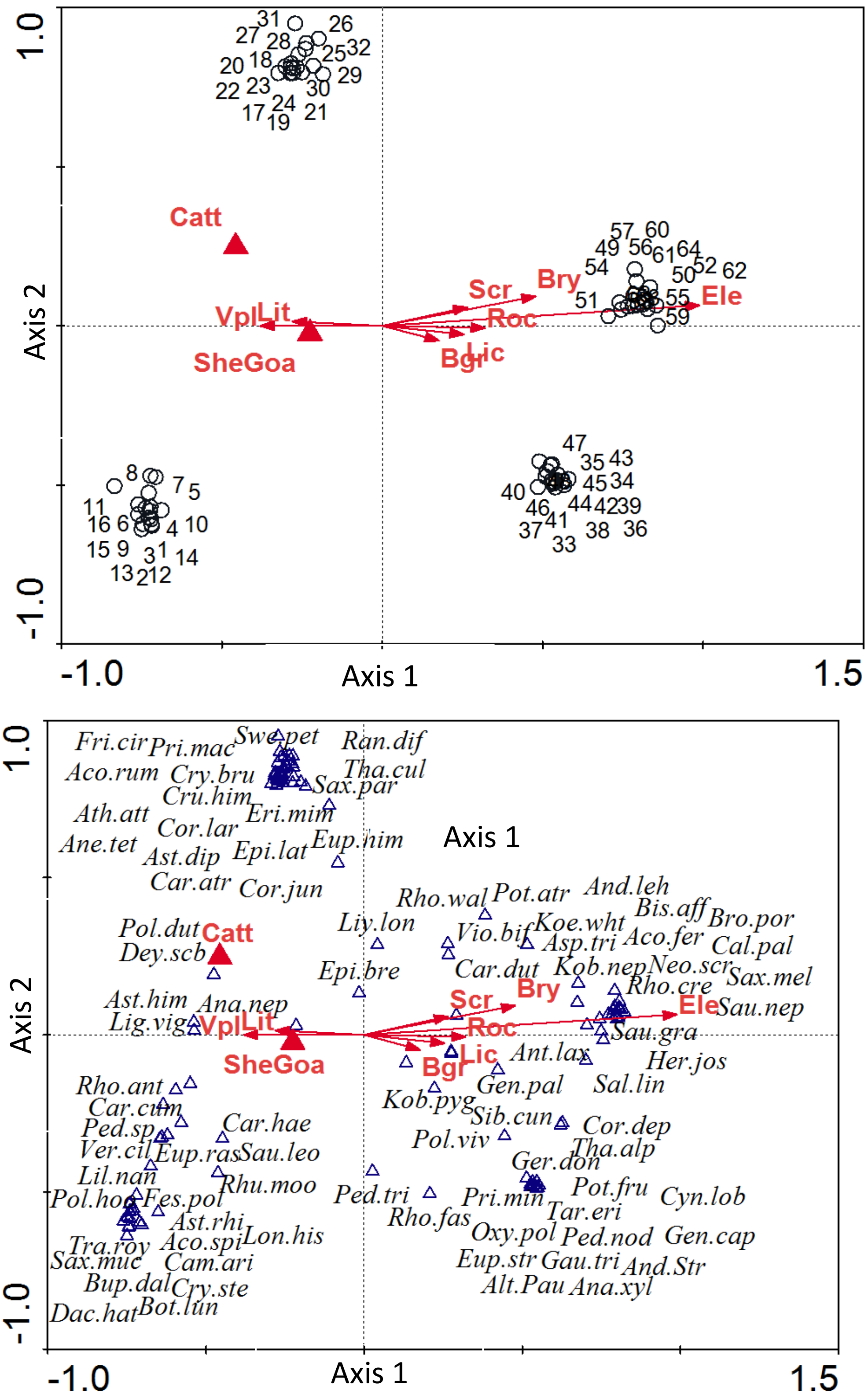

Figure 4. CCA biplot for (a) sample and (b) species along with environmental variables. Abbreviations for environmental variables are given in Appendix 3 and those for species are given in Appendix 4.

Neopicrorhiza scrophulariiflora (Neo.scr), *Saxifraga melanocentra* (Sax.mel), *Saussurea graminifolia* (Sau.gra), *Bromus porphyranthos* (Bro.por), *Pedicularis siphonantha* (Ped.sip), *Androsace lehmannii* (And.leh) and *Aconitum ferox* (Aco.fer) had strong affinity towards high elevation at open substrates (Bgr.) and distributed toward the positive end of CCA axis 1 (Fig. 4b). The negative end of CCA axis 1 and axis 2 explained that the species like *Dactylorhiza hatagirea (*Dac.hat), *Thalictrum cultratum (*Tha.cul), *Selinum wallichianum* (Sel.wal), *Swertia petiolata* (Swe.pet), *Carex atrata* (Car.atr), *Polystichum duthiei* (Pol.dut), *Hackelia uncinata* (Hac.unc), *Veronica ciliata* (Ver.cil) and *Ligularia virgaurea* (Lig.vir) were correlated towards lower elevation, nutrient richer soil with higher vascular cover and higher litter cover (Fig. 4b).

Rhodiola smithii (Rho.smi), *Taraxacum eriopodum* (Tar.eri), *Gentiana capitata* (Gen.cap), *Aletris pauciflora* (Ale.pau) and *Gaultheria trichophyla* (Gau.tri) had strong affinity towards substrates with high lichen and bryophyte cover. *Polygonum viviparum* (Pol.viv), *Pedicularis bicornuta* (Ped.bic), *Sibbaldia cuneata* (Sib.cun), *Rhodiola fastigiata* (Rho.fas), *Kobresia pygmaea* (Kob.pyg), *Viola biflora (*Vio.bif) and *Epilobium brevifolium* (Epi.bre) were the species equally distributed towards all gradients (Fig. 4b).

Palatable species like *Kobresia pygmaea* (Kob.pyg), *Carex atrata* (Car.atr) and *Dactylorhiza hatagirea* (Dac.hat) were more on the negative end of axis first. Similarly, un-palatable species such as *Neopicrorhiza scrophulariiflora* (Neo.scr) and *Rhodiola fastigiata* (Rho.fas), and poisonous species such as *Aconitum ferox* (Aco.fer) were observed in positive end of axis first (Fig. 4b).

3.3 Species Diversity Measurement

Vegetation sampling in all four sites recorded 179 species of vascular plant, belonging to 109 genera and 51 families. Asteraceae was the largest family (14 genera) among all the families recorded. *Pedicularis* (Orobanchaceae) with eight species was the largest genus throughout the summits (see Appendix.4). Among 179 plants species recorded in four summits, 108 (60.33%) species were palatable for livestock grazing (Table 4). Among all the palatable species, 34 (31%) species were recorded to be highly preferred, 31 (28.7%) moderately preferred, 28 (25.92%) less preferred and 15 (13.88%) species were rarely preferred to livestock (Fig. 5). Out of total species, 18 (10.05%) species were recorded as poisonous to grazing animal. *Aconitum* spp., *Delphinium* spp. were the most common and deadly poisonous plants to the domestic animal in the study area. There was 53 (29.60%) species noted as un-palatable to livestock grazing (Table 4), such as *Pedicularis* spp., *Rhodiola* spp., *Swertia* spp. and all ferns species.

γ-diversity was highest in SMB (overall 110 species) and lowest in SMD (39) and it showed that species diversity was increased up to SMB (4200 m) and then decreased towards summit located at higher elevation (SMC and SMD) thus indicating an unimodal pattern of species distribution along the elevation gradient (Table 4). Similar was the trend for palatable, unpalatable and poisonous species (Table 4). Also at the plot levels (of both 3 m × 3 m and 1 m × 1 m) the overall species richness was significantly higher in mid-summit (SMB) compared to the lower (SMA) and higher (SMC and SMD) elevation summits (one-way ANOVA, $p<0.05$; Table. 5). SMB (4100 m) was found to be located at the transitional zone between lower alpine and higher alpine region and ecotonal effect was found to be marked.

One way ANOVA also showed that at both the plot levels (3 m × 3 m and 1 m × 1 m) the proportion of palatable species was decreased, but un-palatable and poisonous species were increased linearly with increasing elevation (Table 5). Vegetation sampling at 1 × 1 m plots level (α-diversity) revealed a significant different pattern in palatable and un-palatable species diversity but the value of poisonous species did not show significant pattern in diversity (Table 5).

Table 4. Number of species (% in parentheses) at landscape-level according to palatability in four summits.

	SMA	SMB	SMC	SMD	Overall
Palatable	60 (65.21)	70 (63.63)	38 (56.71)	20 (51.28)	108 (60.33)
Un-palatable	24 (26.08)	29 (26.36)	22 (32.83)	14 (35.89)	53 (29.60)
Poisonous	8 (8.69)	11 (10.00)	7 (10.44)	5 (12.82)	18 (10.05)
Overall	92	110	67	39	179

Table 5. Measurement of total species richness (α-diversity) and richness of palatable, unpalatable and poisonous species at 3 m x 3 m and 1 m x 1 m plot levels in four summits.

	Study sites				Overall	*F*	*p*
	SMA (4000 m)	SMB (4200 m)	SMC (4450 m)	SMD (4650 m)			
All species richness							
3x3 m plot level*	64.00 ± 0.00[a]	71.50 ± 6.06[b]	55.50 ± 2.98[ac]	45.25 ± 8.18a[cd]	59.06 ± 3.54	4.11	0.03
1x1 m plot level*	16 ± 0.50[a]	17.875 ± 0.99[b]	13.87 ± 0.68[ac]	11.31 ± 1.02[ad]	14.76 ± 0.51	11.43	0.001
Palatable species richness							
3x3 m plot level*	40.25 ± 1.10	37.75 ± 2.86	36.50 ± 2.66	32.50 ± 2.21	36.75 ± 1.26	1.95	0.17
1x1 m plot level*	10.06 ± 0.26	9.43 ± 0.48	9.18 ± 0.27	8.12 ± 0.51	9.20 ± 0.21	4.04	0.01
Unpalatable species richness							
3x3 m plot level*	8.25 ± 0.75	16.00 ± 3.46	18.50 ± 2.87	25.75 ± 4.42	17.12 ± 2.15	5.16	0.01
1x1 m plot level*	2.06 ± 0.24	4.00 ± 0.47	5.12 ± 0.46	9.93 ± 0.45	5.28 ± 0.41	63.6	0.001
Poisonous species richness							
3x3 m plot level*	5.75 ± 0.62	6.00 ± 1.82	6.50 ± 1.50	7.25 ± 1.43	6.37 ± 0.65	0.21	0.88
1x1 m plot level*	1.43 ± 0.12	1.50 ± 0.28	1.62 ± 0.22	2.00 ± 0.38	1.64 ± 0.13	0.85	0.47

*Similar letters in the superscript denotes no significant variation between summits (at $p<0.05$ level) based on one-way-ANOVA and Tukey range test.

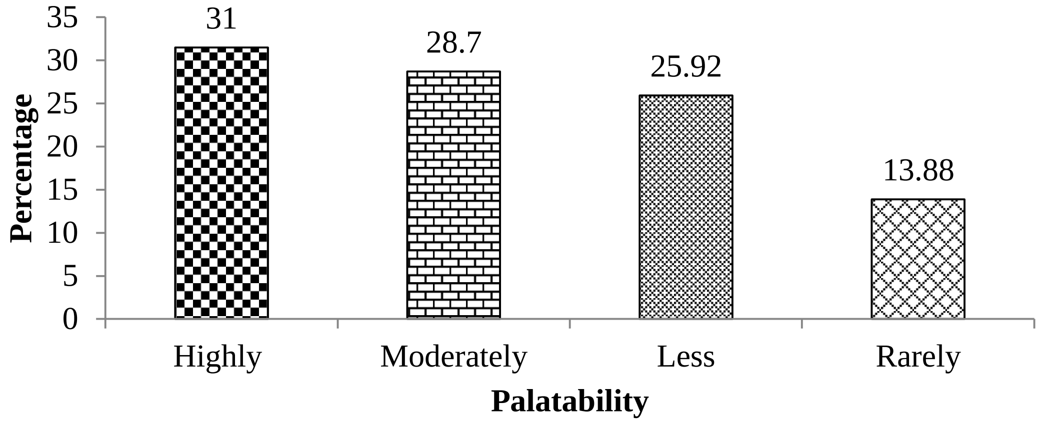

Figure 5. Percentage at landscape-level of species according to palatability in summits representing different ecotones along elevation gradient.

Species richness among four aspects (N, S, E and W) did not show consistent trend, though the results were statistically significant (Table 6, Fig. 6). In two-way ANOVA, the significant interaction between aspect and summit revealed that the effect of aspect was different in different summits (Table 6). In SMA, higher number of palatable species was recorded in north-west aspect, followed by un-palatable species in west and poisonous species in east aspect. In SMB, palatable species and un-palatable species were higher in west aspect; whereas poisonous species were found to be higher in south aspect. In SMC, palatable and un-palatable species were higher in north aspect, but contradictically, poisonous species were found to be equal in all four aspects. In SMD, the number of palatable and un-palatable species was higher in south aspect; whereas poisonous species was recorded higher in south and west aspects.

Table 6. Two-way ANOVA showing the effects of summit and aspect on species richness at the level of 1 m x 1 m plot. Species richness values were $\log_{10}$ transformed before analysis.

Source	Sum of Squares	Df	Mean Square	F	*P*
Intercept	81.10	1	81.10	9099.38	<0.0001
Summit	0.39	3	0.13	14.73	<0.0001
Aspect	0.10	3	0.03	3.84	0.019
Summit * Aspect	0.30	9	0.03	3.76	0.001
Error	0.42	48	0.08		
Total	82.33	64			

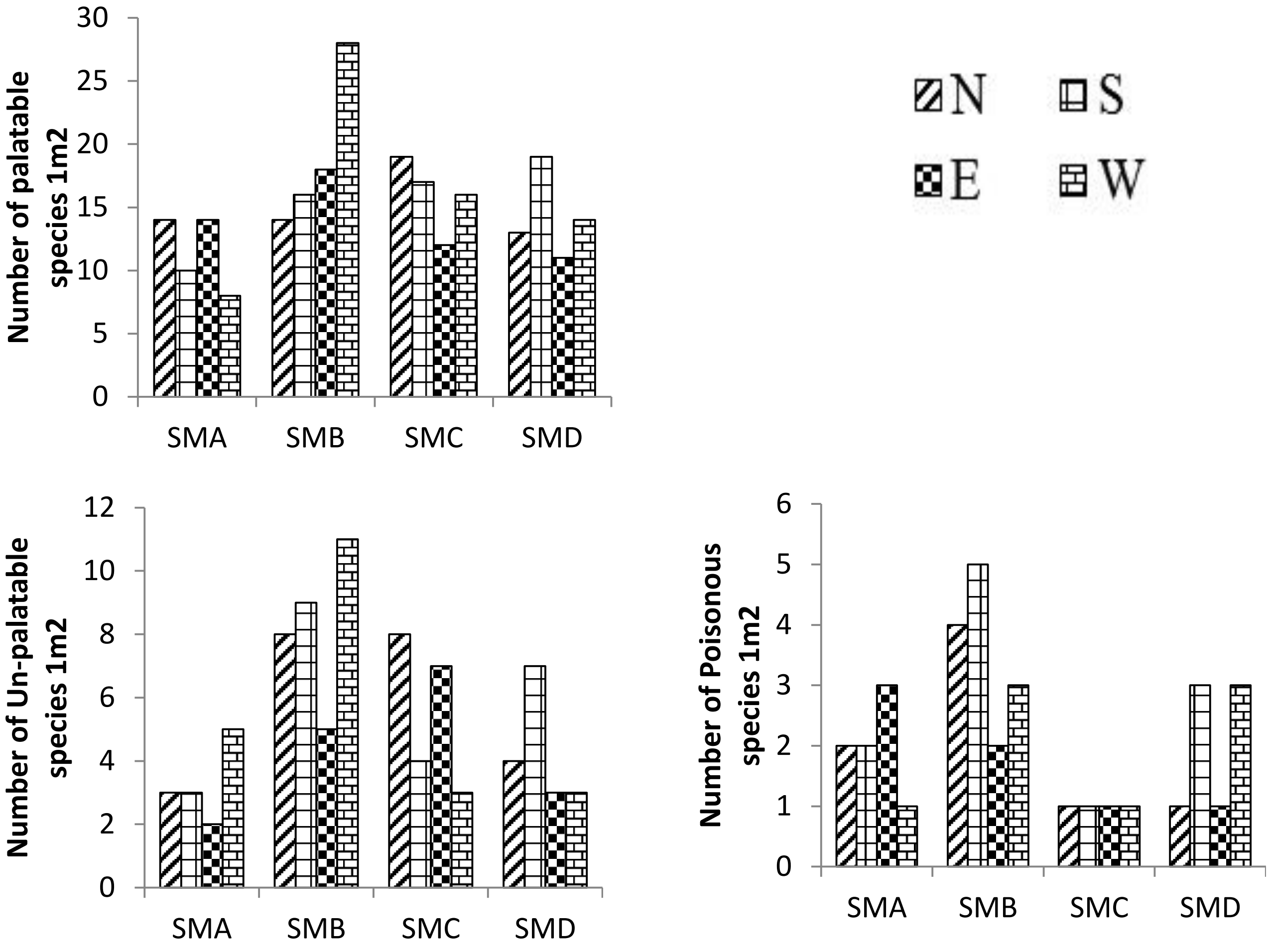

Figure 6. Number of species in 1 m^2 plots at four aspects (at main compass directions, N – north, S – south, E – east, and W – west) in summits along elevation gradient.

3.4 Plant Life Form Diversity

In all the four summits, chamaephytes (51.66%) were the dominant life form (Table 7). The second largest group was hemicryptophytes (27.22%), followed by cryptophytes (13.33%), phanerophytes (3.88%) and therophyes (3.33%) (Table 7). Similar result was found for the richness of different life forms at the plot level (Table 7).

Proportion of chamaephytes was higher in lowest summit (SMA), which decreased linearly towards higher-elevation summits. The percentage of hemicryptophytes, on the other hand, increased with increasing elevation (Table 7). Percentage of cryptophytes was also highest at higher summits, but it did not exhibit a linear trend. Phanerophytes and therophytes also showed linear decreasing trends with increasing elevation. No phanerophytes and therophytes were recorded from the highest summit (SMD).

Table 7. Plant life form diversity at the landscape (summit) and plot level in summits along elevation gradient. At the summit level percentage distribution of species among the life forms in each summit are given in parentheses.

Life form*	Study summits				Overall	F	P
	SMA	SMB	SMC	SMD			
Summit level							
CHP	50 (54.34)	58 (52.72)	31 (46.26)	15 (38.46)	93 (51.66)	-	-
HCP	20 (21.73)	32 (29.09)	27 (40.29)	16 (41.02)	49 (27.22)	-	-
CRP	13 (14.13)	13 (11.81)	6 (8.95)	8 (20.51)	24 (13.33)	-	-
PHP	5 (5.43)	3 (2.72)	1 (1.49)	0.00 (0.00)	7 (3.88)	-	-
THP	4 (4.34)	4 (3.63)	2 (2.98)	0.00 (0.00)	6 (3.33)	-	-
*1 m x 1m m plot level***							
CHP	10.06 ± 0.41	9.56 ± 0.53	7.50 ± 0.48	4.68 ± 0.48	7.95 ± 0.35	26.01	0.0001
HCP	4.50 ± 0.36	5.25 ± 0.38	5.93 ± 0.33	7.12 ± 0.53	5.70 ± 0.23	7.38	0.0001
CRP	1.68 ± 0.31	1.56 ± 0.25	1.50 ± 0.15	2.37 ± 0.17	1.78 ± 0.12	2.94	0.04
PHP	0.50 ± 0.12	0.18 ± 0.10	0.00 ± 0.00	0.00 ± 0.00	0.17 ± 0.04	8.3	0.0001
THP	0.18 ± 0.10	0.00 ± 0.00	0.31 ± 0.15	0.00 ± 0.00	0.12 ± 0.04	2.85	0.04

*CHP= chamaephytes, HCP= hemicryptophytes, CRP= cryptophytes, PHP= phanerophytes, THP= therophyes

**data shown are mean ± SE.

In the case of both palatable and un-palatable species, chamaephyte was the dominant life form (>50% of the species), followed by hemicryptophytes, cryptophytes, therophyte and phanerophytes. However, majority of poisonous species were cryptophytes, followed by chamaephytes, hemicryptophytes, and phanerophytes. There was no any poisonous species found under the class therophyte (Fig. 7).

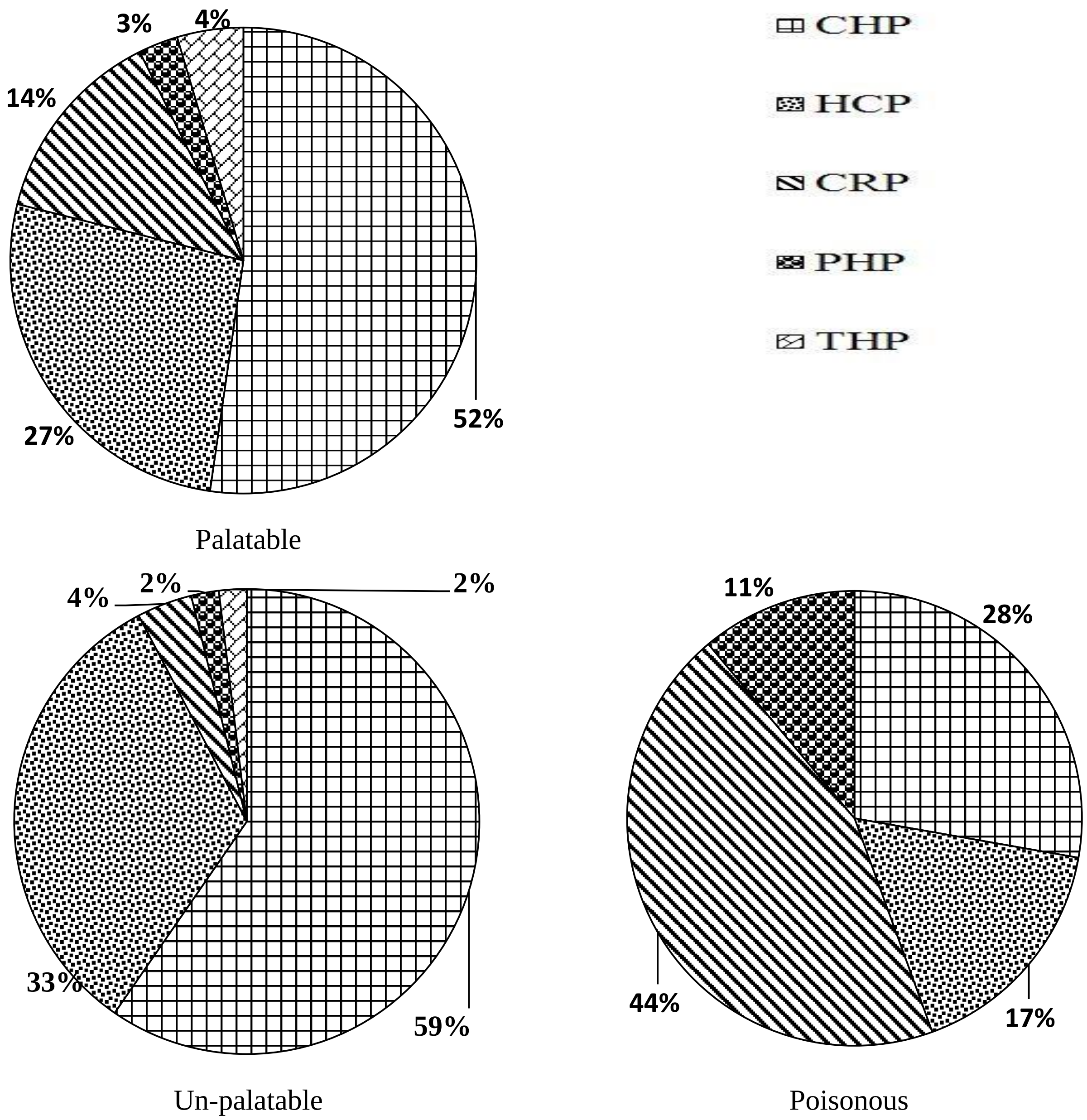

Figure 7. Life form distribution in three palatability classes of species.

3.5 Biogeographical Pattern

Over 70 % of species recorded in the study summits were Himalayan endemics, followed by pan-Himalayan (19.55%) and broad-range species (10.05 %). Himalayan endemics were dominant in all three classes of palatability (50-69%), followed by pan-Himalayan (21-39%), and broad-range species (10-14%) (Fig. 8). Proportion of Himalayan endemics increased with increasing elevation of the summits (Table 8). Higher proportions of pan-Himalayan and broad-range species were recorded in the lowest summit (SMA), and these decreased with increasing elevation.

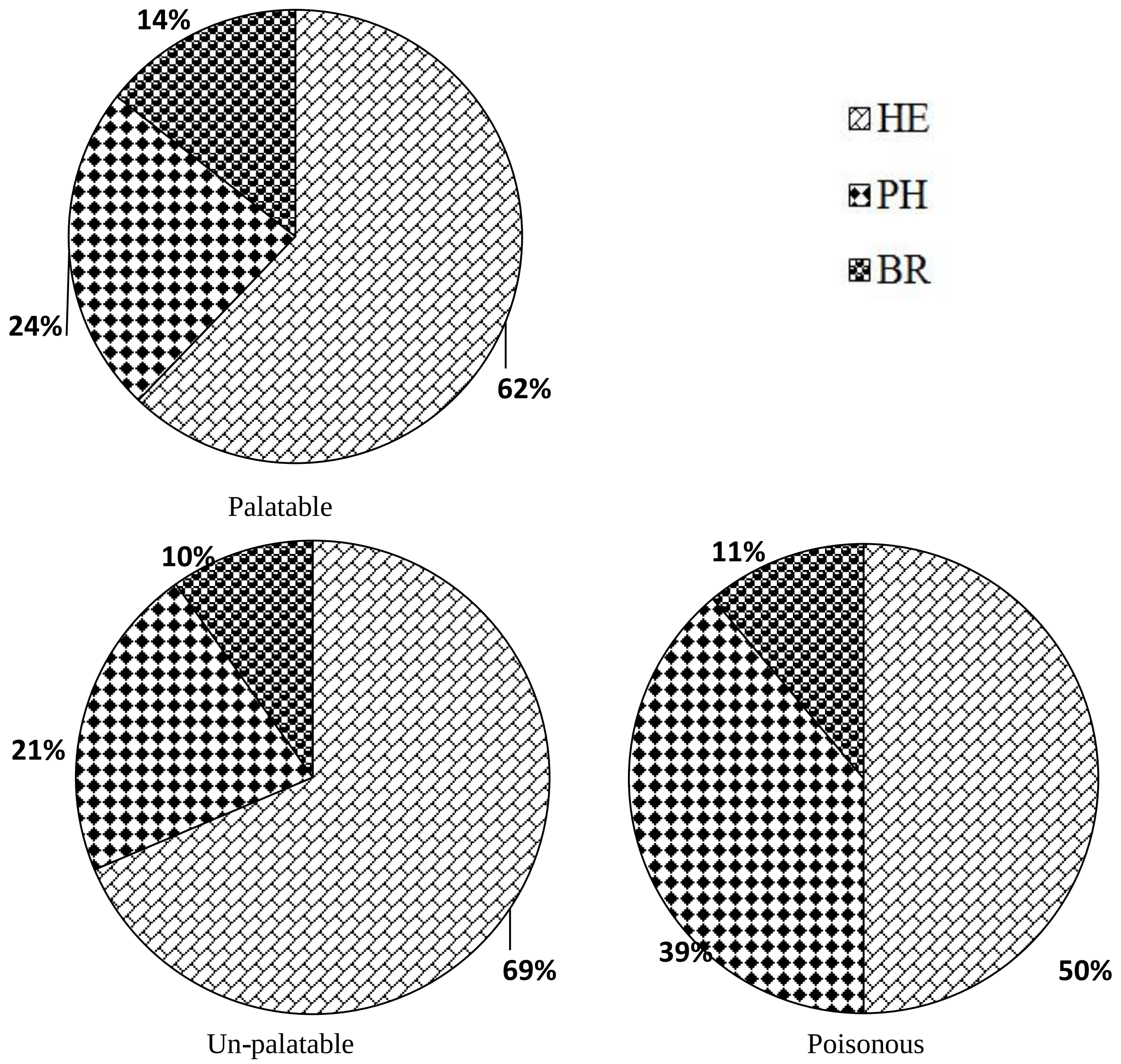

Figure 8. Biogeographical pattern in three palatability classes of species

Table 8. Percentage (number of species parentheses) of species under three biogeographical domains (chorotypes) in four summits along elevation gradient.

Chorotypes	Summits				Overall
	SMA(4000 m)	SMB(4200 m)	SMC(4450 m)	SMD(4650 m)	
Himalayan endemic (HE)	56(60.86)	76(69.09)	49(73.13)	30(76.92)	126(70.39)
Pan-Himalaya (PH)	21(22.82)	18(16.36)	9(13.43)	5(12.82)	35(19.55)
Broad-range of distribution (BR)	15(16.30)	16(14.54)	9(13.43)	4(10.25)	18(10.05)

3.6 Relative Cover and Frequency of Plant Species

Relative cover and frequency of species present in 1 × 1 m plots (in total, 114 plots) in all summits were calculated. The unique and common species in the study summits, with their relative cover, frequency and palatability is given in Table 9 (for detail see Appendix 4). In all the four summits, abundance (in terms of relative cover and frequency) of palatable species was much higher than un-palatable and poisonous species (Fig. 9). The abundance of un-palatable species was high in mid-elevation summit (SMB), but that of poisonous species was high in low-elevation summit (SMA) (Fig. 9).

The number of unique and common species varied with the elavational gradient. The number of common species was greater among summits that are adjacent or close to each other and the number decreased among summits that are faraway. Thus, there were seven species common to SMA and SMB and only one species common to SMA and SMD (Table 9). The number of unique (specie restricted to one summit) species were 11 in SMA, 33 in SMB, 16 in SMC and 19 in SMD.

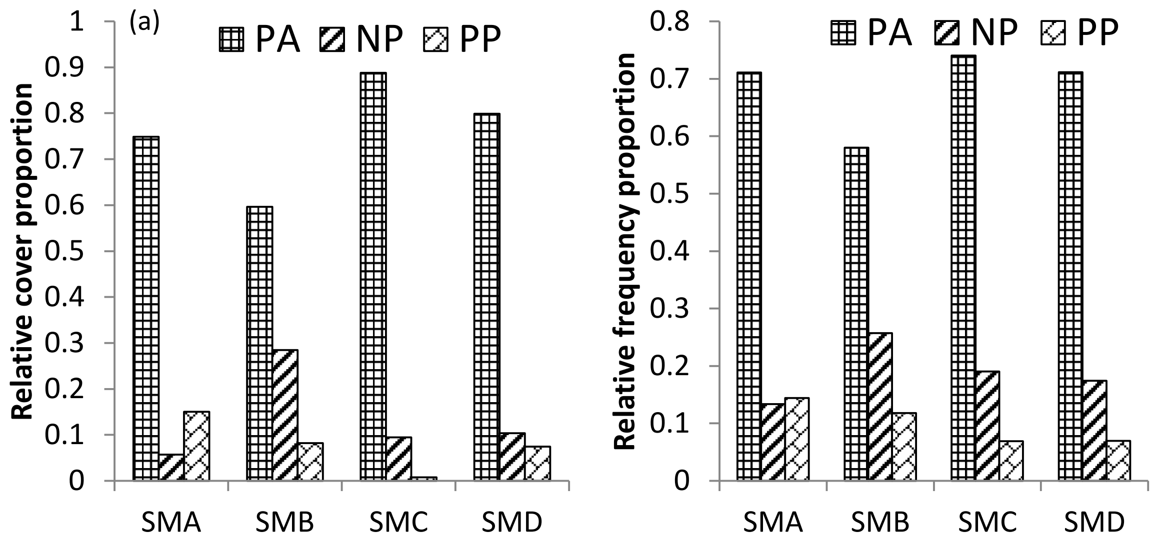

Figure 9. (a) Relative cover and (b) relative frequency of species under three palatability classes (PA-palatable, NP- un-palatable, PP-poisonous plants) in four study summits.

Table 9. Unique and common species in study summits for detail see Appendix 3 (* Represent relative cover and frequency).

Categories	Number of species				Species with highest abundance (*relative cover/relative frequency)
	PA	NP	PP	Total	
Species common in all summit	2	1	0	3	*Anaphalis nepalensis* (0.02/0.045), *Kobresia pygmaea* (0.307/0.07), *Polygonum viviparum* (0.09/0.08)
Species common in SMA, SMB and SMC	4	1	0	5	*Carex hematostama* (0.17/0.08), *Epilobium bervifolium* (0.007/0.04), *Euphrasia himalayica* (0.01/0.04), *Pedicularis trichoglossa* (0.01/0.05), *Danthonia cumminsii* (0.04/0.06)
Species common in SMB, SMC and SMD	4	1	0	5	*Carex dhuthiei* (0.02/0.04), *Kobresia nepalensis* (0.09/0.04), *Rhodiola wallichiana* (0.03/0.03), *Sibbaldia cuneata* (0.02/0.02), *Viola biflora* (0.01/0.06)
Species common in SMA and SMB	3	1	3	7	*Aster himalaicus* (0.01/0.02), *Duyeuxia scabrescens* (0.01/0.04), *Ligularia virgaurea* (0.02/0.08)
Species common in SMB and SMC	4	1	0	5	*Anthoxanthuum laxum* (0.008/0.01), *Gentienella paludosa* (0.008/0.009), *Llyodia longiscapa* (0.01/0.01)
Species common in SMC and SMD	3	0	0	3	*Cortia depressa* (0.02/0.06), *Salix lindleyana* (0.06/0.01), *Saussurea graminifolia* (0.05/0.03)
Species common in SMA and SMD	1	0	0	1	*Festuca polycolea* (0.01/0.01)
Species common in SMA and SMC	1	1	0	2	*Rhodiola fastigiata* (0.01/0.03), *Saxifraga mucronulata* (0.06/0.08)
Species common in SMB and SMD	3	1	0	4	*Asplenium trichomanes* (0.02/0.03), *Koenigia islandica* (0.01/0.04), *Saxifraga parnassifolia* (0.01/0.02), *Potentilla atrosanguinea* (0.12/0.02)
Species unique to SMA	8	3	0	11	*Athyrium wallichianum* (0.002/0.005), *Dactylorhiza hatagigirea* (0.005/0.005), *Malaxis muscifera* (0.002/0.02)
Species unique to SMB	20	10	3	33	*Aster diplostephioides* (0.01/0.03), *Corydalis cashmeriana* (0.005/0.01), *Fritillaria cirrhosa* (0.001/0.003)
Species unique to SMC	11	4	1	16	*Anaphalis xylorhiza* (0.009/0.03), *Primula primulina* (0.006/0.01), *Thalictrum alpinum* (0.008/0.06)
Species unique to SMD	11	5	3	19	*Aconitum ferox* (0.02/0.02), *Neopicrorhiza scrophulariiflora* (0.006/0.01), *Saussurea nepalensis* (0.01/0.03)

Chapter Four: Discussion

4.1 Transhumance and Management

Result of sampling plot revealed that, the area harbored high percentage of palatable plant species (108 out of 179). Thus, present study pastureland showed strong potential to support livestock farming. Many other previous works also showed result that, alpine pasturelands are the major basis for livestock production (Beg 2010; Zhou *et al.* 2010). Alpine Himalaya grassland and many of Trans-Himalayan area are utilized for livestock grazing since time immemorial (Ning *et al*. 2013). The Himalaya pastureland is providing a wide range of habitats supporting high biological diversity (Jia *et al.* 2011). Livestock farming is the main source of livelihood of people and is the backbone to the local economy. Alpine Himalayan grasslands are considered as the integral part for the agro-pastoral ecosystem services.

According to the herders, traditional system of management of pastureland was rotational practice of grazing and rotational burning that might be used to promote growth of desired palatable species. According to Karki *et al.* (1999) and Aryal *et al*. (2014), a similar type of traditional system of pasture management was reported in Langtang Natinal Park, central Nepal. Thus, rotational grazing showed strong affiliation to the balance and maintenance of ecosystem. Moreover, Pariyar (1994) found that the stocking density (0.64) of alpine pasture land was still lower than the actual carrying capacity (1.42) for the transhumance activity compared to other rangeland type of lower elevation of Nepal. He further noted that stocking density at lower elevation (such as tropical and temperate pastureland) was higher but carrying capacity was far lower. Thus, alpine pasture land is still not exploited in full potential for the transhumance related activities.

In upper Chamelia valley, not all the households take their cattle to the grassland individually. However, there is the practice of combining cattle's of 4-7 households and 2-4 herders go with each group. This traditional way of transhumance decreases the human pressure on the alpine rangeland. The government of Nepal recently has formulated Rangeland Policies (2012) in order to upgrade the status of the pastureland and thereby increasing its productivity. In addition, policy has stipulated wider range of applications for the sustainable management and conservation. Thus, are week implementation, monitoring and evaluation of the policies in mountain region. This is because they are located far remote and fragile geography for the regular assessment by government. Thus, the integration of traditional practices with scientific approaches would be the better choice for the sustainable conservation of alpine pastureland.

4.2 Species Interaction with Environmental Variables

Based on DCA analysis, the length of gradient of first axis among all summits indicated that there was high composition turnover along this main gradient. The result of CCA also indicates effective separation of species along the main gradient. Various local scales of environmental factors on the mountain summits could directly affect the species diversity on lower-elevation summits and decreasing diversity towards high-elevation. In fact, the decrease in diversity towards higher elevations could be the result of low moisture content, high rock cover, precipitation and relatively low temperature than the lower elevation (O'Brien 1998). In addition, other factors like ecophysiology of particular species, habitat limitation and constraints, intense solar radiation and long-term snow accumulation (Chapin and Körner 1996; Brown 2001; Körner 2000; 2003) also considered as driving factors in species composition at the mountain summits.

Regarding the grazing effect in each mountain summit studied, the effect of grazing was positively correlated to the presence of higher number of palatable species in summits located at lower elevation (SMA and SMB) as compared to the summits located at higher elevation. Even though, livestock settlements (sheds) were located close to these summits but present result did not reveal the negative impact of grazing in such mountain summits. Another probable reason might be related to the exploitation of area was still by lower number of cattle, sheep and goats. In contrast to this finding, the previous studies (Karki *et al.* 1999; Aryal *et al*. 2014) showed a negatives impact of grazing in different parts of Himalaya Nepal. The high intensity of grazing significantly affects the species composition in the ecosystem. But moderate grazing favors the species heterogeneity and leads to species diversity (Mulder *et al*. 2001; Pucheta *et al*. 2004 and Zou *et al*. 2015). Thus, based on this result, it could be predicted that the study area has still higher potential to hold the grazing pressure in future.

4.3 Factors Governing Species Richness

The species richness in plant communities depend on combination of varying degree of environmental conditions such as microhabitat qualities and different intensities of anthropogenic activities. Thus, plant species having different physiological combinations and structural traits are able to grow and reproduce along the environmental proximities and form unique diversity complex in the nature. In present study, species richness showed marked significant unimodal pattern with elevation in different scale of measurement (1 × 1 m, 3 × 3 m plot, and landscape level). But, the range restricted species such as Himalayan endemic species were found to be increased as elevation increased. The obtained result showed similar trend with previous studies such as Vetass and Grytness (2002) in Nepal Himalaya; and Noroozi *et al.* (2011) in Iran Mountain. Similarly, some interpolation works have also been conducted in relation to altitude and plants species richness of Nepal and reported unimodal pattern (Bhattarai and Ghimire 2006; Rokaya *et al*., 2012).

The species diversity was found highest at SMB (4100-4200 m) that may be the result of ecotone effect (between sub-alpine and alpine region). The species richness was found to be strongly influenced by ecotone effect at certain transitional zone along the elevation gradient in Himalaya (Vetass and Grytness 2002; Carpenter 2005). The linear decrease in species diversity after reaching its peak at mid elevation has also been proved by Cornwell and Grubb 2003; Carpenter 2005; Kharkwal *et al*. 2005 and Bruun *et al*. 2006 in the previous studies conducted in the Himalaya and other mountain ranges. This transitional zone provides both the overlapping communities as well as those restricted to ecotone only (Smith 1997). Here, elevation itself represents a complex combination of numerous other environmental variables, including temperature, precipitation, potential evapo-transpiration and edaphic factors including soil texture and substrate stability (Ramsay and Oxley 1997, Klimes 2003; Salick *et al.* 2014).

In our study, the result shows a uniodal distribution of all, palatable, unpalatable and poisonous species. The obtained result was similar to overall diversity of present study. However, proportionally, there is increase of un-palatable and poisonous species with increase elevation. It is known that there is increase in stressful environment with the increase in elevation. Plants in such condition survive with its morphological modification and production of secondary metabolites. These plants can be in cushion form, thick leaved, thorny and aromatic which automatically make them un-palatable and poisonous. In addition to this, the rise in temperature and longer growing season is also supposed to favors un-palatable and poisonous plants (Ziska *et al*. 2009). Also, the environment with barren soil and windy erosion is inhabited by un-palatable and poisonous plants (Zuo *et al*. 2009). Hence, the result shown by our study also goes along with the theories and findings. The presence of high proportion of palatable species at lower elevation might be due to less stressful environmental condition.

Similarly, heterogeneous habitat of plant species was created by aspect. Aspect can also be effective on the species composition, diversity and richness (Nuzzo, 1996). Present result showed that northern aspect had positive correlation at lower elevation, for providing hospitable habitat for the species diversity such as in SMA. So far, it might be the northern aspect, which provides moist habitat, and moisture, which is one of the limiting factors for the species growth (Korner 2003). Similarly, previous study conducted in the Himalaya recorded high number of species in North aspect such as in Marcelo and Maxim (2001) and Mohamamad (2008). But, when elevation is increased from the alpine to sub-nival and nival, the northern aspect becomes more hostile due to accumulation of snow for longer period of time. In this regard, exposure and solar radiation become limiting factors for the vegetation growth. Present finding also suggested that the higher number of species is observed in different aspects other than northern direction. But, the trend was not found similar in all mountain summits, such as SMB showed higher number of species in west slope, SMC had in east slope and SMD showed more number of species in south slope of the compass direction. Several researchers such as Pook and Moore (1966); Marcelo and Maxim (2001) and Mohamamad (2008) have obtained similar results.

Carmel and Kadmon (1999) studied the effect of slope and aspect on vegetation change and concluded that slope and aspect strongly affect the rate of vegetation change with the largest change occurred on north-west facing slopes. Comparatively in upper summits, the solar radiation was higher in exposed aspects such south and east aspects and snow melts earlier than north-west aspect (Lomolino *et al.* 2006; Vittoz *et al*. 2010). According to Ahmad and Rais (1998), snow cover on southeast aspect is completely melted at middle of June. The exact and concrete cause to provide favorable environment for the particular species in higher summits is yet to be determined. But it can be speculated that the species richness per direction could be specific to landscape orientation, its exposure, solar radiation, steepness and other anthropogenic causes such as grazing, trampling and harvest of plant materials.

Both local and regional environmental and spatial processes control the abundance of species (Cottenie, 2005). The present study also support this result, the abundance (in terms of relative cover and frequency) of palatable species was much higher than un-palatable and poisonous species in the four summits. From an ecological perspective, grazing has marked effects on abundance of plant species (Van der Wal *et al*. 2011). High intensity grazing can reduce abundance and can alter species composition of grassland. For example, high livestock density leads to increase in the abundance of unpalatable (or less palatable) species, such as weeds and exotic invasive species (Pakeman 2004; Fosaa and Olsen 2007). Exotic species are more competitive and have different growth responses compared with native species. Moderate grazing to some extent promote abundance by creating high habitat heterogeneity leading to rich in diversity of plant species (Mulder *et al*. 2001; Pucheta *et al*. 2004 and Zou *et al*. 2015).

4.4 Life Form Classification

Based on life forms categorization of overall species revealed that chamaephyte was dominant among all life forms along elevation gradient. The number of hemicryptophytes increased along with increasing elevation. Conversely, chamaephyte decreased along with increasing elevation. Pharswan *et al.* (2010) when studied in Garhwal Himalaya had recorded similar trend. But, in some other study, the number of hemicryptophytes was found to be dominant along the elevation gradient such as in Hindukush, Naga Parbat and Ladakh (Klîmes 2003), and Western Himalaya (Khan *et al*. 2013). Because their study was conducted up to the life zone (around 6000 m) but this study was limited up to the 4650 m.

However, increase proportion of chamaephyte with increasing elevation in Swiss Alps (by Vittoz *et al*. 2010) supports present findings but their study was limited to short elevation gradient. The hemicryptophytes might be dominant if the gradient taken is similar to the gradients taken by Klimes (2003) studied in Himalaya Ladakh. The numbers of phanerophytes decreased with increasing elevation was obtained from our findings, Klimes (2003); Pharswan *et al.* (2010) and Vittoz *et al*. (2010) supported it in the previous research conducted in the Himalaya.

Pharswan *et al*. (2010) suggested that the phanerophytes showed higher affinity to higher soil depth, higher moisture and warm temperature at lower elevation. As elevation increased, the soil depth decreased and scree and rock cover increased due to which the number of phanerophytes found to be decreased (Pharswan *et al*. 2010; Vittoz *et al*. 2010). Similarly, the number of therophytes also decreased as altitude increased because they have to complete their life within the certain favorable period and remain dormant rest of the year. But, cryptophytes were found to be tolerable at higher elevation because of their colonel properties (Klimes 2003).

4.5 Biogeographical Pattern(Chorotype)

The Himalayan endemic species were found to be greatly confined at higher elevation. It might be the result of narrow niche and less dispersal capacity. Higher proportions of Pan-Himalayan and broad range species were recorded in lower summit (SMA), and these decreased with elevation altitude proportionally, which suggested that SMA was suitable for these species in aspect to suitable environmental condition such as low temperature, thick soil layer and so species should have higher dispersal capacity and persistence longer life. This result was supported by previous findings such as in Sierra de Cartagena of southeastern Spain (Ferrer-castán and Vetaas 2003) and in Swiss inner Alps (Vittoz *et al.* 2010).

The higher elevation at mountain summits harbored higher number of restricted species and endemic species, which are considered vulnerable to environmental stochasticity. Small change in temperature at present climate change scenario may affect the habitat of such species (Salick *et al.* 2009). Greater isolation and niche differentiation in alpine regions due to fragile topography lead restricted species migration (Chapin and Körner 1996). It also leads to upward movement of species, where the mountain peak act as limiting factor, making the species more susceptible to extinction (Grabherr *et al.* 1995; Erschbamer *et al.* 2010). Thus, the range restricted species at the mountain tops are considered more critical at global climate change scenario.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

Based on the present study following conclusions are made:

- The record of higher number of palatable species in the study area suggested that pastureland area is suitable and have high potential for livestock farming. Thus, the livelihood of local people is contingent with agro-pastoral ecosystem prevalent in the study area. This result further ensures the hypothesis that alpine pasture land supports livelihood of the local people.

- The result showed unimodal pattern of vascular plant diversity along the elevation gradient at different scale of measurement. Environmental factor play significant role in species diversity and composition in alpine area. Elevation and aspect are the major influencing environmental factors. The species richness was high in shady slope (N-W) in lower summits but in upper summit species richness is found in exposed (S-E) slopes, it might be related to the higher intensity of solar radiation. Solar radiation could be limiting factors for the development of vegetation at higher summits.

- In overall, chamaephyte is the dominant life form in the study area followed by hemicryptophyte. Chamaephyte decreases as elevation increases but the percentage of hemicryptophyte increases along with elevation, which is followed by cryptophyte. This indicates that the harsh climate at higher mountain harbors higher percentage of clonal plants. This result supports the hypothesis that higher elevation at alpine-nival zone enhances the development of clonality in species composition.

- Further higher number of range restricted species (such as Himalayan endemic) found in summits at higher elevation supports another hypothesis that mountain summits enhances and harbor higher percentage of range restricted species.

- The study will help bringing in convergence between the indigenous and formal knowledge systems for developing an approach for the sustainable management of pastoralism.

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Appendix 1. Total income of the valley by provide forage to sheep and goat.

Income source	Number of sheds							Overall income Rs. (million)
	1	2	3	4	5	6	7	
Total number of Sheep and Goats	750	600	650	550	650	500	650	
Total number of Sheep	550	350	490	400	450	400	500	
Total number of Goats	200	250	160	150	200	100	150	
Total number of Sheep and Goats selling out of hundred	13	19	10	12	7	8	11	
Total Number of Sheep and Goats Selling per year (Mean)	98	114	65	66	46	40	72	
Total income from Selling (Rs. 16000) per Sheep and Goat	1568000	1824000	1040000	1056000	736000	640000	1152000	8016000
Load carrier Sheep and Goats (out of hundred)	30	40	45	33	35	32	33	
Load carries Sheep and Goats (mean, 15kg and rate Rs. 40 per kg)	225	240	293	182	228	160	215	
Total income from carrying load by Sheep and Goats	135000	144000	175800	109200	136800	96000	129000	925800
Wool give by each Sheep (Mean, 0.5 kg) and total wool of Sheep from each Shed (Mean, kg)	275	175	245	200	225	200	250	
From 12 Sheep wool, single coat and paint is prepared and total coat and paint produce from each Shed	23	15	20	17	19	17	21	
Total cost (Rs. 5000) for each coat and paint total income	115000	75000	100000	85000	95000	85000	105000	660000
Total income	1818000	2043000	1315800	1250200	967800	821000	1386000	9.6018

*Total cost for one Sheep and Goat (Mean, coast)	Rs. 16000
*Total weight carried by Sheep and Goat (Mean, Kg.)	15
*Allowance after carrying load per kg.	Rs. 40
*Total wool obtained from each Sheep (Mean, Kg.)	0.5
*Total number of Sheep required for one coat and paint	12

*Total cost for one coat and paint	Rs. 5000

Appendix 2. Environmental variables (mean ± SE) recorded among quadrats in four summits.

Summit/ Aspect	Elevation (m) (Elv)	Aspect (0) (Asp)	Slope (0) (Slo)	Vascular plant cover (%) (Vpl)	Rock cover (%) (Roc)	Scree cover (%) (Scr)	Lichen cover (%) (Lic)	Bryophyte cover (%) (Bry)	Bareground (%) (Bgr)	Litter cover (%) (Lit)
SMA	4000	211.06 ± 26.87	43.75 ± 1.07	74.26 ± 4.60	13.81 ± 4.90	0.00 ± 0.00	1.09 ± 0.35	1.31 ± 0.30	2.28 ± 0.66	7.23 ± 1.27
SM B	4200	192.12 ± 24.01	32.50 ± 1.10	75.38 ± 4.75	4.65 ± 2.19	0.00 ± 0.00	2.16 ± 0.48	4.19 ± 0.95	3.13 ± 0.74	8.45 ± 0.88
SMC	4450	220.50 ± 25.83	22.50 ± 1.69	73.06 ± 0.76	6.50 ± 0.93	0.00 ± 0.00	5.18 ± 0.36	5.06 ± 0.33	3.43 ± 0.57	6.75 ± 0.55
SMD	4650	282.50 ± 26.85	42.5 ± 2.35	53.75 ± 5.85	33.93 ± 6.77	0.44 ± 0.32	2.34 ± 0.38	3.25 ± 0.51	3.37 ± 0.52	3.08 ± 0.43
$\chi2$ value	63	7.05	47.2	15.7	20	9.28	11.43	16.210	7.160	30.42
p	<0.0001	0.07	<0.0001	0	<0.0001	0.02	0.01	0.001	0.060	<0.0001

*Figure in parentheses represents shrub cover. **χ2 and P-value based on Kruskal Wallis Test (where grouping variable was summit types).

Appendix 3. Relative importance of environmental variables on species composition analyzed based on CCA. The statistical significance (p-value) of variables was derived using a Monte Carlo permutation test with 9999 replicates.

Variables	Variable abbreviation	Variance explain	F	*p*
Elevation* (m)	Elv	0.67	6.98	0.0001
Sheep and goats*	Shegot	0.66	6.29	0.0001
Cattle*	Catt	0.64	6.61	0.0001
Bryophyte cover* (%)	Bry	0.28	2.75	0.0001
Vascular plant cover* (%)	Vpl	0.24	2.39	0.0001
Rock cover* (%)	Roc	0.24	2.29	0.0001
Lichen cover* (%)	Lic	0.21	2.05	0.0008
Litter cover (%)	Lit	0.14	1.4	0.06
Scree cover (%)	Scr	0.14	1.37	0.15
Bareground (%)	Bgr	0.11	1.08	0.31

* Variables has significant value <0.05.

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Scree cover (%)	Scr	0.14	1.37	0.15
Bareground (%)	Bgr	0.11	1.08	0.31

* Variables has significant value <0.05.

Appendix 4. List of plant species recorded in the four summits along elevation gradients. Relative cover and frequency of individual species in 1 × 1m quadrat of each summits.

S.N	Name of species with author citation and Family	Abbreviation used in ordination	Palatability	Life form	Chorotype	Empirical data	SMA		SMB		SMC		SMD	
							Relative cover	Relative frequency	Relative cover	Relative frequency	Relative cover	Relative frequency	Relative cover	Relative frequency
1	*Aconitum ferox** Wall. ex Ser. (Ranunculaceae)	Aco.fer	PP	CRP	HE	4650							0.043	0.020
2	*Aconitum spicatum** (Brühl) Stapf (Ranunculaceae)	Aco.spi	PP	CRP	HE	4200 - 4650							0.029	0.025
3	*Aconogonum rumicifolium** (Royle ex Bab.) H. Hara(Polygonaceae)	Aco.rum	MP	HCP	HE	4200			0.019	0.021				
4	*Aletris pauciflora** (Klotzsch) Hand.-Mazz. (Liliaceae)	Ale.pau	HP	CRP	HE	4200					0.007	0.026		
5	*Allium prattii* C.H.Wright (Amaryllidaceae)		MP	CRP	HE	4000	0.024	0.064	0.009	0.045	0.010	0.013	0.006	0.045
6	*Anaphalis contorta* var. *contorta* (D. Don) Hook.f. (Asteraceae)		NP	CHP	PH	4000 - 4200					0.009	0.035		
7	*Anaphalis nepalensis** var. *nepalensis* (DC.) Airy (Asteraceae)	Ana.nep	NP	CHP	HE	4000 - 4650								
8	*Anaphalis royleana* DC. (Asteraceae)		NP	HCP	BR	4000								
9	*Anaphalis triplinervis* var. *monocephala* (DC.) Airy Shaw (Asteraceae)		NP	HCP	PH	4200								
10	*Anaphalis xylorhiza** Sch. Bip. ex Hook. f. (Asteraceae)	Ana.xyl	NP	HCP	HE	4450								
11	*Androsace lehmannii** Wall. ex Duby (Primulaceae)	And.leh	LP	CHP	HE	4000 - 4450							0.070	0.005
12	*Androsace strigillosa** Franch (Primulaceae)	And.str	LP	CHP	HE	4650					0.010	0.030		
13	*Anemonastrum tetrasepalum** (Royle) Holub. (Ranunculaceae)	Ane.tet	PP	CHP	PH	4000			0.008	0.010				
14	*Anemone demissa* Hook. f. & Thomson (Ranunculaceae)		PP	CHP	PH	4200 - 4650								

16	*Anthoxanthuum laxum** (R. Br. ex Hook. f.) Veldkamp (Poaceae)	Ant.lax	HP	HCP	HE	4650			0.001	0.007				
17	*Arenaria glanduligera* Edgew. ex Edgew. & Hook (Caryophyllaceae)		RP	HCP	HE	4450								
18	*Arisaema jacquemontii* Blume (Araceae)		PP	CRP	HE	4000 - 4200								
19	*Asplenium trichomanes** L. (Aspleniaceae)	Asp.tri	NP	HCP	PH	4000			0.015	0.003			0.022	0.035
20	*Aster diplostephioides** (DC.) C. B. Clarke (Asteraceae)	Ast.dip	NP	HCP	HE	4000 -4200			0.010	0.035				
21	*Aster flaccidus* Bunge (Asteraceae)		NP	HCP	BR	4650								
22	*Aster himalaicus** C. B. Clarke (Asteraceae)	Ast.him	PP	HCP	HE	4000 - 4200	0.015	0.027	0.007	0.017				
23	*Astragalus rhizanthus** subsp. *candolleanus* (Benth.) Podlech (Fabaceae)	Ast.rhi	LP	CHP	HE	4200 -4450	0.124	0.027						
24	*Athyrium wallichianum** Ching (Athyriaceae)	Ath.wal	NP	HCP	HE	4000	0.002	0.005						
25	*Berberis kumaonensis* C. K. Schneid. (Berberidaceae)		HP	PHP	HE	4000								
26	*Bistorta affinis** (D. Don) Greene (Polygonaceae)	Bis.aff	MP	CRP	HE	4200							0.042	0.040
27	*Botrychium lunaria** (L.) Sw. (Ophioglossaceae)	Bot.lun	LP	THP	PH	4200	0.002	0.016						
28	*Bromus porphyranthos** Cope (Poaceae)	Bro.por	HP	HCP	HE	4000 - 4450							0.012	0.060
29	*Bupleurum dalhousieanum** (C. B. Clarke) Kozo-Polj. (Apiaceae)	Bup.dal	LP	CHP	BR	4000 - 4450	0.013	0.016						
30	*Caltha palustris* var.*himalensis** (D.Don) Mukerjee (Ranunculaceae)	Cal.pal	RP	HCP	HE	4200							0.005	0.005
31	*Campanula aristata** Wall. (Campanulaceae)	Cam.ari	HP	CHP	HE	4200	0.001	0.005						
32	*Campanula latifolia* L. (Campanulaceae)		HP	CHP	HE	4000								
33	Campanula white* (Campanulaceae)	Cam.sp											0.003	0.005

34	*Carex atrata** subsp. *pullata* L. (Cyperaceae)	Car.atr	HP	HCP	HE	4200			0.003	0.003				
35	*Carex duthiei** C.B. Clarke (Cyperaceae)	Car.dut	HP	HCP	PH	4000 -4450			0.025	0.038	0.012	0.043	0.007	0.015
36	*Carex haematostoma** Nees (Cyperaceae)	Car.hem	HP	HCP	HE	4000 -4200	0.174	0.080	0.036	0.010	0.022	0.004		
37	*Cassiope fastigiata* (Wall.) D. Don (Ericaceae)		NP	CHP	HE	4000 -4650								
38	*Comastoma falcatum* (Turcz.) Toyok. (Gentinaceae)		LP	CHP	PH	4000								
39	*Cortia depressa** (D. Don) C. Norman (Apiaceae)	Cor.dep	MP	HCP	HE	4200 - 4650					0.028	0.069	0.014	0.045
40	*Corydalis cashmeriana** Royle (Papaveraceae)	Cor.cas	LP	CHP	HE	4450			0.005	0.010				
41	*Corydalis meifolia* wall. (Papaveraceae)		LP	CHP	HE	4000								
42	*Corydalis govaniana** Wall. (Papaveraceae)	Cor.gov	LP	CHP	HE	4200			0.001	0.017				
43	*Corydalis juncea* Wall. (Papaveraceae)		LP	CHP	HE	4000 - 4450								
44	*Corydalis trifoliata** Franch. (Papaveraceae)	Cor.tri	LP	CHP	HE	4200			0.004	0.028				
45	*Cotoneaster microphyllus* Wall. ex Lindl. (Rosaceae)		MP	CHP	HE	4000 -4200								
46	*Crucihimalaya himalaica** (Edgew.) Al-Shehbaz *et al.*(Brassicaceae)	Cru.him	MP	HCP	HE	4000 - 4200			0.006	0.021				
47	*Cryptogramma brunoniana** Wall. ex Hook. & Greville (Pteridaceae)	Cry.bru	NP	CRP	PH	4000	0.001	0.011						
48	*Cryptogramma stelleri** (S. G. Gmel.) (Pteridaceae)	Cry.ste	NP	HCP	PH	4000			0.001	0.010				
49	*Cynanthus lobatus** Wall. ex Benth. (Campanulaceae)	Cyn.lob	MP	CHP	HE	4450					0.015	0.009		
50	*Cynoglossum zeylanicum* (Vahl ex Hornem) Thunb. ex Lehm. (Boraginaceae)		HP	THP	PH	4000								
51	*Cypripedium himalaicum* J. Linn. Soc. (Orchidaceae)		LP	CRP	HE	4650								
52	*Dactylorhiza hatagirea** (D. Don) Soó (Orchidaceae)	Dac.hat	HP	CRP	PH	4000	0.005	0.005						

53	*Danthonia cumminsii** J. D. Hooker (Poaceae)	Dan.cum	HP	HCP	HE	4000 - 4650	0.040	0.064	0.017	0.014	0.001	0.004		
54	*Delphinium brunonianum* Royle (Ranunculaceae)		PP	CRP	HE	4200								
55	*Delphinium vestitum* Wall. ex Royle (Ranunculaceae)		PP	CRP	HE	4200								
56	*Deyeuxia scabrescens** (Griseb.) Munr. ex. Duthie (Poaceae)	Dey.sca	HP	HCP	HE	4000 - 4450	0.015	0.043	0.006	0.042				
57	*Draba elata* Hook. F. & Thomson (Cruciferae)		MP	CHP	HE	4000 -4650								
58	*Dracocephalum heterophyllum* Benth.(Lamiaceae)		RP	CHP	PH	4650								
59	*Elsholtzia eriostachya* (Benth.) Benth. (Lamiaceae)		MP	THP	PH	4200								
60	*Ephedra gerardiana* Wall. ex Stapf (Ephedraceae)		MP	CHP	PH	4000								
61	*Epilobium brevifolium** D.Don (Onagraceae)	Epi.bre	MP	HCP	HE	4200	0.001	0.011	0.005	0.021	0.007	0.022		
62	*Epilobium latifolium** L. (Onagraceae)	Epi.lat	MP	HCP	HE	4000 - 4450			0.004	0.021				
63	*Epilobium wallichianum** Hausskn. (Onagraceae)	Epi.wal	MP	HCP	HE	4200 -4650							0.010	0.035
64	*Eritrichium canum* (Benth.) Kitam./ Eritrichium blue (Boraginaceae)		HP	CHP	HE	4200								
65	*Eritrichium minimum** (Brand) H. Hara (Boraginaceae)	Eri.min	HP	CHP	HE	4200			0.005	0.024				
66	*Euphorbia cf. himalayensis** (Klotzsch) Boiss. (Euphorbiaceae)	Eup.him	PP	CHP	HE	4000 -4200			0.002	0.024				
67	*Euphorbia strayarchi** Boiss. (Euphorbiaceae)	Eup.str	MP	HCP	PH	4200 -4450					0.013	0.056		
68	*Euphrasia himalayica** Wettst. (Scrophulariaceae)	Eup.pol	LP	CHP	HE	4000 - 4650	0.011	0.043	0.001	0.003	0.018	0.009		
69	*Festuca polycolea** Stapf (Poaceae)	Fes.pol	HP	HCP	HE	4000 - 4200	0.015	0.011					0.001	0.005
70	*Fragaria nubicola* Lindl. ex Lacaita (Rosaceae)		HP	CHP	HE	4000								
71	*Fritillaria cirrhosa** D. Don (Liliaceae)	Fri.cir	HP	CRP	HE	4000 -4450			0.001	0.003				

72	*Galium megacyttarion* R. R. Mill (Rubiaceae)		MP	CHP	HE	4000						
73	*Gaultheria trichophylla** Royle (Ericaceae)	Gau.tri	RP	CHP	PH	4000 -4450			0.137	0.017		
74	*Gentiana capitata** Buch.-Ham. ex D.Don (Gentinaceae)	Gen.cap	NP	HCP	HE	4450			0.005	0.013		
75	*Gentiana stipitata* Edgew. (Gentinaceae)		NP	CHP	HE	4000						
76	*Gentiana tubiflora** (G. Don) Griseb. (Gentinaceae)	Gen.tub	NP	HCP	HE	4000					0.010	0.005
77	*Gentienella paludosa** (Hooker) H. Smith (Gentinaceae)	Gen.pal	NP	CHP	PH	4450 -4650	0.008	0.003	0.005	0.009		
78	*Geranium donianum** Sweet (Geraniaceae)	Ger.don	RP	CHP	PH	4000 -4200	0.001	0.003	0.024	0.035		
79	*Geum elatum* Wall. ex G. Don (Rosaceae)		RP	CHP	PH	4200						
80	*Goodyera* repens (L.) R. Br. (Orchidaceae)		HP	CRP	BR	4000 - 4200						
81	*Gypsophila cerastioides** D.Don (Caryophyllaceae)	Gyp.cer	LP	CHP	PH	4200	0.003	0.003				
82	*Hackelia uncinata** (Benth.) C.E.C.Fisch. (Boraginaceae)	Hac.unc	RP	CHP	HE	4200	0.006	0.010				
83	*Heracleum nepalensis* D. Don (Umbelliferae)		NP	CHP	HE	4000 - 4200						
84	*Heracleum wallichii* DC. (Umbelliferae)		NP	CHP	HE	4000 - 4200						
85	*Herminium josephii** Rchb. f. (Orchidaceae)	Her.jos	HP	CRP	HE	4000					0.002	0.005
86	*Impatiens* SP* (Balsaminaceae)	Imp.sp				4200	0.004	0.031				
87	*Impatiens* sulcata Wall. (Balsaminaceae)		LP	CHP	HE	4000						
88	*Juncus himalensis* Klotzsch (Juncaceae)		PP	CRP	PH	4000 - 4450						
89	*Juncus membranaceus** Royle ex. D .Don (Juncaceae)	Jun.mem	PP	CRP	HE	4450	0.013	0.017				
90	*Juncus thomsonii** Buchenau (Juncaceae)	Jun.tho	PP	CRP	PH	4000 -4450					0.003	0.025
91	*Juniperus squamata* Buch.-Ham. ex D. Don (Cupressaceae)		NP	PHP	PH	4200						
92	*Kobresia nepalensis** (Nees)	Kob.nep	MP	HCP	HE	4000 -4650	0.052	0.003	0.073	0.004	0.091	0.040

	Kuk. (Cyperaceae)													
93	*Kobresia pygmaea** (C. B. Clarke) C. B. Clarke (Cyperaceae)	Kob.pyg	MP	HCP	HE	4000 -4650	0.122	0.070	0.118	0.038	0.307	0.069	0.073	0.070
94	*Koenigia islandica** L. (Polygonaceae)	Koe.isl	LP	CHP	BR	4200			0.013	0.010				
95	*Koenigia nepalensis* D. Don (Polygonaceae)		LP	CHP	PH	4200								
96	*Ligularia virgaurea** (Maxim.) Mattf. ex Rehder & Kobuski (Compositae)	Lig.vir	PP	CHP	PH	4200	0.029	0.080	0.018	0.038				
97	*Lilium nanum* forma *nanum** Klotzsch (Liliaceae)	Lil.nan	HP	CRP	HE	4200	0.006	0.043	0.001	0.007				
98	*Llyodia longiscapa** Hook. (Liliaceae)	Lyo.lon	HP	CRP	HE	4000 -4200			0.014	0.010	0.004	0.009		
99	*Lomatogonium carinthiacum** (Wulfen) Rchb. (Gentinaceae)	Lom.car	MP	CHP	BR	4200 - 4450					0.002	0.004		
100	*Lonicera hispida** Pall. ex Willd. (Caprifoliaceae)	Lon.his	HP	PHP	BR	4000 - 4200	0.005	0.005						
101	*Lycopodium selago* L. (Lycopodiaceae)					4200								
102	*Malaxis muscifera** (Lindl.) Kuntze (Orchidaceae)	Mal.mus	HP	CRP	HE	4000 - 4200	0.002	0.021						
103	*Morina polyphylla* Wall. ex DC. (Morinaceae)		PP	CHP	HE	4000 -4200								
104	*Nardostachys grandiflora* DC. (Caprifoliaceae)		NP	CRP	HE	4200								
105	*Neopicrorhiza scrophulariiflora** (Pennell) D. Y. Hong (Plantaginaceae)	Neo.scr	NP	CRP	HE	4000 - 4450							0.006	0.010
106	*Oxygraphis polypetala** (Royle) Hook. f. & Thomson (Ranunculaceae)	Oxy.pol	RP	HCP	HE	4200					0.005	0.013		
107	*Oxyria digyna* (L.) Hill (Polygonaceae)		LP	CHP	BR	4450-4650								
108	*Parnassia nubicola** Wall. ex Royle (Parnassiaceae)	Par.nub	RP	HCP	HE	4200 - 4650							0.008	0.020
109	*Pedicularis bicornuta** Klotzsch (Orobanchaceae)	Ped.bic	NP	CHP	HE	4200			0.004	0.003				
110	*Pedicularis longiflora var. tubiformis* Rudoiph		NP	CHP	BR	4200								

	(Orobanchaceae)													
111	*Pedicularis megalantha** D. Don (Orobanchaceae)	Ped.meg	NP	CHP	HE	4450 - 4650			0.008	0.017				
112	*Pedicularis new* (Orobanchaceae)					4000 -4200								
113	*Pedicularis nodosa** Pennell (Orobanchaceae)	Ped.nod	NP	CHP	HE	4000 - 4450					0.007	0.004		
114	*Pedicularis rhinanthoides* Schrenk (Orobanchaceae)		NP	CHP	HE	4250								
115	*Pedicularis roylei* Maxim. (Orobanchaceae)		NP	CHP	HE	4450								
116	*Pedicularis siphonantha** D. Don (Orobanchaceae)	Ped. Sip	NP	CHP	HE	4200							0.006	0.010
117	*Pedicularis trichoglossa** Hook. F. (Orobanchaceae)	Ped.tri	NP	CHP	HE	4650	0.016	0.016	0.015	0.003	0.006	0.052		
118	Pedicularis* 1 (coll no. ANCA 1265) (Orobanchaceae)	Ped.sp				4000 -4200	0.044	0.011	0.002	0.003				
119	*Phleum alpinum* L. (Poaceae)		HP	HCP	BR	4000								
120	*Polygonatum hookeri** Baker (Liliaceae)	Pol.hoo	MP	CRP	PH	4200 - 4450	0.008	0.021	0.010	0.003				
121	*Polygonum macrophyllum* D. Don (Polygonaceae)		MP	CRP	BR	4000 - 4450								
122	*Polygonum viviparum** L. (Polygonaceae)	Pol.viv	MP	CRP	BR	4200	0.094	0.080	0.011	0.024	0.057	0.069	0.063	0.065
123	*Polystichum castaneum** (C. B. Clarke) B. k. Nayar & S. Kaur(Dryopteridaceae)	Pol.cas	NP	CHP	PH	4200	0.001	0.005						
124	*Polystichum duthiei** (C. Hope) C. Chr. (Dryopteridaceae)	pol.dut	NP	HCP	HE	4000			0.005	0.003				
125	*Potentilla anseriana* L. (Rosaceae)		NP	HCP	BR	4200								
126	*Potentilla atrosanguinea** G.Lodd. ex D.Don (Rosaceae)	Pot.atr	RP	CHP	PH	4200 - 4450			0.120	0.021			0.020	0.015
127	*Potentilla fruticosa** L. (Rosaceae)	Pot.fru	RP	CHP	BR	4200 - 4450					0.009	0.043		
128	*Potentilla microphylla** D. Don (Rosaceae)	Pot.mic	MP	THP	HE	4450					0.004	0.004	0.026	0.035
129	*Potentilla peduncularis* D. Don (Rosaceae)		RP	CHP	HE	4200 -4650								
130	*Potentilla saundersiana* Royle (Rosaceae)		MP	HCP	PH	4000								

131	*Primula* (Dolpa Blue) (Primulaceae)													
132	*Primula atrodentata* W. W. Sm. (Primulaceae)		RP	HCP	HE	4450								
133	*Primula glomerata* Pax. (Primulaceae)		LP	CHP	HE	4200								
134	*Primula macrophylla** D. Don (Primulaceae)	Pri.mac	RP	CHP	PH	4200			0.005	0.003				
135	*Primula minutissima** Jacquem. ex. Duby (Primulaceae)	pri.min	RP	THP	HE	4200 - 4450					0.006	0.017		
136	*Primula primulina** (Spreng.) H. Hara (Primulaceae)	Pri.pri	LP	HCP	HE	4450					0.009	0.048		
137	Primula west Himalaya (Primulaceae)					4450								
138	*Ranunculus brotherusii** Feryn (Ranunculaceae)	Ran.bro	LP	HCP	PH	4200 -4450			0.010	0.010				
139	*Ranunculus diffusus** DC. (Ranunculaceae)	Ran.dif	HP	CHP	PH	4200			0.002	0.010				
140	*Rheum moorcroftianum** Royle (Polygonaceae)	Rhe.moo	MP	HCP	PH	4000 - 4650							0.195	0.030
141	*Rheum spiciforme** Royle (Polygonaceae)	Rhe.spi	MP	CHP	HE	4000 - 4200			0.026	0.007				
142	*Rhodiola bupleuroides** (Wall. Ex Hook .f. & Thomson) (Crassulaceae)	Rho.bup	NP	CHP	HE	4000 - 4200							0.015	0.010
143	*Rhodiola cretinii** (Raym.-Hamet) H. Ohba (Crassulaceae)	Rho.cre	NP	CHP	HE	4650							0.007	0.030
144	*Rhodiola fastigiata** (Hook. f. & Thomson) S. H. Fu (Crassulaceae)	Rho.fas	NP	CHP	PH	4450	0.001	0.016			0.019	0.039		
145	*Rhodiola himalensis* (D.Don) S. H. Fu. (Crassulaceae)		NP	CHP	HE	4000 - 4450								
146	*Rhodiola imbricata* Edgew. (Crassulaceae)		NP	CHP	HE	4450								
147	*Rhodiola smithii** (Raym. - Hamet) S. H. Fu (Crassulaceae)	Rho.smi	NP	CHP	HE	4650					0.025	0.009		
148	*Rhodiola wallichiana** (Hook.) S. H. Fu (Crassulaceae)	Rho.wal	NP	HCP	HE	4200 -4450			0.016	0.035	0.008	0.017	0.033	0.030
149	*Rhododendron anthopogon** D. Don (Ericaceae)	Rho.ant	PP	PHP	HE	4450	0.107	0.037	0.034	0.010				

150	*Rhododendron campanulatum* D. Don (Ericaceae)		PP	PHP	HE	4000 - 4200								
151	*Rumex acetosa* L. (Polygonaceae)		HP	CHP	BR	4000								
152	*Rumex nepalensis* Spreng. (Polygonaceae)		LP	HCP	BR	4000								
153	*Salix hylematica* C. K. Schneid. (Salicaceae)		LP	CHP	HE	4000 - 4200								
154	*Salix lindleyana** Wall. ex Andersson (Salicaceae)	Sal.lin	LP	HCP	HE	4000 - 4200					0.006	0.013	0.068	0.015
155	*Saussurea graminifolia** Wall. ex DC. (Asteraceae)	Sau.gra	MP	HCP	HE	4200 -4650					0.058	0.013	0.023	0.030
156	*Saussurea leontodontoides** (DC.) Sch. Bip. (Asteraceae)	Sau.leo	NP	HCP	PH	4000 - 4450	0.012	0.016	0.010	0.003				
157	*Saussurea nepalensis** Spreng. (Asteraceae)	Sau.nep	LP	HCP	HE	4450 - 4650							0.010	0.030
158	*Saxifraga aristulata* Hook. f. & Thomson (Saxifragaceae)		RP	CHP	PH	4450								
159	*Saxifraga brunonis* Wall ex. Ser. (Saxifragaceae)		RP	CHP	HE	4000 - 4450								
160	*saxifraga melanocentra** Franch.(adoxoides Griff.) (Saxifragaceae)	Sax.mel	LP	CHP	HE	4000 -4200							0.002	0.015
161	*Saxifraga mucronulata** Royle (Saxifragaceae)	Sax.muc	MP	HCP	HE	4650	0.060	0.080			0.015	0.004		
162	*Saxifraga parnassifolia** D. Don (Saxifragaceae)	Sax.par	MP	CHP	HE	4000 -4450			0.010	0.021			0.001	0.005
163	*Scrophularia pauciflora** Benth. (Scrophulariaceae)	Scr.pau	LP	CHP	HE	4200			0.005	0.010				
164	*Selinum wallichianum** (DC.) Raizada & Saxena (Umbelliferae)	Sel.wal	NP	CHP	HE	4000 - 4200			0.089	0.056				
165	*Senecio chrysanthemoides** DC. (Asteraceae)	Sen.chr	RP	CHP	PH	4200			0.003	0.007				
166	*Senecio kumaonensis** Duthie ex C. Jeffrey & Y. L. Chen (Asteraceae)	Sen.kum	LP	CHP	HE	4200			0.013	0.007				
167	*Senecio kunthianus* Wall. ex DC. (Asteraceae)		LP	CHP	HE	4000 -4200								
168	*Sibbaldia purpurea** Royle (Rosaceae)	Sib.pur	HP	CHP	HE	4000							0.027	0.060

169	*Sibbaldia cuneata** Hornem. ex Kuntze (Rosaceae)	Sib.cun	HP	CHP	PH	4450 - 4650			0.028	0.007	0.021	0.026	0.020	0.010
170	*Silene caspitella* F. N. Williams (Caryophyllaceae)		HP	CHP	HE	4200								
171	*Silene gonosperma** (Rupr.) Bocquet (Caryophyllaceae)	Sil.gon	HP	CHP	BR	4000 - 4200			0.001	0.003				
172	*Silene kumaonensis* F. N. Williams (Caryophyllaceae)		HP	CHP	HE	4000								
173	*Silene setisperma* Majumdar (Caryophyllaceae)		HP	HCP	HE	4000 - 4200								
174	*Sinocarum normanianum** (Cauwet & Farille) Farille (Umbelliferae)	Sin.nor	LP	CHP	HE	4200			0.001	0.014				
175	*Sinopodophyllum hexandrum* Royle (Berberidaceae)		PP	HCP	HE	4000								
176	*Stellaria congestiflora* H. Hara (Caryophyllaceae)		HP	HCP	HE	4000 - 4200								
177	*Swertia ciliata* (D. Don ex G. Don) B. L. Burtt (Gentinaceae)		NP	CHP	HE	4000 -4450								
178	*Swertia cuneata* D. Don (Gentinaceae)		NP	CHP	HE	4000								
179	*Swertia multicaulis** D. Don (Gentinaceae)	Swe.mul	NP	CHP	HE	4000			0.025	0.021				
180	*Swertia petiolata** D. Don (Gentinaceae)	Swe.pet	NP	HCP	HE	4200			0.067	0.017				
181	*Taraxacum eriopodum** DC. (Compositae)	Tar.eri	HP	CHP	HE	4450					0.002	0.017		
182	*Thalictrum alpinum** L. (Ranunculaceae)	Tha.alp	PP	CHP	BR	4200					0.008	0.069		
183	*Thalictrum cultratum** Wall. (Ranunculaceae)	Tha.cul	MP	CHP	PH	4000 - 4450			0.002	0.003				
184	*Trachydium roylei** Lindl. (Apiaceae)	Tra.roy	MP	CHP	PH	4000	0.050	0.070						
185	Veronica ciliata* Fisch (Scrophulariaceae)	Ver.cil	HP	CRP	BR	4200			0.001	0.003				
186	*Viola biflora** L. (Violaceae)	Vio.bif	MP	HCP	BR	4000 - 4650			0.008	0.056	0.010	0.043	0.008	0.060
187	*Woodsia alpina* (Bolton) Gray (Woodsiaceae)		NP	THP	BR	4200								

* Taxa included in ordination. 1: CHP = chamaephytes, CRP = cryptophytes, HCP = hemicryptophytes, PHP = phanerophytes, THP = therophytes. 2: HE = Himalayan endemic, NE = Nepal endemic, PH = pan-Himalayan distribution, BR = broad range of distribution.

Un- palatable (NP):	Not grazed by animals at any stage; possibly poisonous or harmful
Highly palatable (HP):	Species which were preferred the most by domestic animals.
Moderately palatable (MP):	Species with usual preference by the livestock.
Less palatable (LP):	Species with less first choice.
Rarely palatable (RP):	Species not often grazed under compulsion when no other feed exist.
Poisonous (PP):	Species cause dead.