# SPECIES RICHNESS ACROSS THE FOREST-LINE ECOTONE IN CENTRAL HIMALAYAN LANDSCAPE OF NEPAL

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**Submitted By**

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# DECLARATION

I, Diwas Dahal, hereby declare that the piece of work entitled **"Species Richness across Forest-line Ecotone in Central Himalayan Landscape of Nepal"** presented herein is genuine work done originally by me and has not been published or submitted elsewhere for a requirement of a Degree programe. Any literature, data works done by others and cited within this dissertation has been given due acknowledgement and listed in the references.

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# ABSTRACT

With the main objective of exploring the species richness and composition in forest-line ecotone together with altitudinal pattern in different slope aspect (north and south) this research was done in the transitional zone (Ecotone) of forest to non-forest landscape of Central Himalaya (Langtang) Nepal. Data were collected from 27 plots in the northern aspect and 21 plots in the southern aspect of 10m × 10m (altogether 48 plots combining both the aspect). Qualitative and quantitative analysis of environmental variables and disturbance indicator were also recorded in each sampling plot. Altogether 83 species and 93 species of vascular plants were recorded in the north and south aspect respectively. The data thus obtained were analyzed by using ordination technique, Canonical Correspondence Analysis (CCA), Detrented Correspondence Analysis and Regression Analysis. Major factors related to variation in species richness were altitude, canopy cover and slope. With the increase in altitude species richness was found to decrease in the southern aspect whereas, there was slight increase in species richness near above the forest-line in northern aspect. Mean species richness between the forest and open landscape of northern aspect indicated no significant differences. On other hand, compared to northern aspect there was a significant difference in southern aspect with forest plots having higher species richness. Though, grazing not being highly significant in both the aspect species richness was found to be high in the grazed plots of northern aspect due to moderate grazing and comparatively lower in the southern aspect due to high human intervention and grazing pressure. Species richness trend was found to be decreasing with the increase in slope in both the aspect due to high water runoff, unstable soil condition and rocky patches found on the steep slope of the study area.


*Keywords:* CCA, DCA, Ecotone, α-diversity, β-diversity.

# TABLE OF CONTENTS

# CHAPTER – I
# INTRODUCTION

## 1.1 Background

Spatial pattern of species richness and their underlying mechanism have long been focused on biodiversity and bio-geographical research (Rosenzweig, 1995; Brown and Lomolino, 1998). Over the years, investigators tended to focus on the distinct ecosystems and communities (e.g. Mediterranean, grassland, boreal) (Holland et al., 1991; Rissser, 1995 a; Smith et al., 2001). However, in recent years, areas of transition between ecological communities (also termed as ecotone) are receiving more attention in biodiversity research. An ecotone is not simply a boundary or an edge, the concept assumes the existence of active interaction between two or more ecosystem (or patches of ecosystem), which results in the ecotone having properties that do not exist in either of the adjacent ecosystem (Odum, 1996).

Mountains are excellent systems for evaluating ecological and bio-geographic patterns and theories of species richness (Körner, 2000). Presence of varieties of eco-climatic zones within a short latitudinal distance makes mountains as a best laboratory for such studies. A fundamental characteristic of mountain ecosystem is the drastic change in climate and vegetation from its base to the summit. Elevation gradient in mountains also lead to the differentiation of soil type, texture which helps in diversification of floral composition (Brown, 2001; Lomolino, 2001).

Most of the studies have revealed general patterns of decreasing species richness with increasing latitude (Rapoport, 1982; Willig et al., 2003; Hillebrand, 2004). In mountain areas, such studies have focused to follow the elevation pattern since it is one of the major influencing factors to most of the climatic and geographic variables (Barry, 1992; Körner, 2000). Species richness along the altitudinal gradient in mountainous region has received increasing attention in recent years (Stevens, 1992; Rahbek, 1995; (Körner, 2000; Tang et al., 2006). Many studies reported a decline in the number of species with the increasing elevation (Brown, 1988; Stevens, 1992; Begon et al., 1996; Lomolino, 2001). Rahbek (1995), however presented a critical review of the literature and showed that approximately half of the studies had a mid altitude peak in species richness. Some other studies have also reported the humped-shaped relationship between species richness and altitude including Whittaker and Niering (1975); Liberman et al (1996); Grytnes and Vetaas (2002) and Carpenter (2005).

The forest-line ecotone is a major concern in ecological studies as it serves as an "early warning" indicators or detectors of global climate change through the tracking of changes in ecotonal locations over a real time (Kupfer and Cairns,1996; Holtmeier and Broll, 2005) because communities in the forest-line ecotone may be more vulnerable to climate change (Lewin,1985). Furthermore, elevational pattern of species distribution helps to understand the possible effect of climate change e.g. by providing baseline information from which to measure the effect of climate change and anthropogenic changes on vegetation.

The compositional change of plant species in the transition zone between sub-alpine forests to alpine vegetation in the mountains near tree-line is a major representative of transitional communities in the mountain ecosystems. According to Stevens (1992) and Lomolino (2001) species richness should be higher within the forest-line ecotone (Classical edge-effect hypothesis) than that of adjacent communities due to interchange of species between forest and open alpine communities.

Like elevation, aspect is another major factor in bringing variation in species richness and composition in mountains. Variation in the climatic factors (intensity and duration of light, precipitation, wind velocity and direction etc.), and non climatic factors (slope and nature of the terrain, edaphic factors) may also be associated with the aspect of the mountains. Though, elevational pattern of species richness and composition was explored by most of the researcher in the Himalayan region, very few studies have been attempted so far to explain the influence of aspect on species richness. A study by Panthi et al. (2007) has shown that total species richness was found to be significantly higher on the northern aspect than that of south aspect in trans-Himalayan region.

## 1.2 Objectives

The overall objective of the study is to assess spatial patterns of species richness and composition along the forest line ecotone in the Central Himalayan region (Langtang) of Nepal with following specific objectives:

I. To describe altitudinal patterns of plant species richness in the subalpine-alpine range of Langtang region in both (north and south) the aspects.

II. To compare plant species richness and composition from forest to non-forest landscape in both the aspects.

III. To explain the vegetation environment relationship in both the aspects of the study area.

## 1.3 Limitation of the Study

The major limitation of the study are:

I. Only two vertical transect were laid down in the southern aspect for the field survey due to inaccessible topography of the study area than that of northern aspect where three vertical transect were laid down.

II. Most of the soil parameter was analyzed in the laboratory of Central Department of Environmental Science only after the completion of the field work.

# CHAPTER – II

# REVIEW OF LITERATURE

The major objective in biogeography and ecology is to understand the causes of taxonomy diversity gradients. Such gradients occur at spatial scales ranging in extent from few meters to thousands of kilometers (Nilsson and Wilson, 1991; Hillebrand, 2004) and the elevation patterns of species richness and their underlying mechanisms have long been a controversial issues in biodiversity and biogeography research and several hypothesis have been proposed in the past decades (Pianka, 1966; Huston, 1994; Lomolino, 2001; Whittaker et al., 2001).

The most frequent relationship between elevation and richness are, in order; a humped shaped species richness curved; a pleatue of high species richness at lower elevation; and a monotonic decrease in species richness with increasing elevation (McCoy, 1990; Rahbek, 1995, McCain, 2005). According to the continuum concept species composition changes gradually (Whittaker 1956; Austin 1980), but the change in species composition around the forest-line ecotone of mountain is rapid.

Yoda (1967); Mac Arthur (1972); Stevens (1992) found a decreasing trend in species richness with increasing elevation, additionally some authors have argued that species richness decreases at higher elevations due to an increase in unfavourable (more variable and/or more extreme) climatic conditions (MacArthur, 1972; Tenow, 1973), an isolation from areas with similar elevation (Mac Arthur, 1972). Whereas Grytnes and vetaas(2002) found a humped shaped relationship with a peak in species richness at intermediate elevation. Rahbek (1995) in his study concluded that humped shaped relationships are most common in both tropical and non-tropical bioms.

The optimum humidity conditions and high productivity in the mid-elevation region resulted by the optimal combination resources availability resulted a hump-shaped species pattern of Spermatophyte in Hubei province (Hau, 2006). The mid elevation ranges with an optimal combination of environmental resources are more preferable for many species to co-exist (Lomolino, 2001; Brown, 2001).

Plant community of a region is a function of time; however, altitude, slope, latitude, aspect, rainfall and humidity play a role in a formation of plant communities and their composition (Kharkwal et al., 2005).

In the Himalayan region of southeastern Ohio, the effect of aspect on temperature, soil moisture availability and in turn vegetation growth was observed influencing the distribution of species (Wolfe et al., 1949; McQueenuy, 1950; Hutchins et al., 1976). Slope aspect plays key role in the distribution of some ground flora species (Cantlon, 1953; Hutchins et al., 1976). Panthi et al., 2007 revealed significantly more species on the north aspect than on the south aspect at the elevation range of 3000-4000 m a.s.l of Manang, a Trans-Himalayan inner valley of Nepal similarly in a study in Guilam Province of Iran species diversity was found to be more in northern aspect due to humid soil and less solar energy favoring better growing condition (Hashemi, 2010).

A study conducted by Shrestha and Vetaas (2009) in the arid-trans Himalayan landscape of Nepal on the effect of forest ecotone on species richness revealed that the species turnover was, in general low and species richness did not vary very much between the forest and open landscape which is attributed to the grazing and growing pressure in the area that may have lowered the tree-line, DCA revealed a continuous change in species composition across the forest border ecotone.

There are a variety of species richness along the environmental gradients ( Pausas and Austin, 2001). Huston (1979, 1994) reviewed species richness as being determined by the interaction of disturbance with environmental gradients and competitive exclusion. Although over any large region the distribution of specie richness is likely to be governed by two or more environmental gradients (Margules et al.,1987; Pausas, 1994; Austin et al.,1996). The variation of species richness along elevation gradients has been documented for variety of taxa and geographical areas (Terborgh, 1977; Stevens, 1992; Rahbek. 1997; Brown, 2001; Bhattarai and Vetaas, 2004).

Many studies have found relationships between changes in species richness and a gradient of nutrient availability. According to Grime (1979) few species are able to tolerate extreme conditions of nutrient deficiency, as resource increases, more species can survive and hence species richness rises. Huston (1980) found a decrease of tree species richness along the nutrient gradient in Costa Rican forest while Tilman (1982) and Austin (1989) showed a humped curve in tropical forest of Borneo. Factors that have been suggested to explain mean elevation peaks in species richness include intermediate productivity (Rosenzweig, 1995), maximum humidity (Rahbek, 1995), an up slope mass effect for certain taxa (Kessler, 2000) and the mid domain effect (Colwell and Lees, 2000; Grytnes, 2003).

Braakhekke and Hoftman (1999) found maximum species richness at intermediate values of the nutrient ratios N/P, P/K and particularly K/N while testing their resource balance hypothesis of plant diversity. Austin et al. (1996) tree species richness slightly positively related to soil nutrients.

Vetaas (1997) found that vascular plant species richness and also climber and herbaceous species richness were positively related to $p^H$ in a study in the Himalayas.

Brown (1981), Wright (1983) and Currie (1991) have suggested that the capacity of the environment to support species is determined by the availability of energy. Knight et al. (1982) and Austin et al. (1996) found a negative relationship between species richness and annual incoming solar radiation in Southern Africa and South Eastern Australia respectively.

According to Huston (1979) species richness reaches a maximum at some intermediate level of disturbance. A study by Vetaas (1997) revealed increase in species richness in Oak forest with intermediate canopy disturbance controlling other environmental variables.

# CHAPTER – III

# MATERIALS AND METHODS

## 3.1 Study Area

The study area lies in Langtang National Park (LNP), Central Nepal. LNP is the first mountainous park of Nepal, gazetted in 26th march 1976 by the then His Majesty's Government of Nepal with assistance from the UNDP/FAO to preserve the Himalayan flora and fauna of Central Nepal in its natural state. It covers an area of about 1710 sq. Km and extended in three districts namely; Rasuwa, Nuwakot and Sindhupalchowk. The elevation of the park ranges between 792 m a.s.l (Bhotekoshi) and 7245 m a.s.l (Mount Langtang Lirung) extending from 27˚57'36" to 28˚22'48" and 85˚12'36" to 85˚52'48" in the Central Himalayan region. Specifically the present study area is in the periphery of the popular trekking route to Gosikunda from Dhunche of the Rasuwa district. The study covered altitudinal range of 3550 m a.s.l to 4350 m a.s.l, in distinct forest line ecotone.

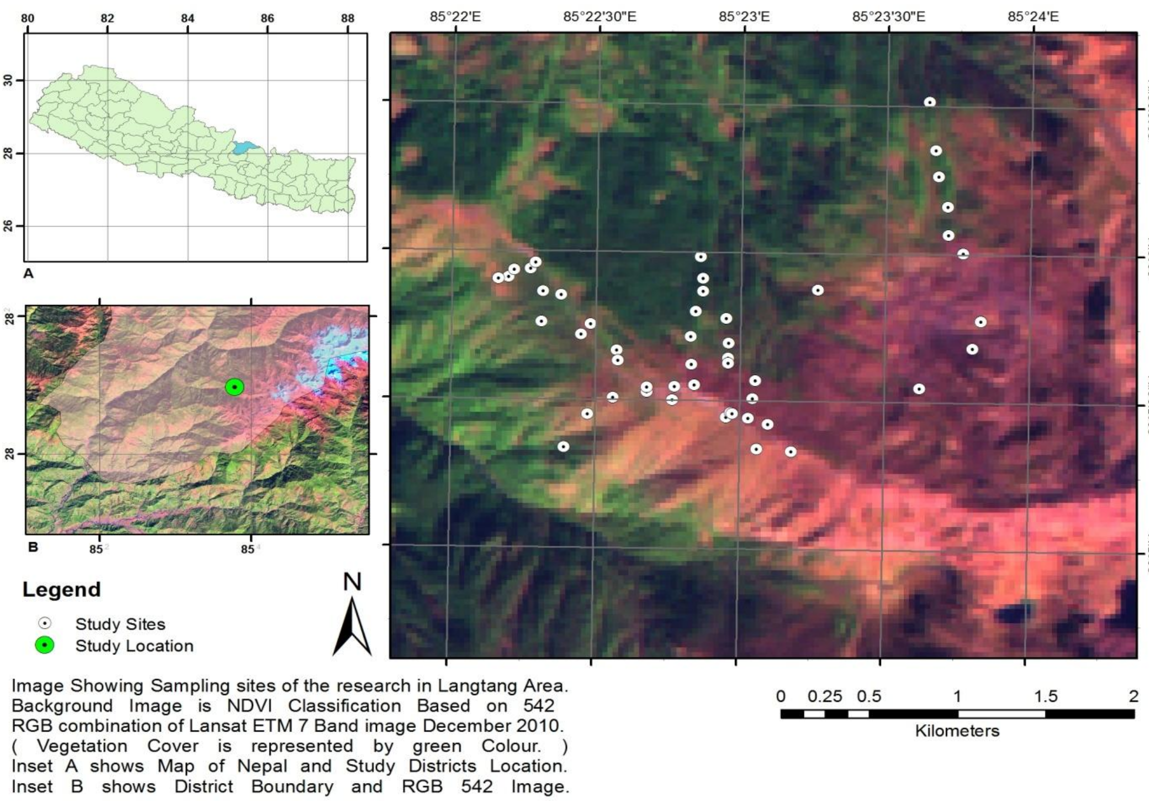


**Figure 1: GIS based map showing the study area.**

## 3.2 Climate

The seasonal climatic pattern of Nepal is dominated by the eastern monsoon which occurs from June to September. The incidence of precipitation is mainly related to the aspect, attitude and the presence of rain shadow effect. At higher altitudes, the importance of orographic precipitation is greater. The study area lies in the high altitude area where summer snow accumulates only above 5500m. In the Autumn, the storms from the north west occasionally brings deep snow down to 4000m During the winter, precipitation is generally sparse with little snow melting below 4000m (Fox, 1974b). However, in the late spring, snow is able to build up on the upper south slope on the main ridges due to the greater incidence of cloud which reduces the effective isolation. Temperature varies considerably with aspect, altitude and cloud cover. There is a $6^0$ C drop in temperature for every 1000m rise in elevation (DUHE, 1977).

There is no metrological station in the study area. Climatic data for Kyanging station were analyzed to interpret the rainfall and temperature pattern of the study area. The Kyanging station is situated almost at the same elevation as study site is similar to the study area in many aspects.

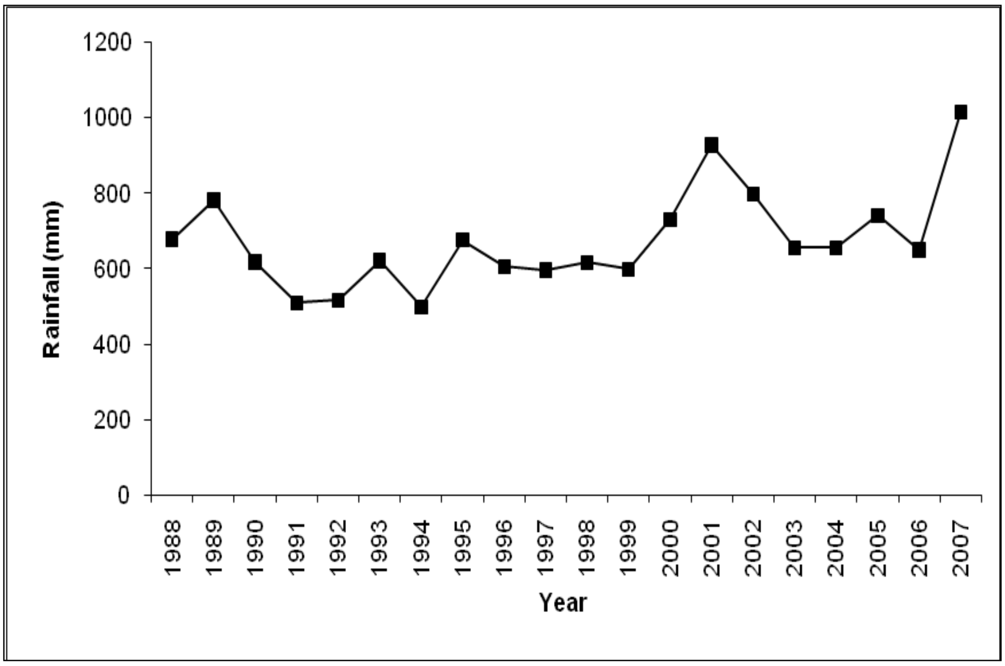


**Figure 2: Mean Annual Rainfall in mm (1988-2007)**

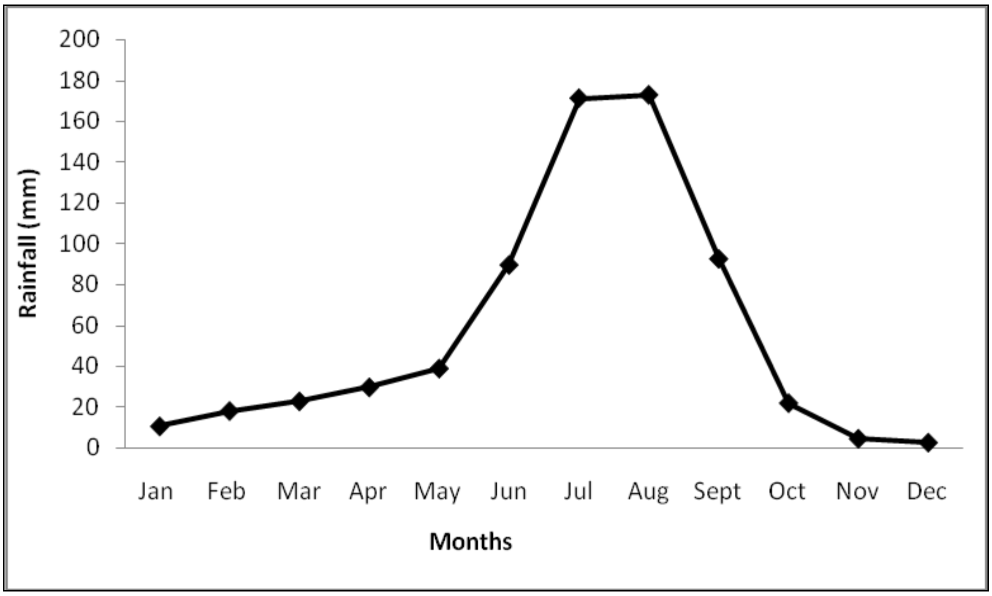


**Figure 3: Mean Monthly Rainfall in mm (1988-2007)**

The annual rainfall in the study area ranges from about 500mm to 700mm (Fig 2). After 1999 A.D, there is abrupt increase and decrease in mean annual rainfall. From the year 2003 to 2006 there is almost similar pattern in annual rainfall. There is increase in rainfall in the monsoonal months after May and it peaks during the month of July and August. The decrease in rainfall occurs after August. Minimum rainfall occurs during the winter season i.e. January and December.

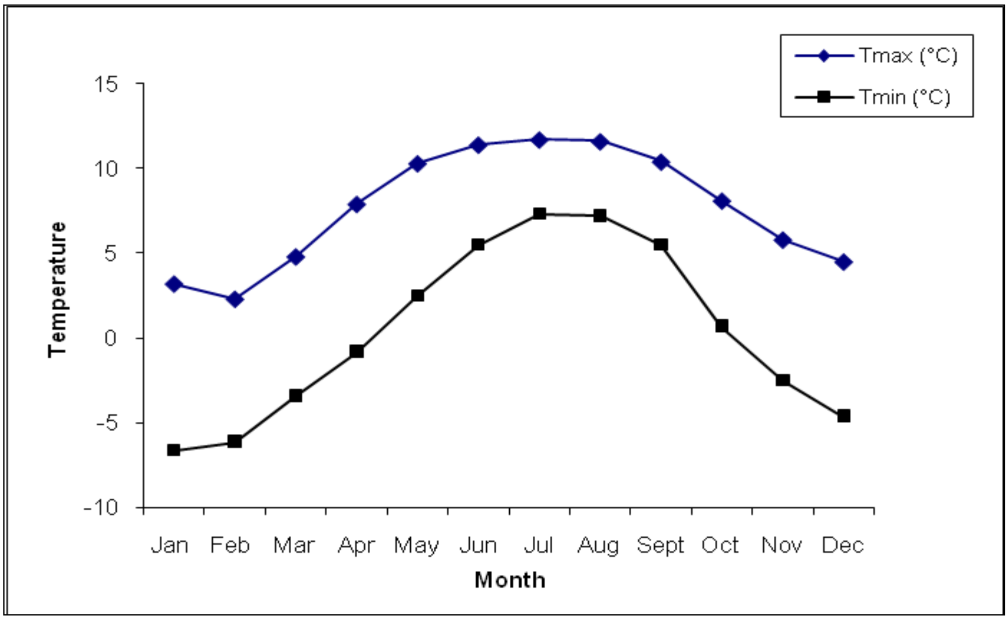


**Figure 4: Maximum and Minimum Monthly Temperatures in $^{0}$C (1988-2007)**

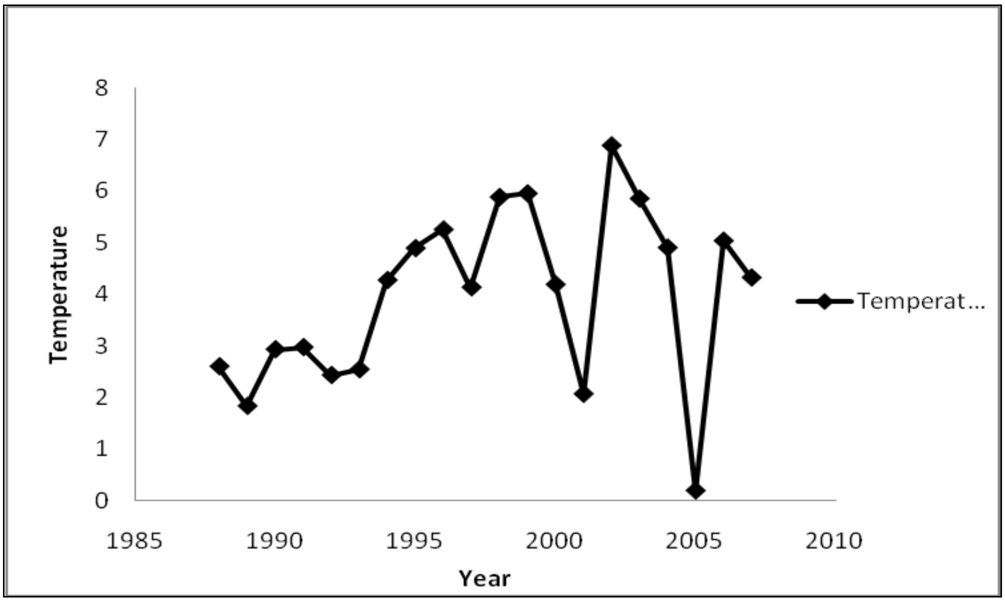


**Figure 5: Mean Yearly Temperature in $^{0}$C (1988-2007)**

High monthly temperature are observed during the month of monsoon season i.e. during summer which is generally near to 10$^{0}$C and minimum temperature are observed during the winter months which falls below 0$^{0}$C.

## 3.3 Geomorphology

The LNP occupies tectonically interesting and important position within the Nepal Central Himalaya. The fore Himalaya occurs between 3,000-4,000m along the south margin of the park. The Langtang and Jugal Himals are considered integral parts of the Great Himalaya Range. The region between the Langtang Ri and Shisha Pagma is the transition zone linking the Great Himalaya and Tibetan Marginal Ranges (Hagen, 1969). Igneous, metamorphic and migmatite rock types are found within the park. Young skeletal soils are found in the upper valley where weathering rate is high. Matured soils are found in the lower forested area, mainly of fertile loams. The mean proportion of sand has decreases with elevation and loamy-sands become predominant below 2,440m. Hot springs occurring near Timure and Syabrubensi along the Bhotekoshi are an indicator of deep seated tectonic activity, and is still present in these relatively young mountains.

## 3.4 Drainage and Hydrological Regime

Due to steep slope and rugged topography, all the rivers in the park are torrential and are following swiftly over rock and boulder substrata. There are two types of rivers; those fed partially by glaciers (Langtang Khola and Bhote Koshi) and those which do not have glacial origins (Trishuli, Phalangu, Tadi Khola). The drainage of the park can be divided into two main parts. South of the Gosaikunda Lekh-Dorje Lhakpa range drainage is southwards and then east into the Sunkoshi (which confluence point is Saptakoshi) but the Phalangau and Tandi Khola drain south west ward into the Bhote Koshi (which confluence point is Narayani ). North of this range drainage is initially westward into the Bhote Koshi-Trishuli river and then southward again into the Narayani. Major standing water bodies in the park include the three main lakes at Gosaikunda (Gosaikunda, Bhairabkunda, Saraswatikunda ) and two at Naukunda, five at Panch Pokhari and one at Garwang Chho (Ganeshkunda). In addition to these, there are numerous lakes and ponds in most valley system at higher altitudes of above 3600m. In northern slope, winter snow retain up to several months. But in contract to this, snow rarely remains on the ground for more than a few days on the south facing slopes.

## 3.5 Land Use Pattern

Majority of the park area (60.70%) is covered by rock, ice and glaciers. The forest, shrub land and agriculture cover 29.9%, 2.8% and 1.7% of the total land area of Langtang National Park respectively (DNPWC, 2008).The study area lies in the tree line area which consist of transition one of forest and mountain pastures or grasslands. Although grassland only covers 49.4% of the total land area of Langtang National Park they significantly support livelihood of local people and are rich in terms of biodiversity (Ghimire et al., 2008).

## 3.6 Vegetation and Flora

The great variety of vegetation types occurring within the park is one of its most striking features. The complex topography, geology and climatic patterns have enabled a wide range of plant communities to establish themselves in the park area (Malla et al., 1976; DUHE, 1977). So far, 17 vegetation types and 911 species of vascular plants have been described from LNP and surrounding regions (Malla et al., 1976; DUHE, 1977). Vegetation of LNP ranges from sub-tropical and temperate forests, to alpine meadows and scrubs to the nivale zone of dry, screed vegetation. The park lies in meeting point of Indo-Malayan and Palearctic realms. Both if the realms are contributing for its rich biodiversity. The park lies in the Eastern Himalayan alpine shrub and meadow eco-region which is one of the two prominent Global 200 eco-regions in Nepal (Basnet, 2006).

The lower sub-alpine zone (3000-3600 masl) is characterized by the predominance of conifers, such as *Abies spectabilis* and *Tsuga demosa*, which are mixed with *Acer campbellii* and *Rhododendron barbatum* in damp sites and gullies. *Abies spectabilis* forest mostly occurs at relatively higher altitudes. *Rhododendron arboreum*, *R.campanulatum* and *Betula utilis* are also found mixed with *Abies spectabilis*. A rare conifer *Larix himalaica* is found in significant number along the Langtang River forming narrow forest belt mixed with *Rhodendron companulatum*. The upper sub-alpine zone (3600-4000 masl) is mainly characterized by *Betula utilis* forest in nort-facing slopes. *Betula utilis* is associated with *Rhodendron companulatum*, *R.lepidotum, R. barbatum,* later being setter and stunted above the tree line. In drier habitats (south facing slopes), *B.utilis* is absent and *R.companulatum* is associated with *Juniper indica* and *Juniper recurva*.

Tree species such as *Abies spectabilis, Betula utilis* and twisted *R.companulatum* dominate tree line vegetation in north facing slope. However, true tree line forest vegetation is rarely developed in the south facing slope due to drier habitat and steep topography. Above tree line (4000-4500 masl), the vegetation is dominated by shrubs, mainly comprising *Berberis spp*., *Ephedra gerardiana, Hippophae tibetana, Juniperous indica, Potentialla fructicosa, Rhodendron anthopogon, R.setosum*, etc. Beside these *graminoid* and herbaceous species such as *Bistorta amplexicaulis, Geranium donianum, Kobresia spp., Poa spp., Primula spp*. Etc. dominate the open landscape in lower and upper alpine zones above tree line forming distinct communities.

## 3.7 Fauna

Langtang National Park has a lower diversity of mammals (46 species with many rare mammals such as wild dog, wolf, red panda, musk deer and clouded leopard) than in the eastern and western Himalayas because after the origin of the Himalayas, the Central Himalayas became a barrier between the east and west faunal gateways and the radiation amphitheaters (Khanal, 1993 cited in Yonzon, 1989:21). Under enormous ecological stress some 19,000 inhabitant in 47 villages and another 58000 people living around the park rely on the forest for food, fodder and fuel wood. The low density of larger mammals is an indication of the extent of intrusion by human (Yonzon et al, 1991). The park has recorded a total of 345 bird species including residents and migrants. The park is rich in almost 37 bird families of the world, 58 species of fish and 11 species of herpto-fauna. The park harbors more than 1000 species of plants including endemic plants like *Larix nepalensis, Rhododendron cowaniannum* and *Rhodondendron lowndessi* (Karki and Thapa, 2001).

## 3.8 Socio-Cultural and Economic Aspect

The park offers a rich cultural diversity. The three main ethnic groups in LNP are the Tamang, Yolmo, and Bhotia, is thought to have originated from Tibet of China (DNPWC, 2006). The cultures are discernible by language, house style, dress, ornaments and customs. The Tamangs are traditional cattle herders of the region. Their farmlands and village stretch south of bhote Koshi and Trishuli River. Their religion is related to the Bon and pre-Buddhist doctrines of Tibet. While the people of Langtang Valley are mostly Bhotias with recent Tibetan origin, many have inter mingle with local Tamangs. Generally, they inhabit higher elevation range. The Yolmo people of Helambu region are often referred to as Sherpa. However, the language and socio-cultural set up does not resemble the Solokhumbu sherpas. Their religion and monasteries are rich in Buddhist culture. Other hill tribes and castes such as Brahmin, Chhetri, Newar and Gurung inhabit the lower elevation range along the edges of the park (DNPWC, 2006).

Livestock farming and tourism are main occupation of the people who resides within LNP (DNPWC, 2001). Remote places such as Langtang have begun to experience changes in their social and political structure, economic life and cultural values (Pandey, 2006).The changing economic and social arrangements have made difficult for rural people to have access to the basic agricultural resources.

## 3.9 Methods of Data Collection

### 3.9.1 Vegetation Sampling

The elevation ranges of study sites were 3574m-4055m and 3505m-4074m for north facing slope and south facing slope respectively. The detailed field study was conducted in June-July 2008, which is the flowering season for most of the vascular plant species in the study area. For the study, area with distinct forest line ecotone at tree line was chosen in northern and southern aspects. The forest line was defined as the uppermost limit of closed stands of trees at least 2m in height (Hofgaard, 1997), whereas the tree-line has been defined as the uppermost altitudinal position of a tree at least 2m in height (Kullman, 1993). The vertical transect of 10m x10m was established in the forest-line ecotone (fig 6).

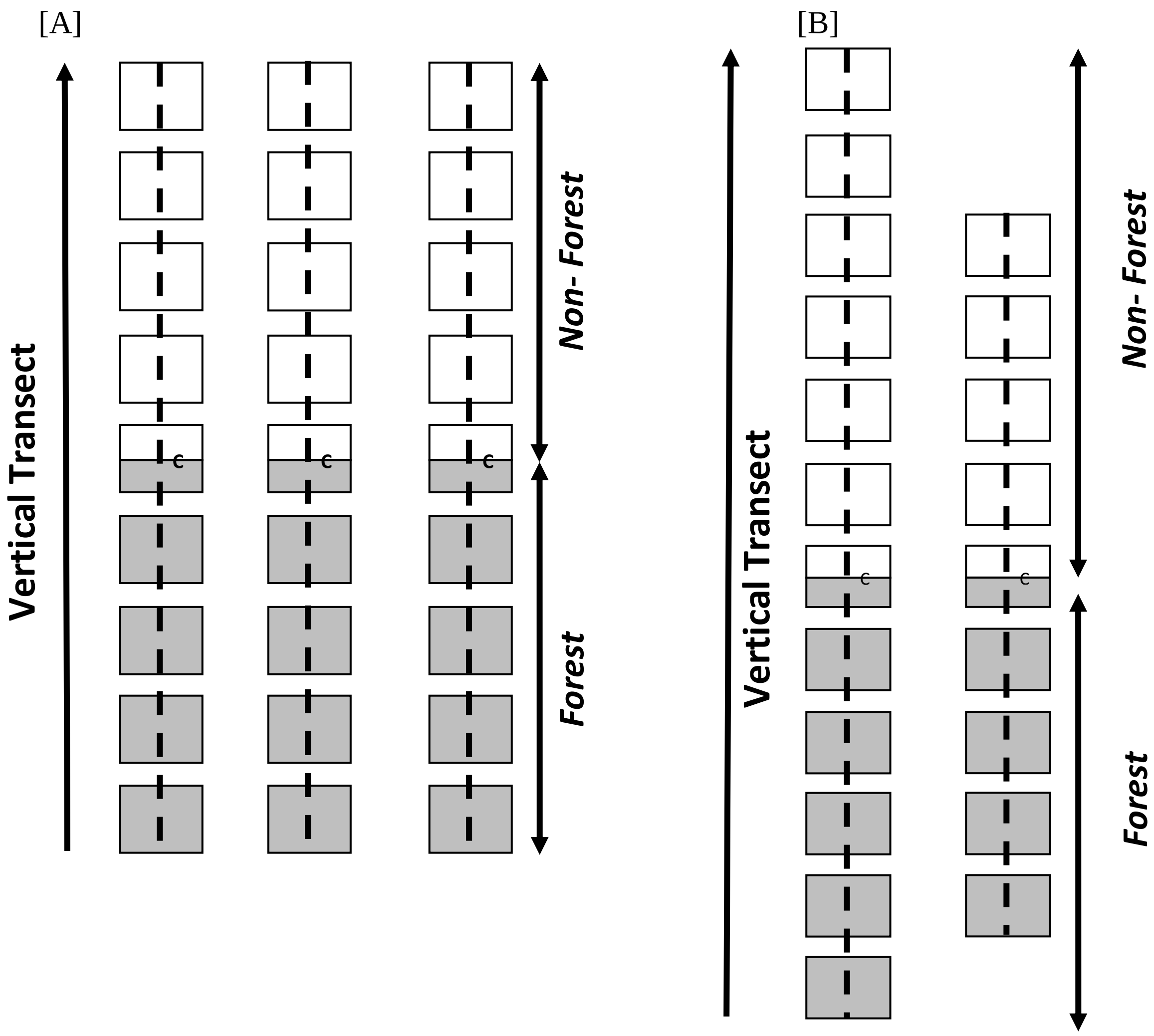


**Figure 6: Showing the sampling design plots in north [A] and south [B] aspect respectively.**

The vertical transect were established in each aspect with more natural and rapid transition from forest to an open alpine landscape. But, in some vertical transect, it was often difficult to make the distinction between forest and non-forest. In such situation, the plot with less than 50% canopy cover was considered as non-forest and of above 50% canopy cover was considered as forest.

In north facing slope, three transects were located. In each transect thus established, nine plots of 10m x 10m were established. A central plot was established in the vertical transect at the boundary between forest and non-forest. Altogether, 27 plots were studied in three vertical transect for north aspect.

In south facing slope, two vertical transect were located in such a way that central plot remained fixed at the boundary between forest and non-forest. Out of two vertical transect, one transect comprised 9 plots and the second transect comprised12 plots of 10m x 10m due to the inaccessible topography of the southern aspect. In the entire vertical transect each plot were approximately 50-70 m apart in both the aspect.

For the collection of species data, each plot was divided into four sub-plots of 5m x 5m (fig 7). The presence/absence of all vascular plants was recorded in each sub-plot. Finally, it was converted in terms of frequency scale of 0 to 4 (0 = species absent in all the four sub-plots, 1=species present in one of the four sub-plots etc.). Sample herbariums were prepared for unidentified species and were identified at the Department of Plant Resources Office, Godavari, Lalitpur.

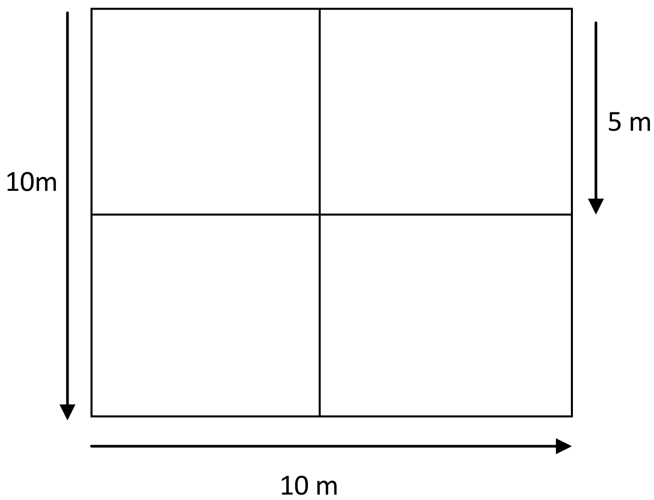


**Figure 7: Sampling plot of 10m x 10m with sub-plots of 5m x 5m.**

### 3.9.2 Environmental Variables and Disturbance Indicators

Qualitative and quantitative environmental variables along with the disturbance indicator were recorded in each sampling plot. Canopy cover and ground cover were estimated visually. Altitude was recorded with altimeter and aspect was measured with compass clinometers. Slope inclination was generated by using software "arc view 3.0" in a digital map of a studied area provided by the Department of Survey, Kathmandu, Nepal and with the help of altitude and aspect recorded. The number of dead trees and cut stumps were counted in each sampling plot. Signs grazing and fire were recorded in terms of cattle droppings and fire scares respectively. Forest versus open landscape, was coded as a categorical variable and similar coding were made for grazing versus non-grazing and fire versus non-fire.

Relative Radiation Index (RRI) was calculated for each sampling plots using the formula given by Oke (1987).

$$RRI = \cos(180-\Omega)\sin(\beta)\sin(\Phi) + \cos(\beta)\cos(\Phi)$$

Where, RRI is a function of latitude ($\Phi$), inclination ($\beta$), aspect ($\Omega$).

### 3.9.3 Soil Sampling

During the field study, soil samples were also collected. The soil sample were collected from the four corner of each sub-plot (i.e. 5m x 5m) from the depth of about 10 cm. Altogether 16 soil samples were taken from each plot of 10m x 10m and mixed to form a composite sample. The soil samples were packed in air tight polythene bags and were brought to the laboratory for analysis after the completion of field work.

Soil moisture content, $P^H$ ($P^H$ meter), conductivity (conductivity meter), nitrogen (Kjeldahl Digestion method), organic matter (Walkley and Black method), phosphorous (Spectrophotometer) and potassium (Flame photometer) were analyzed in the laboratory of Central Department of Environmental Science. Soil temperature was measured directly in the field by using thermometer at the depth of about 10 cm in the sampling site.

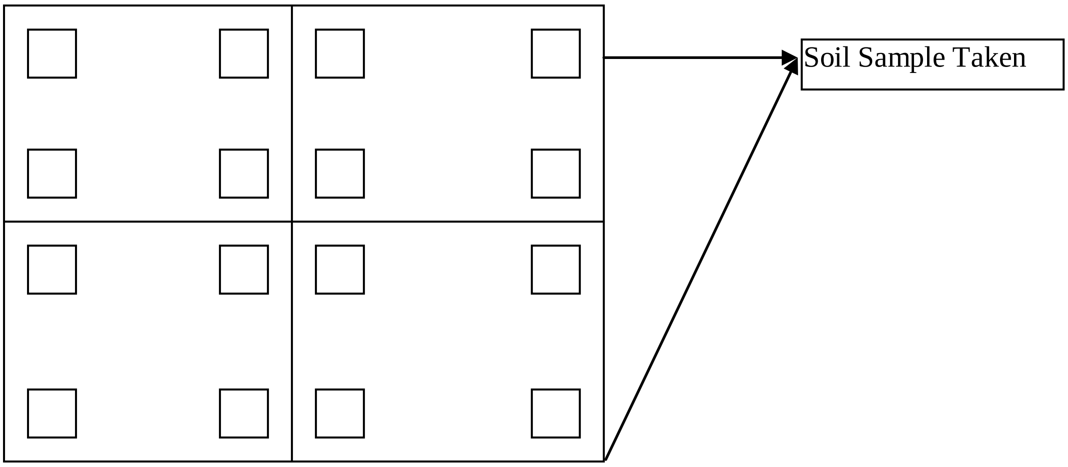


**Figure 8: Corner of each sub-plot from where soil samples were taken.**

**Table 1: Abbreviation and units of disturbance indicator, and environmental and other response variables measured in each sampling plots.**

| Variables | Abbreviation | Units |
|---|---|---|
| altitude | alt | m.a.s.l |
| canopy cover | canop | % |
| cut stumps | cut | numbers |
| dead trees | dead | numbers |
| fire scars | fire | 1/0 |
| sign of grazing | graz | 1/0 |
| field layer cover | gcov | % |
| relative radiation index | rri | - |
| total soil nitrogen | nit | % |
| total organic matter | omat | % |
| total moisture content | mcon | % |
| total soil phosphorous | phos | % |
| pH | ph | pH scale |
| conductivity | cond | µs |
| total soil potassium | pot | % |
| inclination of slope | slop | degrees |
| north east west/south west | aspect | degrees |
| species numbers | sppno | numbers |

## 3.10 Numerical Analysis

### 3.10.1 Univariate Analysis

**Correlation**: Pearson's correlation was used to explore the relationship between the measured environmental variables.

**Regression**: Regression analysis (up to second order polynomials) was performed to explore the relationship of species richness with other environmental variables. The response variable (species richness) is discrete or count data and assumed to have a Poisson distribution and requires a log-link function (McCullagh and Nelder 1989). A Generalized Linear Model (GLM) (McCullagh and Nelder 1989, Hastie and Pregibon 1993, Dobson 2002) was used to test the relationship between species richness (response variables) and each of the predictor variables. During the regression analysis by GLM the response variables were fitted into the models with different environmental variables. The significance of each variable was tested by Chi square test. All the variables were tested up to second order polynomials.

**Student's t-test:** Student's t-test was performed to examine species richness in forest and open plots and grazed and non-grazed plots..

All univariate analysis was performed using statically computer program R version 2.8.1 (R-foundation 2005).

### 3.10.2 Multivariate Analysis

Ordination was used to explore the relationship of vegetation and measured environmental variables and to examine the relative importance of environmental variables for species composition using software CANOCO version 4.5.

In total, 48 plots were studied (27 in north aspect and 21 in south aspect). For ordination analysis, species data were prepared for each aspect. Altogether, 16 environmental variables were studied in each plot. Environmental data were also prepared for both the aspects.

DCA was carried out to find the compositional turnover of species on each axis in terms of standard deviation (SD) unit's i.e. β-diversity (Hill and Gauch, 1980). The gradient length (β-diversity) was found to be 3.05 and 2.4 SD unit for north and south aspect respectively (Table 2). Assuming a unimodel relationship (gradient length > 2.5) between the response and predictor variables, Canonical Correspondence Analysis (CCA) was used. To define overall environmental vegetation relationship, CCA (Ter Braak and Looman, 1986) was done for all data set of north facing plots and south facing plots and combined plots from both aspects.

CCA provides an integrated description of species-environmental relationship by assuming a response model that is common to all species, and the existence of a single set of underlying environmental gradients to which all the species respond. Canonical correspondence analysis has the advantage over other techniques in that it focuses on the relations between species and measured environmental variables and so provides an automated interpretation of the ordination axes (Ter Braak, 1986).

CCA was done in CANOCO with interspecies distance and Hills scaling option. Significance of environmental variables in explaining variation in species data was tested using Monte Carlo Permutation test using forward selection (Vanderpuye *et al*, 2002). During CCA, rare species were weighted down and only significant environmental variables were included (Vetaas and Chaudhary 1998, Buscardo et al. 2008). Ordination diagrams were created using CANODRAW package in CANOCO version 4.5.

# CHAPTER-IV

# RESULTS

## 4.1 Species diversity

Altogether, eighty three and ninety two vascular plant species were recorded in northern and southern aspects respectively. Sixty four and seventy species were found in the plots from forest and open landscape respectively in north facing slope; whereas the number of plant species from forest and open alpine landscape were seventy nine and sixty nine respectively in south facing slope (Table 2).

**Table 2: Species diversity from open and forest landscape of northern and southern aspects.**

| | North | | | South | | |
|---|---|---|---|---|---|---|
| | Forest | Alpine | Total | Forest | Alpine | Total |
| α-diversity | 23 | 24.5 | 23.7 | 34 | 27.8 | 31.4 |
| β-diversity | 1.68 | 2.015 | 3.05 | 1.785 | 2.061 | 2.4 |
| Total species | 64 | 70 | 83 | 79 | 69 | 92 |

There was slightly greater α-diversity (species richness) in open landscape than that of forest landscape of north facing slope but α-diversity was found to be slightly greater in forest landscape than that of open in southern aspect (Table 2). The degree of compositional turnover (β-diversity) was measured in standard deviation (SD) units; β-diversity was found greater in open alpine landscape of both the aspects than that of forest landscape. As a whole, while comparing data from both the northern aspect and the southern aspect, species turnover (β-diversity) was found to be higher in northern aspect (3.05) than that of southern aspect (2.4). On contrary α-diversity was found to be greater in southern aspect (31.4) than that of northern aspect (23.7) indicating high richness in the southern aspect (Table2).

## 4.2 CCA Ordination Result

CCA analyses were done separately for the data set of north and south facing slopes. The summary of results as revealed by CCA is presented in Table 3.

The Eigen value of first axis was much higher than second axis for northern than southern aspect (Table 3).

There was small difference in cumulative percentage variance explained by the first axis for both the aspects i.e. north (23.20) and south (20.3). When first two axes were combined, then they explain 29.3% in north aspect and 27.4% of the south aspect of the vertical transect.

**Table 3: Ordination Summary of CCA for North and South Aspect**

| **Sites** | **North** | | **South** | |
|---|---|---|---|---|
| Ordination Axes | 1 | 2 | 1 | 2 |
| Eigen Values | 0.45 | 0.118 | 0.335 | 0.117 |
| Species Env. Correlation | 0.991 | 0.874 | 0.969 | 0.9 |
| Cumulative % Var. of Species | 23.2 | 29.3 | 20.3 | 27.4 |
| Cumulative % Var. of Species Env. Relation | 62.1 | 78.4 | 51.5 | 69.5 |

Env.=Environment

Var. = Variance

## 4.3 Species Composition

### 4.3.1 Northern Aspect

Though, fourteen environmental variables and three disturbance indicators were recorded in the study, only 4 of them were found significant during forward selection in CCA. These significant variables and indicators were altitude, slope and cut stumps respectively. These are the main underlying environmental variables disturbance indicator influencing species composition.

Cumulative percentage variance of the species environmental correlation for the first axis was 62.1% (Table 3.) indicating first CCA axis accounts for more than half of the variation. The first and second CCA axes altogether explain 78.4% of this variation. The variation explained by the first and both axes together was very high. Species environment correlation of the first axis and the second axis was high which revealed that the first and second axis were very well correlated with the environmental data i.e. r=0.991 and r=0.874 respectively for north aspect.

Species that mostly grow under the forest canopy cover in the northern aspect are confined at the extreme left end of the first CCA axis (Fig 9). Such species include *Abies spectabilis, Potentilla nubicula, Arundanaria spp., Senecio wallichii, Sorbus himalaicus* etc.. Species found in open alpine landscape at higher altitude are confined towards the extreme right end of the first axis (Fig 9).

Such species are *Rhododendron anthopogan, Taraxacum officinale, Euphorbia wallichii, Cardamine nepalensis, Kobresia nepalensis, Gentiana prolita, Rhododendron lepidotoum, Salix lindliana, Llyodia serotina* etc.. Species like *Rananculus spp.***,** *Caltha palustris, Thalictrum spp.***,** *Ligularia sibirica* seems requiring moderately open landscape. Other species like *Anemone trullifolia, Corydalys spp., Fragaria spp., Viola spp.* are found everywhere and are positioned in the central part of the diagram (Fig 9).

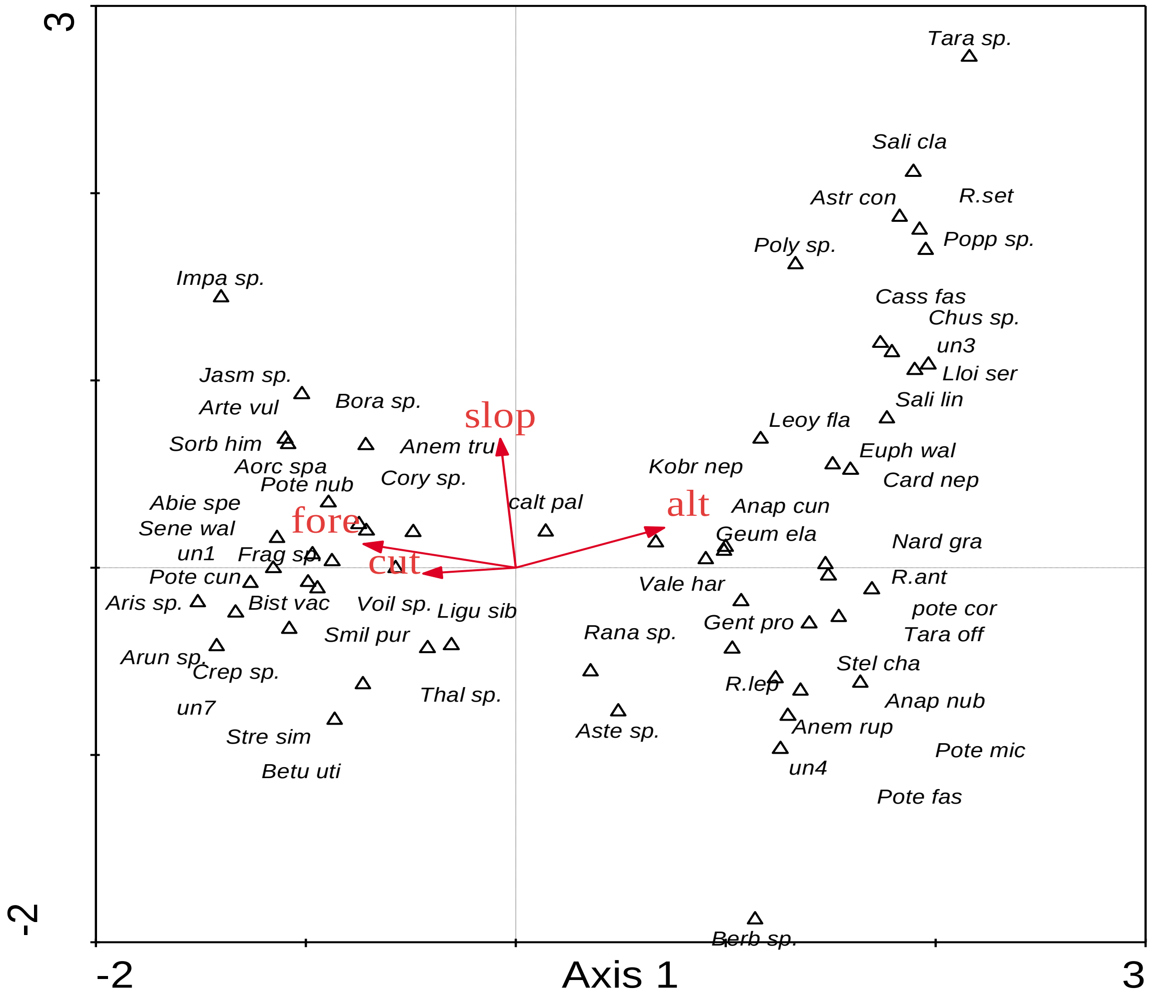


**Figure 9: CCA diagram (biplot) of species, disturbance indicator and environmental variables for northern aspect (Species fit range 10%-100 %)**

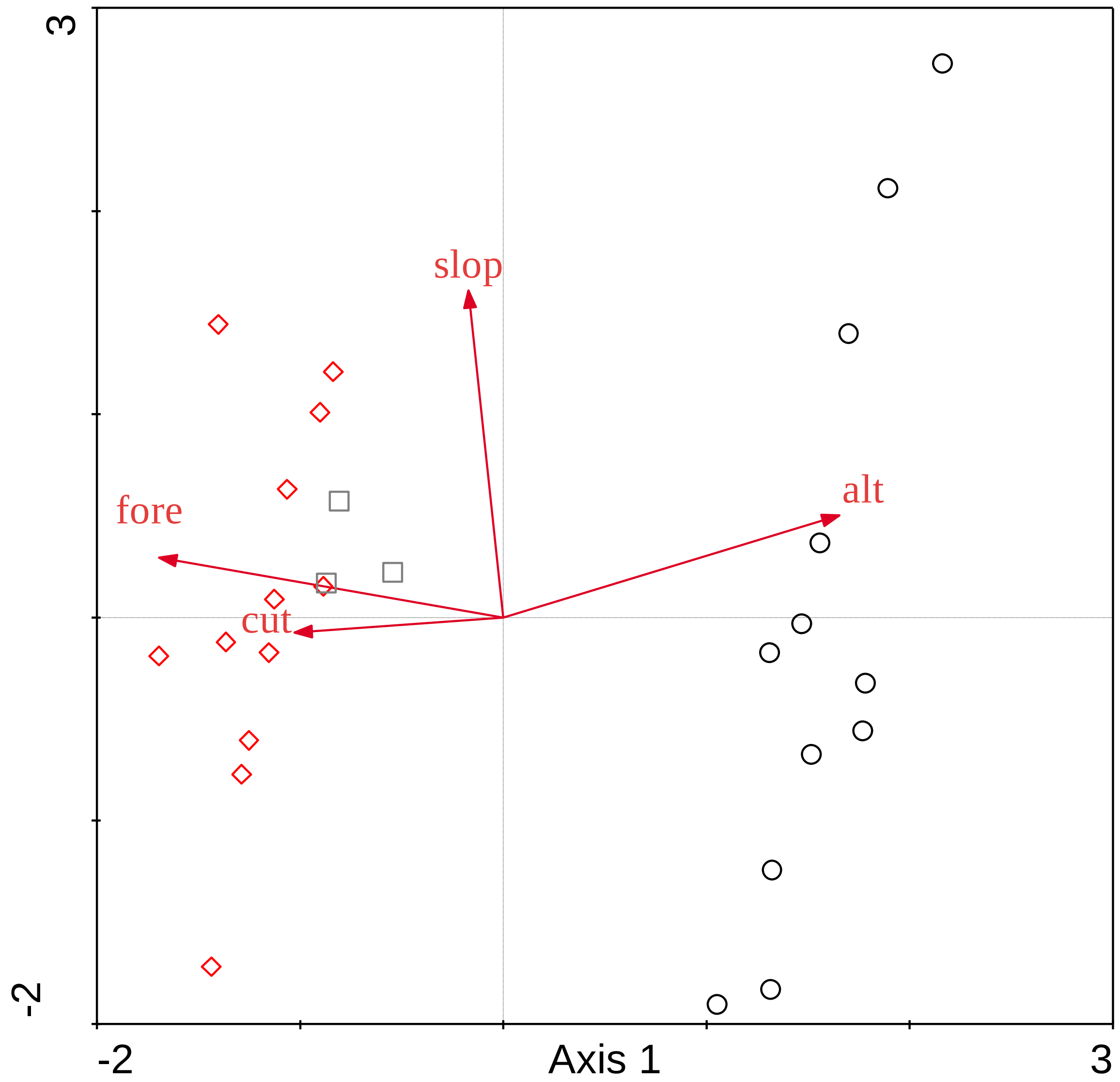


**Figure 10: CCA diagram of northern aspect with samples, disturbance indicator and environmental variables. (Where □ = central plots, ◊= forest plots, ○= open plots).**

### 4.3.2 Southern Aspect

The result from the forward selection in CCA revealed that altitude, cut stumps, pH and forest are the main underlying environmental variables influencing the species composition in southern aspect.

Cumulative percentage variance of the species environmental correlation for the first CCA axis of southern aspect was 51.5% (Table 3.) accounting more than half of the percentage of variation. The first and second axes together explained 69.5% of the variation (table 3.). It is also revealed that the first axis was well correlated with the environmental data (r=0.969) and that too implies for second axis (r=0.900).

Species growing under a forest region are confined at the extreme left end of the first CCA axis & that of growing under a open alpine landscape are confined at the extreme right end of the first CCA axis. Species like *Abies spectabilis, Smilacina purpurea, Crepis spp., Gallium hirtifolium, Viburnum erubescense, Bistorta vaccinifolia* are found under the forest canopy cover whereas species like *R. setesum, Astragallus candolleinus, Potentilla microphylla, Llyodia serotina, Taraxacum officinale, Kobresia nepalensis* are found to be growing in the open alpine landscape of the southern aspect. Species like *Caltha palustris, Androses spp., Potentilla fastigiata, Anaphalis cuneifolia seems* very common and are found at centre of CCA diagam (Fig11).

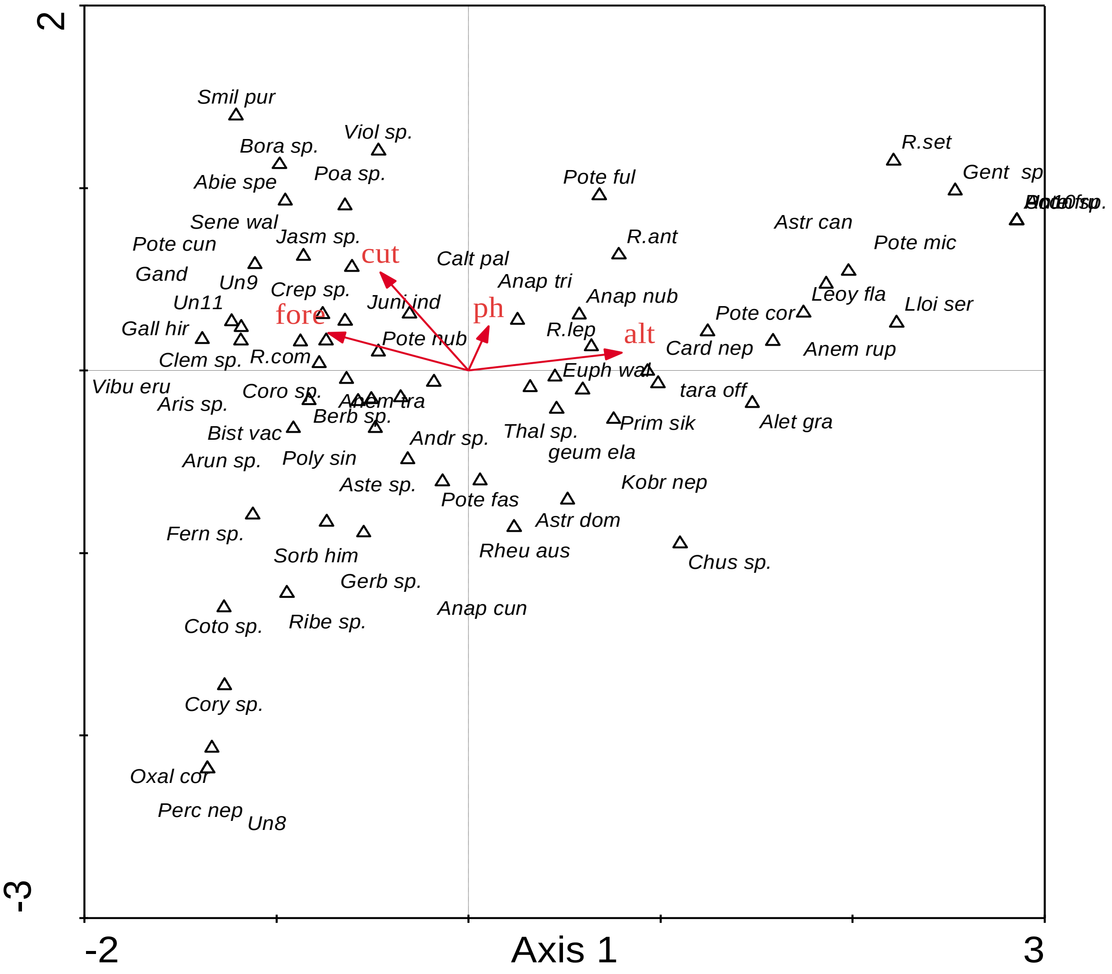


**Figure 11: CCA diagram of southern aspect with species, disturbance indicator and environmental variables. (Species fit range 10%-100%)**

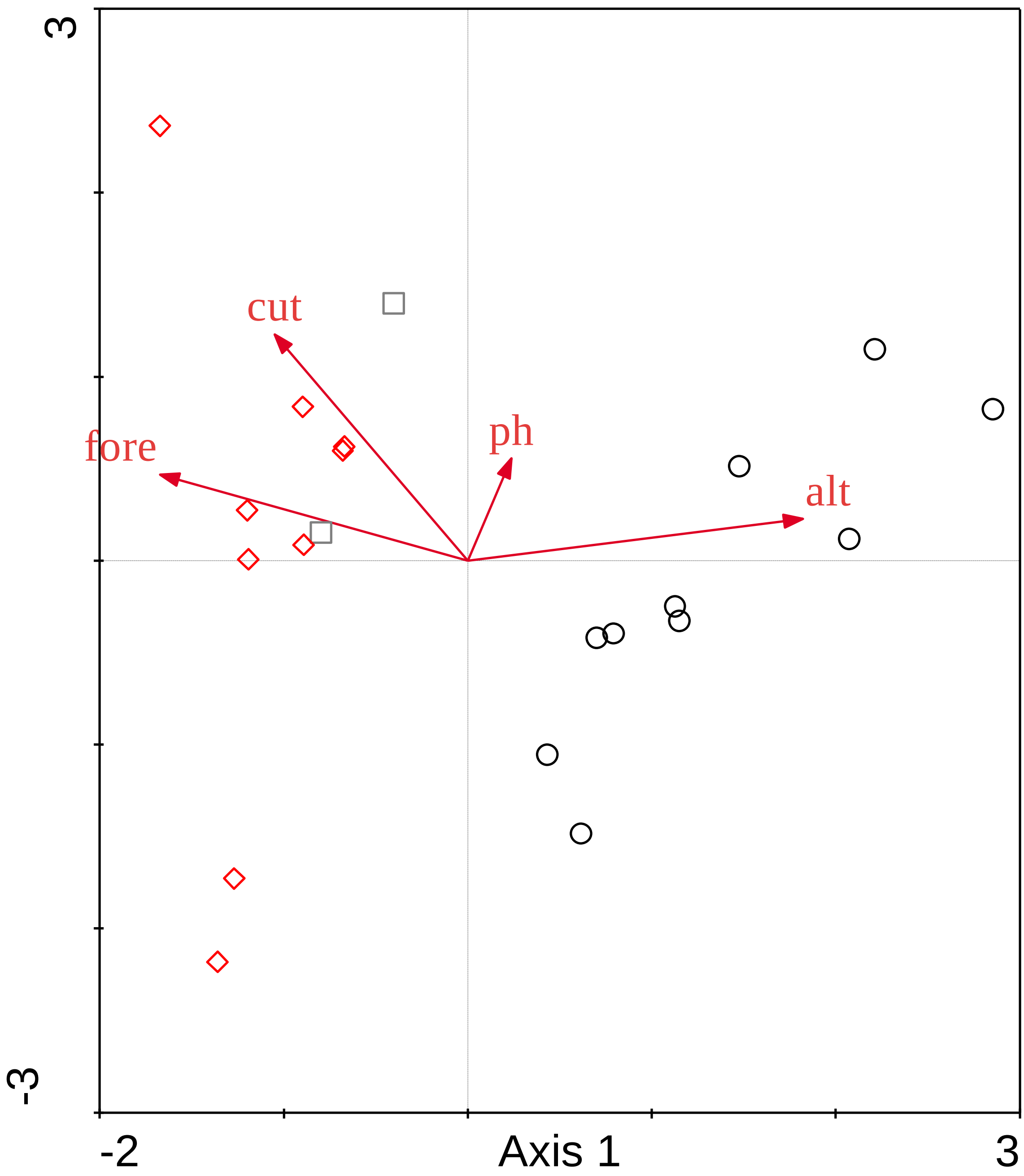


**Figure 12: CCA diagram of northern aspect with samples and environmental variables. (Where □ = central plots, ◊= forest plots, ○= open plots).**

## 4.4 Relationship between Species Richness, Disturbance indicator and Environmental Variables.

### 4.4.1 Northern Aspect

Generalized Linear Model (GLM) was performed using Chi square test to find the relationship between the predictor variables and the response variable. Though the species richness was modeled with each of the environmental variables up to second order polynomial only slope showed a significant relationship ($p<0.05$) with species richness (0.0405) (Table 4.). With the increase in slope there was a decrease in number of vascular plant species.

**Table 4: Relationship between species richness, disturbance indicators and environmental variables for northern aspect as obtained from GLM. Variables with significant relationship ($p<0.05$) are marked with asterisk.**

| Variables | Polynomial order | df | Residual df | Residual deviance | Deviance | P(>/Chi/) |
|---|---|---|---|---|---|---|
| alt | 1 | 1 | 25 | 30.965 | 0.124 | 0.724 |
| canop | 1 | 1 | 25 | 30.544 | 0.545 | 0.460 |
| cut | 1 | 1 | 25 | 29.456 | 1.633 | 0.201 |
| dead | 1 | 1 | 25 | 31.056 | 0.034 | 0.853 |
| fire | 1 | 1 | 25 | 28.164 | 2.025 | 0.087 |
| graz | 1 | 1 | 25 | 30.554 | 0.535 | 0.464 |
| gcov | 1 | 1 | 25 | 31.036 | 0.053 | 0.817 |
| rri | 1 | 1 | 25 | 30.921 | 0.168 | 0.681 |
| nit | 1 | 1 | 25 | 30.068 | 1.021 | 0.312 |
| omat | 1 | 1 | 25 | 31.059 | 0.030 | 0.860 |
| mcon | 1 | 1 | 25 | 31.006 | 0.083 | 0.773 |
| phos | 1 | 1 | 25 | 29.994 | 1.095 | 0.295 |
| ph | 1 | 1 | 25 | 31.078 | 0.011 | 0.915 |
| cond | 1 | 1 | 25 | 31.086 | 0.003 | 0.952 |
| pot | 1 | 1 | 25 | 29.025 | 2.064 | 0.150 |
| slop | 1 | 1 | 25 | 26.893 | 40196 | 0.040* |

### 4.4.2 Southern Aspect

Regression analysis with Generalized Linear Model (GLM) with Chi square test up to second order polynomial was also performed to find the relationship between the predictor variables and response variable (species richness) in the dataset of southern aspect. Response variable was modeled with all the predictor variables. From the analysis, altitude, canopy cover, potassium showed significant linear relationships with species richness (Table 5.). Ground cover and phosphorous content of the soil showed relationship in second order polynomial (Table 5.) Figure13 B indicates that plant species richness decreases with the increase in elevation and high richness is seen in the area with high canopy cover in this aspect.

**Table 5: Relationship between species richness and environmental variables of southern aspect obtained from GLM. Variables with significant relationship (p<0.05) are marked with asterisk.**

| Variables | Polynomial order | df | Residual df | Residual deviance | Deviance | P(>/Chi/) |
|---|---|---|---|---|---|---|
| alt | 1 | 1 | 19 | 21.925 | 7.306 | 0.006* |
| canop | 1 | 1 | 19 | 22.533 | 6.698 | 0.009* |
| cut | 1 | 1 | 19 | 28.360 | 0.870 | 0.358 |
| dead | 1 | 1 | 19 | 29.225 | 0.005 | 0.942 |
| fire | 1 | 1 | 19 | 26.161 | 30.693 | 0.079 |
| graz | 1 | 1 | 19 | 28.961 | 0.269 | 0.603 |
| gcov | 2 | 2 | 18 | 23.714 | 4.385 | 0.036* |
| rri | 1 | 1 | 19 | 29.186 | 0.049 | 0.824 |
| nit | 1 | 1 | 19 | 28.757 | 0.473 | 0.491 |
| omat | 1 | 1 | 19 | 28.654 | 0.576 | 0.447 |
| mcon | 1 | 1 | 19 | 28.073 | 1.157 | 0.282 |
| phos | 2 | 2 | 18 | 22.192 | 5.971 | 0.014* |
| ph | 1 | 1 | 19 | 28.694 | 0.536 | 0.463 |
| cond | 1 | 1 | 19 | 28.970 | 0.260 | 0.609 |
| pot | 1 | 1 | 19 | 25.066 | 4.164 | 0.041* |
| slop | 1 | 1 | 19 | 28.620 | 0.611 | 0.433 |

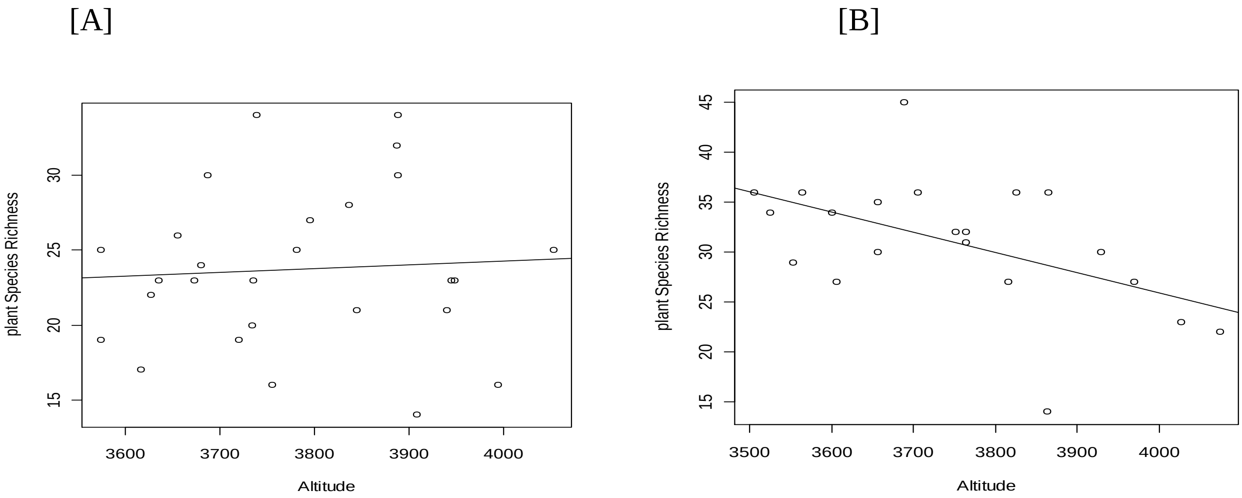


**Figure 13: Relationship between species richness and altitude in [A] north aspect and [B] south aspect.**

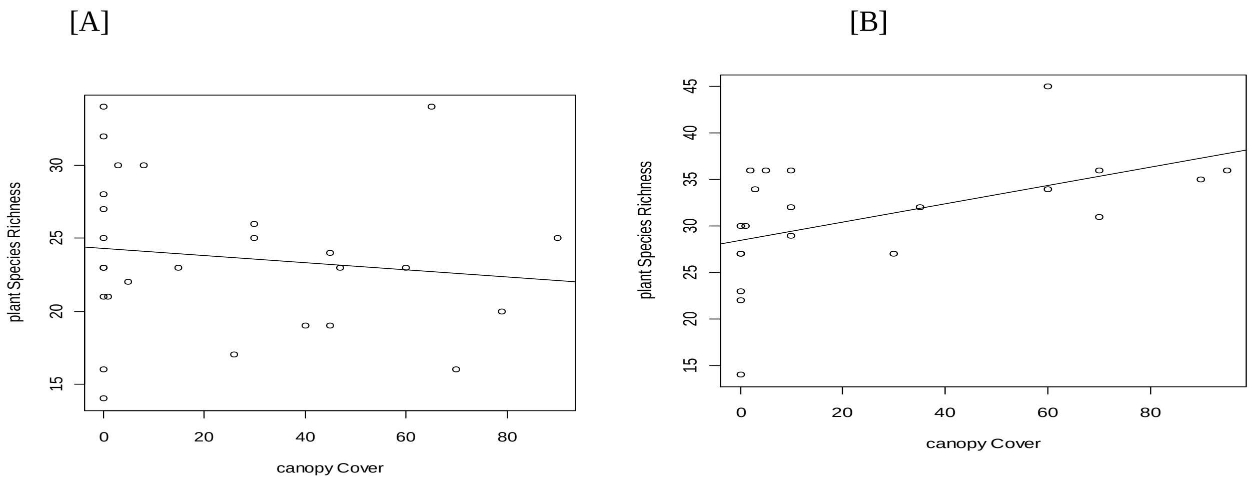


**Figure 14: Relationship between species richness and canopy cover in [A] north aspect and [B] south aspect.**

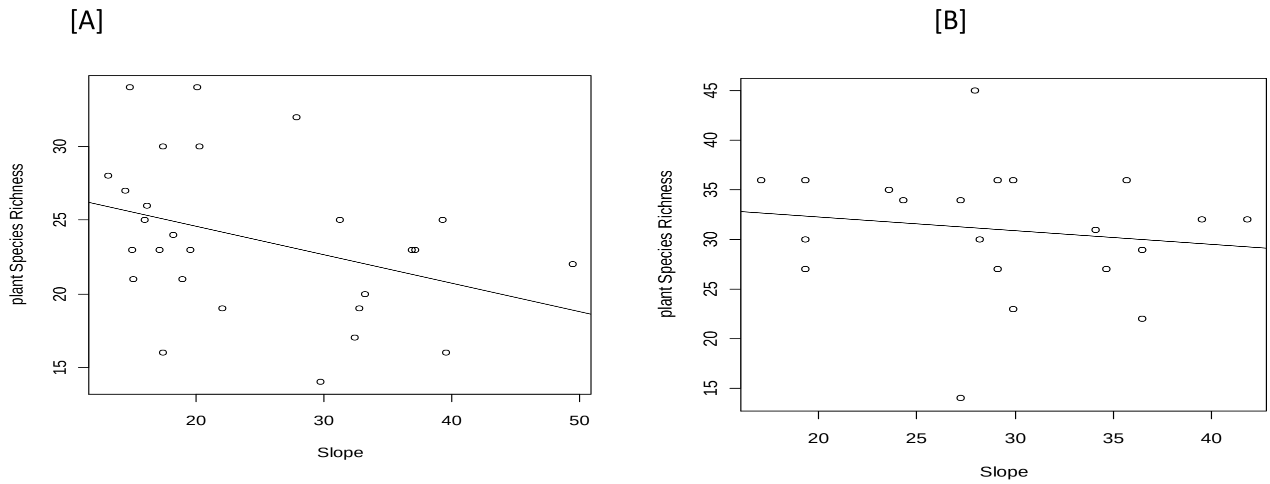


**Figure 15: Relationship between species richness and slope in [A] north aspect and [B] south aspect.**

## 4.5 Relationship between environmental variables and response variable

### 4.5.1 Relationship between response variable and altitude

There is slight increase in number of species with the increase in altitude in the northern aspect (Figure 13) which is also not significant as revealed by the regression analysis (Table 4) whereas there is pronounced decrease in the number of species with the increase in altitude in the southern aspect (Figure 13) which has significant role as revealed by the regression analysis.

### 4.5.2 Relationship between response variable and canopy cover

There is decrease in species richness with the increase in canopy cover (Figure 14) in the northern aspect which has no significant role as shown the regression analysis (Table 4), whereas there is increase in species richness with the increase in canopy cover in southern aspect (Figure 14) and has a significant value as revealed by regression analysis (Table 5).

### 4.5.3 Relationship between response variable and slope

There is decrease in species richness with the increase in slope in both the aspect (Figure 15) but is more significant in the northern aspect as revealed by the GLM regression analysis (Table 4).

## 4.6 Species Richness and Grazing

### 4.6.1 Northern Aspect

The mean number of species was slightly higher in the grazed plots than in not grazed plots in the northern aspect but this was not statistically significant ($t=-0.6045$ $df=25$ $p\text{-value}<0.555$, Fig16).

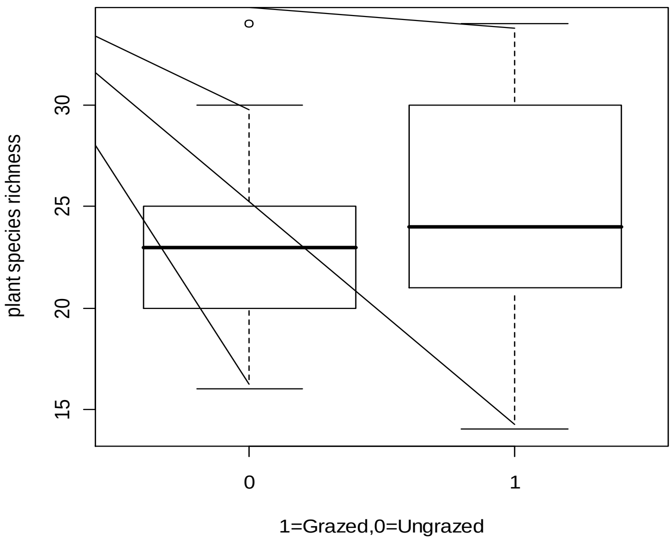


**Figure 16: Box plot showing difference in mean species richness between grazed and un-grazed landscape of northern aspect.**

### 4.6.2 Southern aspect

Mean species richness was found to be high in un-grazed plots than that of grazed plots. Here also, the difference was not significant (t=-0.4679 df =19 p-value<0.6465, Fig17).

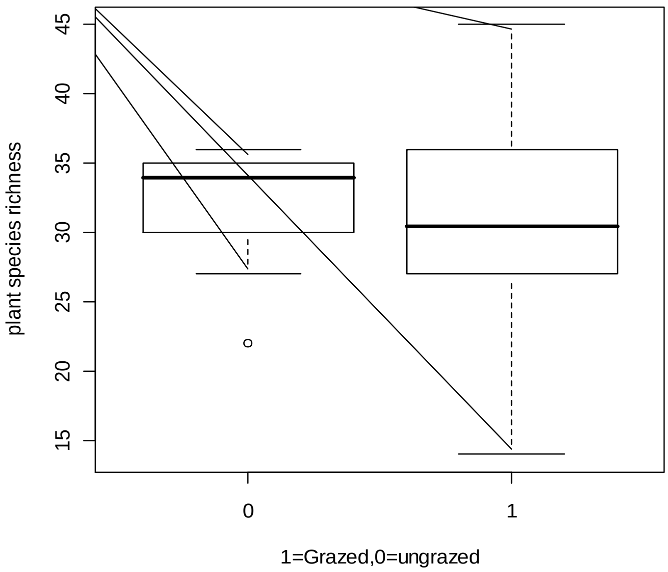


**Figure 17: Box plot showing difference in mean species richness between grazed and un-grazed landscape of southern aspect.**

## 4.7 Species Richness and Forest/Open Landscape

### 4.7.1 Northern aspect

Student's t-test indicates that there was no significant difference in the mean species richness between forest and non- forest plots in north aspect (t=0.6695 df =25 p-value<0.5106, Fig18).

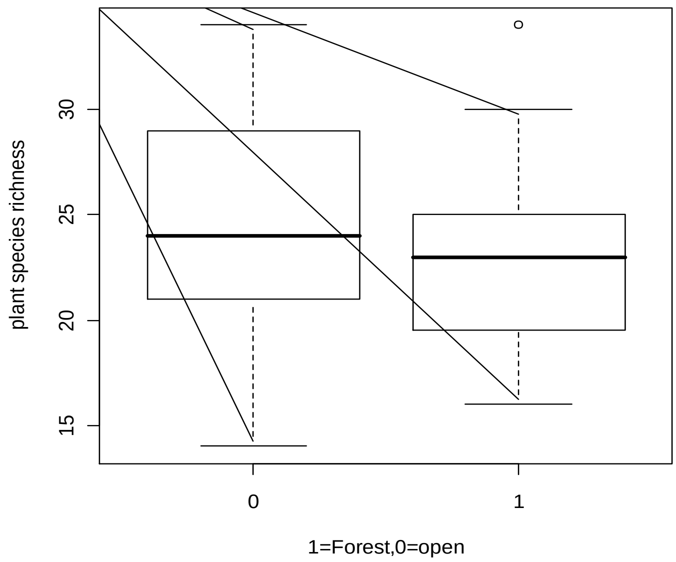


**Figure 18: Box plot showing difference in mean species richness between forest and open landscape of northern aspect.**

### 4.7.2 Southern aspect

Student's t-test indicated a significant difference in the mean species richness of forest and open alpine plots in south aspect (t=2.397 df =19 p<0.0291, Fig 19). Species richness was high in the forest plots than in non-forest plots (Table 2.).

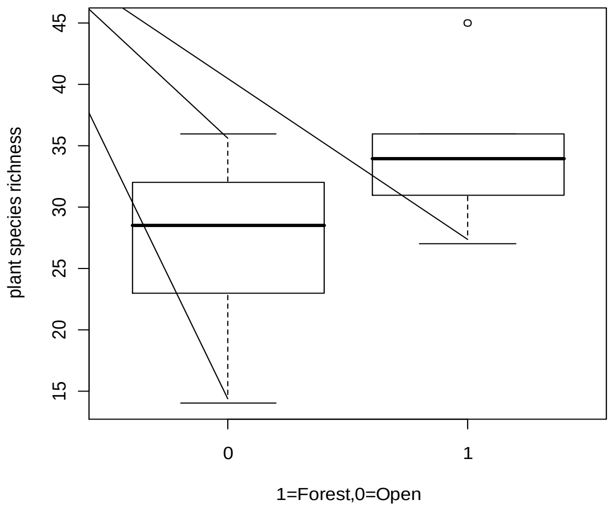


**Figure 19: Box plot showing difference in mean species richness between forest and open landscape of southern aspect.**

# Chapter-V

# Discussions

## 5.1 Species Richness in Relation to Elevation

The relationship of species richness with elevation was found to be different in two aspects. In the southern aspect, species richness was significantly decreased with the gradual increase in altitude where as in northern aspect there was slight increase in species richness with the increase in elevation, though the relation was not statistically significant (Fig13 A and B, Table 4 and 5 ).

The reduction in species in the higher altitude of southern aspect is attributed to the eco-physical constraints such as extremely low temperature, short growing period and geographical barriers. Colwell and Hurt (1994) reported the decrease in species number at higher altitude due to the loss of habitat diversity, environmental condition and lack of adaptability of species to sustain life in hostile climate. As well open alpine area of the study side in the southern aspect is also the periphery of pilgrimage site Gosaikunda. Large number of people makes their visits during the flowering seasons of the plants which may have huge disturbance resulting low species richness. The result thus obtained is also supported by other studies as Grytnes and Vetaas (2002) who had reported a sharp decrease in species richness above 4000m a.s.l in the Central Nepalese Himalaya.

In the northern aspect, there is slight increase in species richness with increase in elevation (Table2.) but the species were mainly concentrated at an altitude of 3800-3900 m a.s.l (Fig 13). The elevation of northern aspect of the study area ranged from 3574-4053 m a.s.l. There was an increase of species richness close above the forest limit, suggesting that the edge effect among the two border communities was less important in determining the species richness (Camarero et. al., 2006). The high richness above the forest line could also be enhanced by the mass effect (Grytnes 2003). Grytnes (2003) also suggested that the proximity of the forest provides a supply of seed that can be established in the open alpine landscape and increase α-diversity.

## 5.2 Species richness and Composition in Forest-Line Ecotone

The highest α-diversity (species richness) in the forested area than in non-forested area in the southern aspect and higher α-diversity in the non-forested area than in the forested area in the northern aspect of the study area is due to several climatic and non climatic factors. But, the higher β diversity was found in open alpine landscape than in forested landscape for both the aspects (Table 2). The higher α- diversity in the open alpine landscape in the northern aspect is linked with the radiation effect as light plays role of limiting factor. As there is low availability of sunlight in the northern aspect and it may reduced to extremely low level inside the forest of northern aspect reducing species richness as reported by Grace and Pugesek (1997) in their study. But in the southern aspect there is sufficient availability of sunlight due to which radiation does not acts as limiting factor thus enhancing species richness in forest cover than in the open alpine of the same aspect.

Altitude and cut stumps had significant effect in species composition of both the aspects. In addition to this, slope in the northern aspect was significant indicating its pronounced effect in the species composition in the northern aspect. The slope in turn may have influence on number of other factors including human disturbance like livestock grazing and collecting forest products (fuel wood, fodder etc.) which may have lead to change in richness and composition.

Almost similar type of species in the forested and open alpine landscape was obtained in both the aspects. This similar composition may be due the relative closeness of the studied aspects and almost the same range of altitude in small area. The altitude and other associated environmental variables may have greater influence than aspects in the species composition which is discussed in the subsequent sections below.

## 5.3 Species richness with respect to different environmental variables and disturbances indicator

### 5.3.1 Species Richness in Relation to Canopy Cover

In the northern aspect, increase in canopy cover resulted drop in vascular plant species richness (Fig 14 A) i.e. α-diversity was found high in the open landscape which show that radiation has important role for plant species richness in this aspect. Increased herb diversity above the forest line was observed by Grytnes and Birks (2003) in their study which is linked to the greater variation in diurnal temperature in the open alpine landscape than compared to the forest. Further more in forested area the depletion of blue light by canopy cover enriches the red and infar-red, so the forest floor receives photo synthetically less active light which tends to limit the variety and productivity of plants growing on the floor (Oke 1987). Study conducted by Grace and Pugesek (1997) supports this fact as shading effect of canopy leads the species to competitive exclusion resulting low species richness.

In the southern aspect, vascular plant species richness increased with the increase in canopy cover. Since, the southern aspect is exposed to sunlight for long duration, the shading effect of canopy cover and radiation cannot profoundly affect the species richness and ultimately other environmental factors get opportunities to play key role. Study reports the higher organic matter and total nitrogen under dense canopy due to the accumulation and decay of leaf litter and roots. Accumulation of nitrogen might be due to the increase in organic matter content of the soil (Hatton and Smart 1984). The accumulation of nitrogen beneath tree canopy may be due to less favorable condition of denitrification and $NH_3$ volatilization beneath the canopy (Barth and Klemmedson 1978). Hence, the soil under the dense canopy exhibits high fertility. Isichei et al (1992) stated that soil under the dense tree canopy may be one of the factors which consists higher organic matter and nitrogen content favoring higher species richness. Muoghalu and Awokunle (1994) also reported the similar results from the rain forest environment of Nigeria. Similar results have been reported from arid and semi arid environments also (Aggarwal et al 1976; Belsky et al 1989; Ebershon and Lucas 1965).

### 5.3.2 Species Richness in Relation to Slope

The significant effect of slope in species richness for the vertical transect of both aspect is related to solar radiation, moisture content, organic matter and other soil character. This showed that slope is more important for species richness in the northern aspect. The slope is relatively higher in the northern slope than in the southern slope and it has more strong effect in solar radiation in northern aspect than in the southern aspect. In the other hand, the very steep slope of the transect on both the aspect showed limited species richness which may be due to unfavorable environmental condition caused by high water runoff, unstable soil condition and rocky patches found on the steep slope of the study area.

### 5.3.3 Species Richness in Relation to Grazing

Studies have shown that livestock grazing increases (Rambo and Faeth 1999; Humphery and Patterson 2000; Pykälä 2004) as well as decreases (Mcintyre and Lavorel 1994; Landsberg et al 2003) plant diversity. Species richness was found to be higher in the grazed plots of northern aspect than in the un-grazed plots. Moderate grazing pressure and human intervention may be the root cause of high species richness in the grazed plots. Higher species diversity is maintained when there is intermediate level of disturbance (Robert and Gilliam 1995). Numerous authors have reported maximum species diversity under intermediate levels of grazing (Zeevalking and Fresco 1977; Milchunas et al 1998; Puerto et al 1990). Such disturbances create open micro-patches in the sub canopy vegetation of the forest allowing high species richness inside forest (Vetaas, 1992). The intermediate disturbance hypothesis (Grime, 1973;, Connel, 1978) predicts species richness at intermediate level of disturbance.

But in southern aspect, high species richness was prevailing in the un-grazed plots then in the grazed plots. This may be due to high human intervention and high rate of grazing by the livestock thus decreasing plant species richness. The result is also supported by the study made by Olff and Ritchie (1998) “Excessive mowing and livestock grazing appear to increase the extinctions of plant population”.

# CHAPTER – VI

# CONCLUSIONS

This study analyzed the species composition and richness in the forest-line ecotone of Langtang National Park, located in the Central Himalayan region. Vertical transect were laid down to check the changes of species composition and richness of vascular plants. Vascular plants species were recorded and their compositional patterns and richness patterns were tested in relation to different quantitative and qualitative environmental variables and disturbance indicator using different statistical (correlation, regression, t-test and ordination) techniques. The result from the forward selection of CCA ordination revealed that altitude, canopy cover, slope and some soil parameters were the main influencing factors for the vegetation of the study area.

The study concludes as follows:

- There is significant decrease in species richness with the increase in altitude in the southern aspect and slight increase in species richness with the increase in altitude in the northern aspect.
- The open landscape of northern aspect was found to have higher species richness than that of the forest landscape whereas, forest landscape of southern aspect was found to have higher species richness than that of open landscape.
- Species turnover (β-diversity) was found to be higher in open landscape of both the aspect.
- Altitude, canopy cover and human disturbance are important variables in determining vegetation composition in both the aspect. Slope has more pronounced effect in the northern aspect than that of southern aspect

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