Variation in Plant Functional Traits along altitudinal gradient and land-use types in Sagarmatha National Park and Buffer zone

A Dissertation submitted for the
partial fulfillment of the requirements
for the Masters of Science in Botany

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CERTIFICATE

This is to certify that the M. Sc. dissertation work entitled "**Variation in plant functional traits along altitudinal gradient and land-use types in Sagarmatha National Park and Buffer zone**" has been carried out by Ms. Srijana Shah under our supervision. The entire work is based on the fieldwork and laboratory research, and the results have not yet been published or submitted for any other degree. We recommended this dissertation work to be accepted as a partial fulfilment for Master's Degree in Botany (Plant Systematics and Biodiversity Unit).

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LETTER OF APPROVAL

The dissertation work submitted by Srijana Shah entitled "**Variation in plant functional traits along altitudinal gradient and land-use types in Sagarmatha National Park and Buffer zone**" has been accepted as a partial fulfillment of the requirements for Masters of Science in Botany (Plant Systematics and Biodiversity Unit).

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ABSTRACT

Plant traits are the charactersistics of a plant species which act as useful predictors of the response to the environmental stimuli. They represent specific functional adaptations to various environmental stresses. This study deals with the variation in plant functional traits along elevation gradient and land-use types in Sagarmatha National Park and Buffer Zone, Solukhumbu district, Nepal. Two field investigations at different seasons (April and September) were made for collecting samples. A relatively large samples was used (involving 60 genera, belonging to 31 families). The land-use types selected included disturbed (cultivated land, exploited forest, and meadow) and less disturbed (natural forest) categories. Altogether, 11 different traits of plants, which included life form, growth form, plant height, clonality, spinescence, leaf dry matter content, stem specific density, bark thickness, twig dry matter content, twig drying time, and specific root length were examined. The selected dominant species have been divided into three different categories of growth form (herb, shrub and tree). It was found that plants adapt in various ways to deal with the changing environmental conditions for which they shows different traits. The application of plant functional traits is very useful to understand vegetation-environment relationships. Statistical analyses showed significant differences between traits along both the elevation gradient and land-use types. In the disturbed land-use categories, we found high variation in a particular trait. Correlation analyses revealed that most of the traits were interrelated. Herbs and shrubs were found to be dominant in the higher elevation and in disturbed land-use categories. Species recorded at high altitude were mostly short basal herbs, while spinesescense and tall trees were observed at the lower altitude. Species recorded in meadows and exploited forests showed high variation in traits due to disturbance mainly grazing, fire, trampling, litter collection, etc. Altitudinal variation, climatic condition and disturbance most strongly influence trait expressions of the study site. Plants show these traits for their defense against the adverse conditions.

Keywords: functional traits, altitudinal gradient, land-use types, disturbances.

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ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of variance
asl	Above sea level
cm	Centimeter
°C	Degree celsius
DNPWC	Department of National Parks and Wildlife Conservation
g	Gram
GIS	Geographic information system
GPS	Global positioning system
GoN	Government of Nepal
KATH	National Herbarium and Plant Laboratories
LDMC	Leaf dry matter content
m	Meter
mg	Milligram
mm	Millimeter
NTFPs	Non timber forest products
PFTs	Plant functional traits
SNP	Sagarmatha National Park
SNPBZ	Sagarmatha National Park and Buffer Zone
SPSS	Statistical package for social science
sq. kms	Square kilometers
SSD	Stem specific density
SRL	Specific root length
TDMC	Twig dry matter content
TDT	Twig drying time
TUCH	Tribhuvan University Central Herbarium
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNEP	United Nations Environment Programme
VDC	Village Development Committee

CHAPTER 1: INTRODUCTION

1.1 Background

Darwin (1859) used the term 'trait' as the predictor of organismal performance. A trait is a distinct characteristic, phenotype, or a quantitative property that influences the performance of an organism. It is usually measured at the individual level and used comparatively across species (McGill *et al*. 2006; Minden 2010). Functional traits are those properties of an organism or a part of an organism which strongly influences fitness through their effects on growth, reproduction and survival (Minden 2010). They are biological attributes of a species that respond to the environmental conditions or processes in an ecosystem (Gitay *et al*. 1997; Lavorel *et al*. 1997). Plants compete for different resources (e.g; nutrients, space, light, moisture). Only those survive, reproduce and increase in number which is best suited at that particular environmental condition (Morris *et al*. 2005).

The importance of functional traits and architectures of plant can be discussed under two different ways. Firstly, they control ecosystem processes and define habitat and resources for other taxa. Secondly, knowledge of trait gives the clear understanding of how vegetation properties change along physio-geographical gradients (Westoby & Wright 2006). Plant ecophysiological traits is clearly linked with biotic interactions involving plants, and ecosystem level properties and processes (Wardle *et al*. 1998). The presence, abundance and diversity of functional traits including morphological, ecophysiological and life history characteristics could be used for estimating particular components of biodiversity and together form a term called 'functional indicators of biodiversity' (de Bello *et al*. 2010).

The floristic complexity of vegetation can be reduced by using plant functional classification (Lavorel *et al*. 2007). This classification helps us to know about the mechanisms that structure the patterns of diversity (Marquet *et al*. 2004), to investigate response of vegetation to environmental gradients and disturbance (Diaz *et al*. 1999; Wana & Beierkuhnlein 2009), and to relate attributes of species to ecosystem properties (Diaz & Cabido 1997). Several methods based on plant traits can be used to characterize functional composition of the vegetation (Ansquer *et al*. 2009). Many questions can be solved effectively beginning with a thorough understanding of how and why key "functional" traits are related, and how these traits affect ecological outcomes such as where a species grows best and where

it is most competitive (Wright *et al*. 2006). Single trait cannot be the only basis for predicting vegetation changes. Hence, a functional analysis between key traits is necessary (Klimesova *et al*. 2008).

Plant traits are expressed in response to the influence of biotic and abiotic factors (Minden 2010). Identifying species differences in functional traits and understanding how these inter-specific differences mediate community response to changes in the environment is very essential (McEnery 2007). At a local scale, plant functional traits are used to predict species responses to grazing, for conservation purposes, and for identifying species vulnerable to land-use changes (de Bello *et al*. 2005). Apart from all these, functional trait also improves our understanding of succession processes and provides the basis for knowing the mechanisms involved (Kahmen & Poschlod 2004). In the past two decades Plant functional traits (PFTs) approach were applied to model the consequence of global environmental change on the vegetation dynamics (Condit *et al*. 1996; Leemans 1997) and to relate plant functional traits to ecosystem functions (Diaz & Cabido 1997; Lavorel *et al*. 2007). PFT is very useful in predicting changes in vegetation and biodiversity as an effect of environmental and disturbance changes, land-use shifts at regional and global scales (Pausas *et al*. 2003).

Diversity is not the same everywhere. Similarly, functional diversity also varies across the globe. Plant distribution pattern is based on the geographic and climatic conditions of a particular place (Cornwell 2006). Plant traits and the environment linkage (i.e. sets of plant attributes consistently associated with certain environmental conditions) are the consequence of the environmental filters of which the major ones are climatic, disturbance and biotic conditions (Diaz *et al*. 1998). These environmental filters can affect diversity of traits, ecosystem structure, and therefore ecosystem function, sometimes without causing considerable changes in species richness and composition. To detect these changes using approaches based on floristic information only may not be enough. This can be more easily detected by functional trait analysis (Diaz *et al*. 1999). For knowing community shifts along environmental gradients, PFTs provide a widely applicable framework (Cornelissen *et al*. 2003; Lavorel *et al*. 2007).

Several researches based on the topic of plant functional traits have been carried out in different parts of the world. Rawal and Pangtey (1994) published a paper on distribution and structural-functional attributes of trees in the high altitude zone of Central Himalaya, India. Similarly, Klimes (2003) published a paper on lifeforms and clonality of vascular plants along an altitudinal gradient in E. Ladakh (NW Himalayas). In Southwest Germany, Kahmen (2004) reported the plant trait responses to

grassland management and succession. Li (2008) has investigated the relationship between functional traits, and discussed how these relationships are influenced by leaf fall pattern (evergreen/deciduous), growth forms (tree/shrub) and other explanatory variables in subtropical forest in Dujiangyan, Sichuan, southwest of China. Similarly, Castro (2008) in the region of Alentejo, Southern Portugal worked on effects of land use change on plant composition and ecosystem functioning in an extensive agro-pastoral system. Dalacho (2009) presented a dissertation on plant species and functional diversity along altitudinal gradients of southwest Ethiopian highlands.

1.1.1 Species traits and Elevation gradient

According to Marquet *et al*. (2004), a proper understanding of the mechanisms that structure the pattern along spatial gradients (e.g. elevation) requires diversity measures to be divided into different components. They commented that functional attributes that include physiological, life history and ecological traits are directly related to the aspect of the physical environment. Variation in elevation results change in climatic factors as well as land area surface. Temperature, air pressure,and solar radiation are the climatic factors that vary with elevation which can all have an influence on the distribution of species (Becker *et al*. 2007).

Elevation, slope inclination and aspect exposition are the topographic factors that play an important role in determining the abundance of PFTs. Elevation is not a single variable but is a complex combination of related climatic variables closely correlated with numerous other environmental properties which includes soil texture, nutrients, substrate stability, etc. (Klimes 2003). Some studies that have been conducted on trait variations in a species along an elevation gradient include those of Morecroft and Woodward (1996), Suzuki (1998), Hultine (2000) and many more authors.

1.1.2 Species traits and land-use types

One of the most important drivers of global biodiversity loss is land use change (Sala *et al*. 2000). Land use and management actions on plant communities induce responses and changes in the community (Diaz *et al*. 2001). Land-use changes includes modified and fragmented habitats, which are more vulnerable to invasive species and plays an important role in shaping and maintaining ecosystem structures and functions. According to Foley *et al*. (2005), land-use changes involve two main impacts

on the biosphere: first, the conversion (i.e. natural habitats altered for human use) and second, intensification (e.g. greater intensity and frequency of disturbance, increased use of external inputs). Predicting the effects of land-use changes on plant community composition is a major challenge. Using data on plant traits, patterns of species response to land-use change can be identified (Foster *et al*. 2003). Habitat loss and fragmentation are the major factors which cause biodiversity loss by decreasing suitable habitats of species and thereby forcing the species to extinction (Thomas *et al*. 2004). The threats to biodiversity loss due to land use or land cover change and global warming is still increasing. Land conversion for agricultural purposes, population growth, socio-economic conditions drive land cover changes.

1.2 Rationale

The PFT framework can provide a link between vegetation responses to environmental change and the effects of these changes on ecosystem properties and function (Grime 2001; Lavorel & Garnier 2002). Many studies have been done related to PFT in other countries. Plant functional trait is a new topic for research in Nepal from which we can get a lot of information related to the vegetation patterns of the study area. This study would provide us with detailed informations about the traits of the dominant plants and elucidates the relationship between plant functional traits, altitude and land-use types.

Plant taxonomy work is also based on floral traits. Botanists have a long-standing interest in flower and fruit traits because most herbarium specimens include flowers or fruits. PFT also help to handle taxonomic diversity, as it groups together species that share common attributes such as life-form, phenology and bioclimatic limits. Hence, studies related to this topic are very necessary to be done. Hooper *et al*. (2002), argued that species richness lacks the explicit power to explain ecosystem level processes, stressing that the functional attributes of species may constitute a better approach to relating global environmental change and inherent ecosystem processes than taxonomic richness.

1.3 Objectives

The broad objective of this research is to study the variation in plant functional traits along the different land-use types and altitudinal gradient in Sagarmatha National Park and Buffer Zone.

The specific objectives are:

- to know the major traits are shown by the dominant plant species present in the study area,
- to assess variation in the traits of dominant species among major land use types, and
- to identify the plant species are best suited for specific altitude and land-use type.

1.4 Limitation of the study

We studied as many traits as possible for the analyses in order to get a better picture of the vegetation difference along different gradients. However, analyzing all the feasible traits is time-consuming and worthless as many traits are not very informative. Hence, only 11 functional traits were selected for the study. Not all of the traits were present in the selected plant species. For example, Specific root length was examined only for the herbaceous species and not for the tree and shrubs. Also due to lack of equipments many possible traits could not be examined. The study was restricted to an elevation range from 2200-3800m. Due to several reasons the plants collected could not be kept safe for long time period in order to do laboratory analysis.

CHAPTER 2: STUDY AREA

2.1 Location and Physiography

Sagarmatha National Park (SNP) is located in the north-eastern part of Nepal in Solukhumbu district. It was established in 19th July, 1976 and was declared as 120th UNESCO World Heritage Site in 1979. The park includes several well-known high peaks of the Himalayas- the most incredible being the Sagarmatha (Mt. Everest), the world's highest peak, gaining an altitude of 8,848m.

SNP covers an area of 1,148 sq.km. The park is located between 27°46'19" to 27°06'45" N latitudes and 86°30'53" to 86°99'08" E longitudes. It covers two VDCs i.e. Namche and Khumjung. The landscape is mainly transversed by three tributaries of the Saptakoshi River Systems, namely Imja Khola, Dudh Koshi and Bhote Koshi. The buffer zone was declared in Jan 1, 2002, and covers an area of 275 sq. km (UNEP 2008). This study has been carried out starting from Surkey (2200m) upto Khumjung (3800m).

2.2 Flora and Fauna

The most dominant vegetation in this protected area is alpine meadow and scrub. Major vegetation zones represented in the park includes: lower subalpine (3000 -3500m), with forests of *Pinus wallichiana*, *Abies spectabilis* and *Juniperus recurva*; upper subalpine (3500-3800m), with birch-rhododendron forest (*Betula utilis*, *Rhododendron campanulatum* and *R. campylocarpum*); lower alpine (above the timber-line at 3800-4000 m), with scrub like *Juniperus recurva*, *Rhododendron anthopogon* and *R. lepidotum*; upper alpine (above 4500-5500m), with grassland and dwarf shrubs; and sub-nival zone with cushion plants from 5500 m to 6000 m. The upper montane zone has been covered by *Pinus wallichiana, Rhododendron arboreum*, *R. triflorum*, and *Taxus wallichiana* are associated with pine at lower altitudes and shrubs include *Pieris formosa*, *Cotoneaster microphyllus* and *Rhododendron lepidotum*. Above 6000m, plant life is restricted to lichens, mosses, dwarf grasses and sedges (UNEP 2008).

The park has 28 mammalian species, 152 species of birds , 6 amphibians and 7 reptiles. Major wildlife includes Musk deer, Snow Leopard, Himalayan Tahr, Red Panda, Himalayan Black Bear, Jackal,

Common Langur and the Himalayan Mousehare. The most common birds are the Impeyan Pheasant (Danphe), Redbilled Cough, Blood pheasant and Yellow-billed Cough (UNEP 2008).

2.3 People, livelihood and Land-use pattern

There are about 6,000 people living inside Sagarmatha National Park and Buffer Zone (SNPBZ). Khumbu is home to Sherpa people. They constitute around 90% of the resident population and the remaining are from other ethnic groups who migrated more recently in search of economic opportunities. No household in Khumbu is able to subsist entirely on farming. The potato is the major cultivated crop at higher altitude while, at lower altitude buckwheat, barley, maize, millet, turnips and other seasonal vegetables are grown. SNP is an famous tourist destination. Tourism here is the major source of income for the local people who are operating lodges and hotels, guiding, climbing, portering, and selling agricultural products. The main livestock are yak and nak which are adapted to high altitude. The constantly increasing numbers of tourists visiting was 3,600 visitors in 1979 to over 25000 in 2010, which has increased the local economy and standard of living with better health, education, and infrastructure facilities (UNEP 2008).

Land-cover classes in Sagarmatha National Park (Humagain 2012)

Land Cover	Definition
Agriculture/Houses	Cultivated areas, built up areas, settlements
Broad Leaf	Broadleaf forest closed to open (100-40)% trees
Mixed Forest	Multi-layered mixed trees
Needle Forest	Needle-leaved closed to open (100-40)% trees
Rock/Soil	Bare Soil, gravels, stones and boulders, rock with few plants
Shrub Grass	Closed to open shrubland (thicket), meadows, grasses
Glacial Lake	Natural water bodies (standing) formed from the glacier
Snow/Glacier	Snow, moving ice

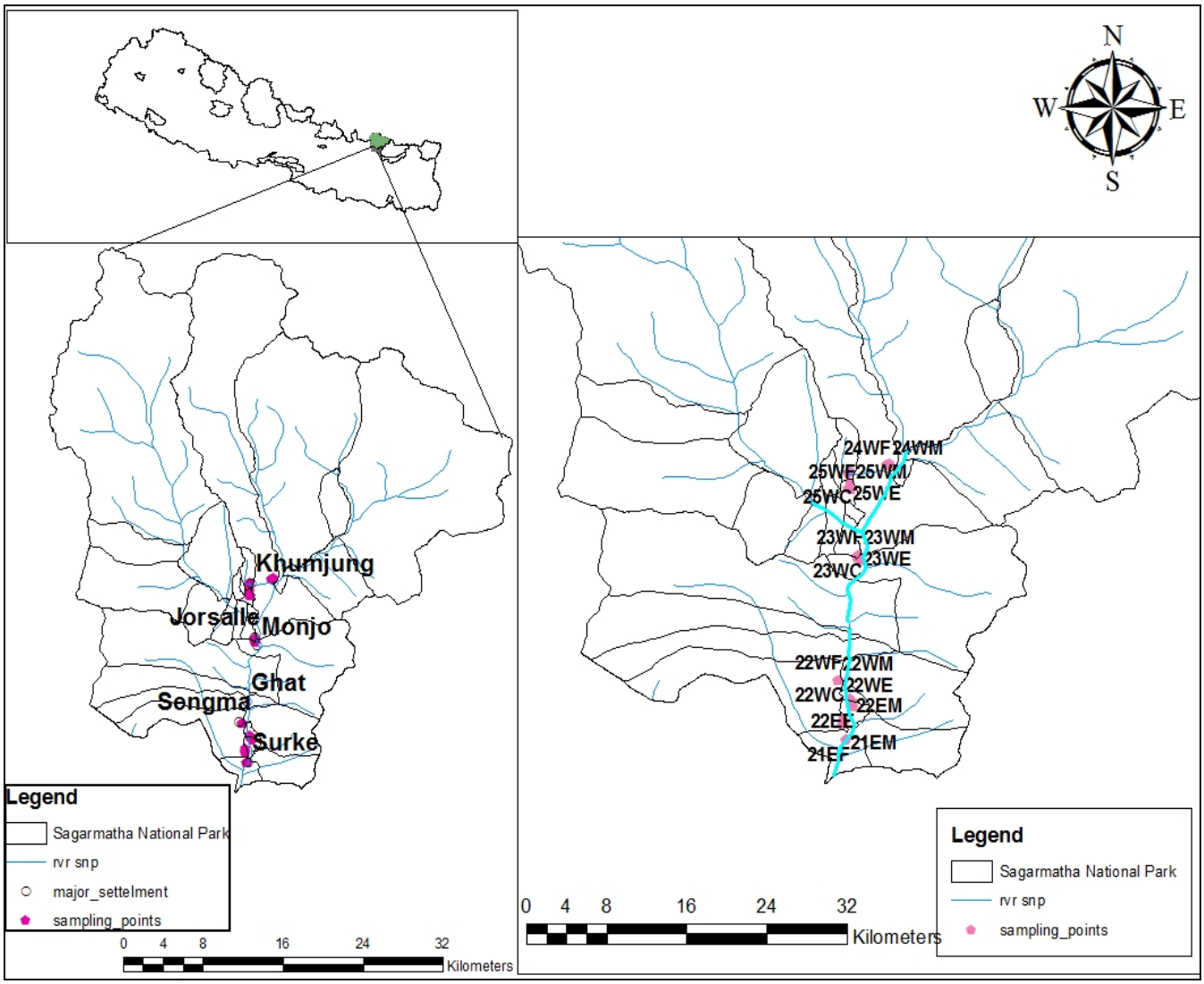


Figure 1: Map of the study site

2.4 Climate

The annual precipitation occurs in the monsoon season from June to September, maximum precipation in the july and the remainder of the year is fairly dry (Fig 2). Precipitation is low as the park is in the rain shadow of the Karyalung-Kangtega range to the south. Annual precipitation is 984mm in Namche Bazar, 733 mm in Khumjung and 1043mm in Tengboche. The climate of Namche Bazar can be classified as humid and tropical, based on the seasonal occurrence of rains, range in annual precipitation, number of rainy days per year and the length of the dry season (UNEP, 2008). The mean

temperature of the coldest month, February, is -0.11°C. Mainly during July to August, the average annual rainfall is approximately 100mm (Fig 2).

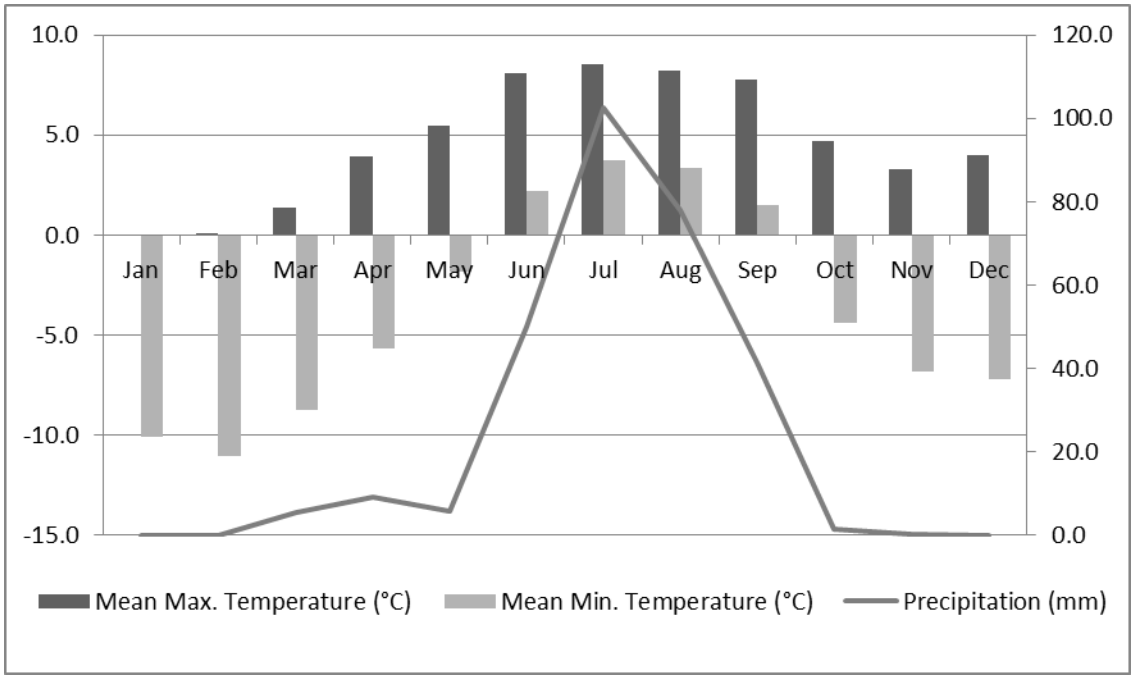


Figure 2: Seasonal maximum and minimum temperature and precipitation pattern of Dingboche. Five years (2006 to 2010) data are averaged for each month. (*Source*: Department of Hydrology and Meterology, GoN).

CHAPTER 3: MATERIALS AND METHODS

3.1 Study design

Sampling was done from 2200-3800m asl varying approximately 400 m. Two different aspects (east facing and west facing) of each valley was chosen for the study purpose. In each aspect four land-use types (cultivated, exploited forest, meadow and natural forest) were selected. A transect of 25m long and 2.5m wide was laid (Scheidegger, Nobis & Shrestha 2010).

11 plant functional traits were examined for 60 plant species belonging to thirty one families, collected from 40 sampled plots. Each of these traits are associated with particular functions among plant that determine the growth and distribution. These traits also help us to understand where a species grow best and where it is most competitive, along with its influence on the ecosystem.

3.2 Collection and identification of plant specimens

Plants were collected from 40 sample plots. The collected specimens were properly tagged during collection with appropriate field notes and vegetative trait was noted on the data-sheet. Five replicates of each species were collected from each plot for further laboratory analysis. Ten individuals were measured for the height. The collected specimens were then kept in zipper bags and then in defreeze until all the analysis was completed. Each specimen was also dried and mounted on the herbarium sheet for identification. The identification was done by comparing herbarium specimens deposited at TUCH as well as from relevant literatures such as: Polunin and Stainton (1984); Stainton (1988); Press *et al.* (2000); Zheng-Yi and Raven (1996-2003) and online source (www.efloras.org). The voucher specimens are deposited at TUCH.

3.3 Land–use Types

Land-use types were classified according to cropping systems, disturbance frequency and intensity. Each land-use category included four different types (Scheidegger, Nobis & Shrestha 2010) described as below:

- **Natural forests:** Area with either pristine character or with a low anthropogenic influence that include low levels of tree harvest that does not alter the forest stand structure and tree species composition. Normally forest stand far from human settlements are reported to have this kind of forest.

- **Exploited forests:** Area with a relatively closed canopy but with an altered stand structure and tree species composition compared to natural forests, either because of intensive exploitation for agriculture, livestock, and collection of fodder and fuel woods or plantation after intensive domestic or commercial forest management.

- **Meadows:** An open grasslands with less than 20% tree coverage. Domestic livestock graze or browse the vegetation, which have seen a great impact on resources.

- **Cultivated lands:** Intensively managed, fertilized, sometimes irrigated and yearly ploughed areas. On slope fields are often terraced and soil erosion is the main problem. Mainly crops, vegetables and some important medicinal or NTFPs can be found to be cultivated in these lands.

3.4 Laboratory techniques

For laboratory techniques the protocols for standardized and easy measurement of plant functional traits worldwide (Cornelissen *et al*. 2003) was followed. Functional traits were either directly measured in the forest, at the research station in the evening after collecting, in the laboratory or deduced later from measured traits.

3.5 Selection of plants

3.5.1 Selection of species in a community or ecosystem

The most abundant species present in high number were chosen by counting the individuals. In forest and other predominantly woody vegetation, the most abundant species of the lower (shrub or herb) vegetation were also selected, even if their biomass was much lower than that of the woody species.

3.5.2 Selection of individuals within a species

Well grown plants, preferably of unshaded condition were chosen. Plants strongly affected by herbivores or pathogens were ignored. Fresh and dry weight of the plants were measured by using weighing machine.

3.5.3 Plant traits measurement

3.5.3.1 Vegetative traits

Growth form

Growth form is mainly determined by canopy height, which may be associated with plant strategy, climatic factors and land use. It is a categorical trait assessed through field observation and consulting literatures and floras. Species were assigned according to one of the following growth form categories:

(1) Short basal	leaves <0.5m long concentrated very close to the soil surface.
(2) Long basal	leaves >0.5m long emerging from the soil surface.
(3) Semi basal	significant leaf area deployed both close to the soil surface and higher up the plant.
(4) Erect leafy	plant erect, leaves concentrated in middle and/or top parts.
(5) Cushions	tightly packed foliage held close to soil surface, with relatively even and rounded canopy boundary.
(6) Tussocks	many leaves from basal meristem forming prominent tufts.
(7) Dwarf shrubs	woody plants upto 0.8m tall.
(8) Shrubs	woody plants taller than 0.8m with main canopy deployed relatively close to the soil surface on one or more relatively short trunks.
(9) Trees	woody plant with main canopy elevated on a substantial trunk.
(10) Palmoids	plants with a rosette of leaves at the top of a stem.
(11) Climbers and scramblers	plants that root in the soil and use external support for growth and leaf positioning.

Life form

It is also a categorical trait assessed through field observation and consulting literatures. Five major life forms were recognized by Raunkiaer (1934). The following are the categories for life form classification:

(1) Phanerophytes	plants that grow taller than 0.50m and whose shoots do not die back periodically to that height limit.
(2) Chamaephytes	plants whose mature branch or shoot system remains below 0.50m, or Plants that grow taller than 0.50m, but whose shoots die back periodically to that height limit.
(3) Hemicryptophytes	periodic shoot reduction to a remnant shoot system, so that buds in the harsh season are close to the ground surface.
(4) Geophytes	annual reduction of the complete shoot system to storage organs below the soil surface.
(5) Therophytes	plants whose shoot and root system dies after seed production and which complete their whole life cycle within 1 year.

Plant height

It is the shortest distance between the upper boundary of the main photosynthetic tissues on a plant and the ground level, in meters. For herbaceous plants the height was measured using the measuring tape. For tree height clinometer was used to measure the angle and the following formula (Zobel *et al*. 1987) was applied.

$$h_1 = b\tan\Theta$$

$$H = h_1 + h_2$$

Where,

b= the distance between tree base to the observer in meter.

Θ= the angle between the horizontal plane and the tree top.

H= total height of the tree in meter.

h_1=height above the eye of the observer in meter.

h_2= eye height of the observer in meter.

Clonality

It is the ability of a plant to reproduce itself vegetatively, thereby producing new ramets (underground units) and expanding horizontally. This was confirmed from various literatures. Species were assigned in one of the following three categories:

(1) Non-clonal	plants which do not develop clonal parts.
(2) Clonal aboveground	plants forming stolons, adventitious buds on leaves (i.e. gemmiparous) and forming other vegetative buds or plant fragments that can disperse and produce new plants.
(3) Clonal belowground	plants forming rhizomes, tubers, bulbs and other adventitious root buds on the main root or lateral roots.

Spinescence

A spine is usually a pointed modified leaf, leaf part or stipule. The type, size and density of spines, thorns and/ or prickles play an obvious role in anti- herbivore defense. This trait is assessed through the selection of one of the following category.

(0) No spines, thorns or prickles.
(1) Low or very local density of soft spine equivalents <5mm.
(2) High density of soft spine or low density of hard, sharp spine equivalents >5mm.
(3) Intermediate or high density of hard, sharp spine equivalents >5mm.
(4) Intermediate or high density of hard, sharp spine equivalents >20mm.
(5) Intermediate or high density of hard, sharp spine equivalents >100mm.

3.5.3.2 Leaf traits

Leaf dry matter content (LDMC)

Fresh weight of each leaf was taken and tagged. After that it was dried in an oven at 60°C for 72 hrs and reweighted for dry mass. LDMC is an estimator for plant tissue density (Wilson *et al*. 1999). Leaves with high LDMC tend to be relatively tough and are thus assumed to be more resistant to physical hazards than leaves with low LDMC. It was calculated by using the following formula:

$$LDMC = \frac{\text{Oven dry wt. of leaf (mg)}}{\text{Fresh wt. (gm)}}$$

3.5.3.3 Stem traits

Stem specific density (SSD)

Oven dry mass of a section of a plant's main stem was taken drying the stem at 60°C for 72 hrs. For herbaceous species or woody species with thin main stems (diameter <6cm), 10cm long section at about one-third of the stem height or length was cut. For calculating the volume of very thin stem the following formula was used,

$$V = (0.5D)^2 \times \pi \times L$$

Where,

V= volume of the fresh stem

D= diameter of the stem

L= length of the stem

$$SSD = \frac{\text{Oven dry mass of the stem (mg)}}{\text{Volume of the stem when fresh } (mm^3)}$$

Twig dry matter content (TDMC)

1-3 terminal twigs of 20cm long from five individuals of dominant trees and shrubs were collected. Fresh mass of the twig was taken and then dried in the oven at 40°C. In every 24 hr each sample was reweighed. Twigs with high dry matter content are expected to dry-out relatively quickly during the dry season in fire-prone regions. Low TDMC may be positively correlated with high potential relative growth rate (Cornellisen *et al.* 2003).

$$TDMC = \frac{\text{Oven-dry mass (mg) of a terminal twig}}{\text{Fresh mass (gm)}}$$

Twig drying time

It is defined as the number of days a twig takes to to dry out completely. In each 24 hours dry mass of twig was measured to see the decrease in weight unless there was no further decrease. It was calculated along with the Twig dry matter content for tree and shrubs.

Bark thickness

Bark is the part of the stem that is external to the wood or xylem. The thickness of the bark was measured in mm. For each tree species, five random measurements of bark thickness are made with Vernier Caliper. Thick bark has shown to insulate meristems and bud primordial from lethally high temperatures associated with fire. It also provides protection of vital tissues against attack by pathogens, herbivores, frost or drought.

3.5.3.4 Belowground traits

Specific root length (SRL)

It describes the amount of harvesting or absorptive tissue deployed per unit mass invested. Plants with high SRL are able to build longer roots for a given dry mass investment and this is achieved by constructing roots of thin diameter or low tissue density.

$$SRL = \frac{\text{root length (m)}}{\text{Dry mass (gm)}}$$

3.6 Statistical Analyses

For analyses of quantitative traits, the overall data was divided into three growth forms (i.e. herb / shrub / tree). Each trait was then tested to find significant difference with land-use types and altitude for three growth forms. This was done to observe more detailed variation in traits of different growth forms.

After a normality test (Shapiro Wilk), traits such as plant height, LDMC and SSD of herbs and shrubs were square root transformed to meet the normality assumption while the remaining data was considered normal and left untransformed.

Analysis of Variance (ANOVA): One-way ANOVA was used to find the variability across means of quantitative traits with land-use types and altitude. Post hoc analysis (Tukey's HSD test) at 5% level of significance was carried out within the results of ANOVA to find more pair wise significant difference of traits with environmental variables. ANOVA was also used to find the altitude wise variation in quantitative traits along different land-use types.

Correlation: Spearman's correlation was done to test the relationship among functional traits in overall altitude. It was also used to explore the relationship among functional traits for each five altitude.

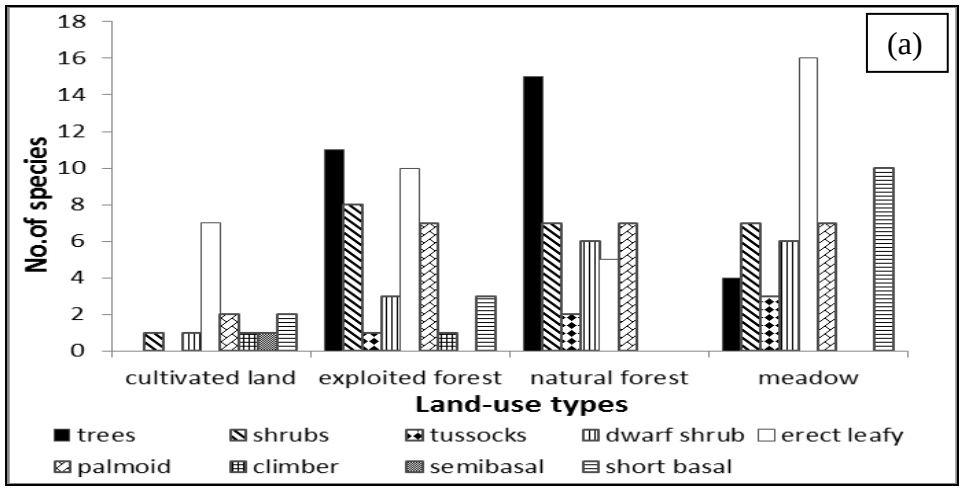
Software used: ANOVA was performed using statistical computer program R version 2.12.1. Correlations was done in SPSS Statistics 17.0. Arc GIS was used to prepare the map of study site.

CHAPTER 4: RESULTS

Sixty most dominant species under thirty one families including five gymnosperms were selected in the 40 sampled plots of which twenty eight species were also observed in other altitudinal as well as land- use gradients (for e.g; *Rhododendron arboreum*, *Artemesia vulgaris*, *Pinus wallichiana*, *Rhododendron lepidotum*, *Senecio diversifolia*). Hence, categorical traits were determined for the repeated species also. The plant communities examined in the present study were composed of trees, shrubs, dwarf shrubs and herbs. The number of the investigated dominant species ranged from 2-3 per transect.

4.1 Growth form along land-use type and altitude

Nine different types of growth forms were recorded from the study site. The plant species collected (both dicots and monocots) include 12 trees, 19 shrubs, 28 herbs and 1 climber. The herbaceous plants included 5 short basal, 1 long basal, 1 semibasal, 13 erect leafy, 3 tussocks and 5 palmoid. The most abundant form was the herbaceous erect leafy followed by trees and shrubs. Tree was dominant in natural forest whereas herbs were found to be less dominant. Short basal and erect leafy herbs were found to be dominant on meadow in comparison to other growth forms. Number of shrubs was higher in the exploited forest in comparison to other land-use types (Fig 3.a). Along the altitudinal gradient, trees and erect leafy herbs decreased in number in comparison to other growth forms. Dwarf shrub and tussocks were dominant at 3400m (Fig 3.b).



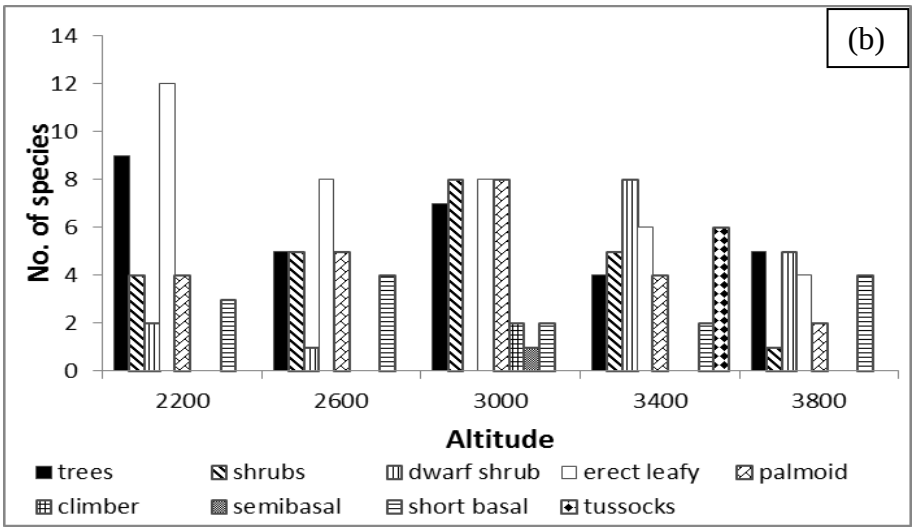
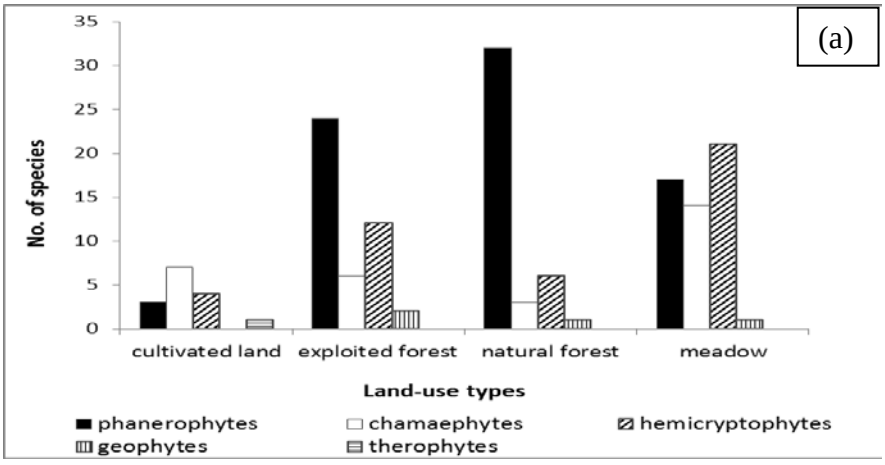


Figure 3: Distribution of different growth forms along (a) land-use types and, (b) altitudinal gradient

4.2 Life form along land-use type and altitude

Contrasting life forms were found to coexist on different land-use type in the study site. Phanerophytes were found to be most abundant in the overall collected species at different altitudes of the natural forest. Similarly, hemicryptophytes and chamaephytes were high in number in meadows (Fig 4.a). Phanerophytes were more dominant at all the altitudes. The number of hemicryptophytes was comparatively high than other life forms at 3400m (Fig 4.b).



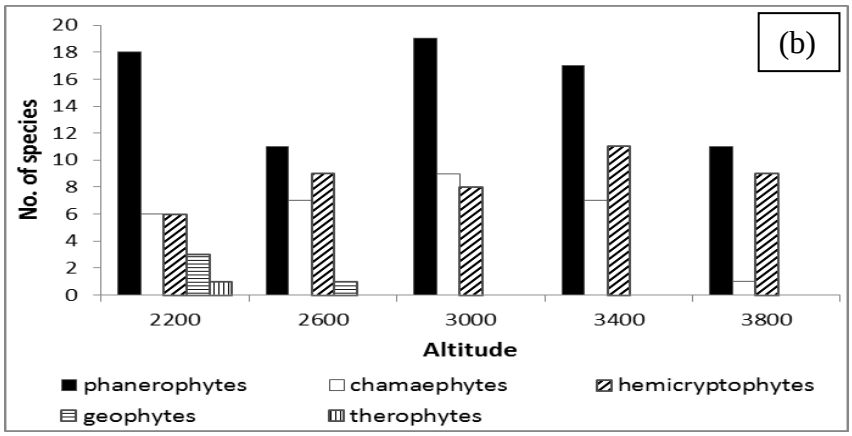


Figure 4: Distribution of different life forms along (a) land-use types and, (b) altitudinal gradient

The canopy was dominated by tree species such as *Abies spectabilis, Pinus wallichiana, Rhododendron arboreum, Tsuga dumosa, Betula utilis* in natural forest. Shrubs such as *Berberis aristata, Rosa sericea, Juniperus recurva* were dominant in meadow.

4.3 Plant height

The plant height of the investigated species ranged from 0.03-15m. Among the herbaceous and shrub species height showed highly significant difference with altitude. Height of the tree species showed significant difference with land-use type and altitude (Table 1). From posthoc analysis significant difference was observed between meadow and natural forest ($p<0.01$). Outlier was observed at 3000m showing the highest value of herb height. Herb height showed lowest value at 3800m with presence of outlier (Fig 5.a). Shrub height showed lowest value at 2600m and highest value at 3000m and3800m (Fig 5.b). Taller trees were present at the natural forest and in the meadows tree with less height were observed (Fig 5.c).

Table 1. Results of One-way ANOVA of height of herbaceous, shrub and tree species

		Herbs		**Shrubs**		**Trees**	
	Df	F value	p-value	F value	p-value	F value	p-value
Land-use type	3	1.2112	0.3055	1.6977	0.1695	11.775	<0.001***
Altitude	4	15.365	<0.001***	7.516	<0.001***	4.8228	0.03071 *

--- Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

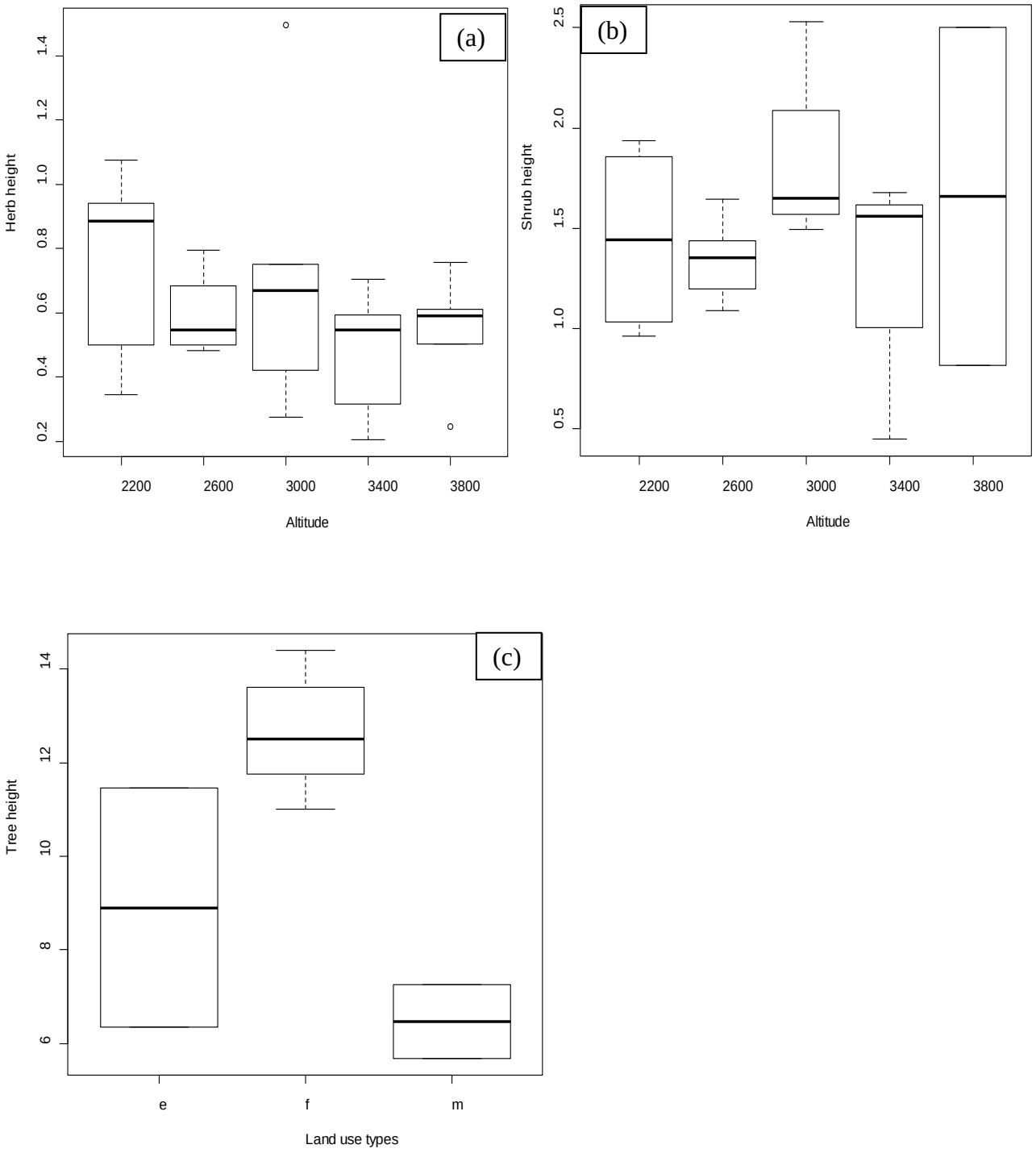


Figure 5: Box-plot showing relationship between (a) herb height along altitude in meter, (b) shrub height along altitude and, (c) tree height in different land use types. The dark line in the box plot represents the median or mid value and its arm represents the quartile value. e represent exploited forest, f for natural forest and m as meadow.

4.4 Clonality

The stolon consisting species such as *Anaphalis busua, Androsacae sarmentosa, Fragaria nubicola,and F. indica* were dominant in exploited forest. Diversity of clonal species was found to more in meadow (Fig 6.a). Non-clonal species were dominant in all the altitudes. At 3400m, stolon, bulb and adventitious bud forming species were found to be dominant. At 2200m non-clonal species were most dominant followed by stolon and vegetative bud forming species (Fig 6.b). The species with vegetative buds were *Arundinaria maling, Impatiens urticifolia* and *Rosa sericea*; and others clonal belowground were *Commelina maculata, Iris clarkei, Malaxis cylindristachya, Senecio diversifolius* and *Rumex nepalensis.*

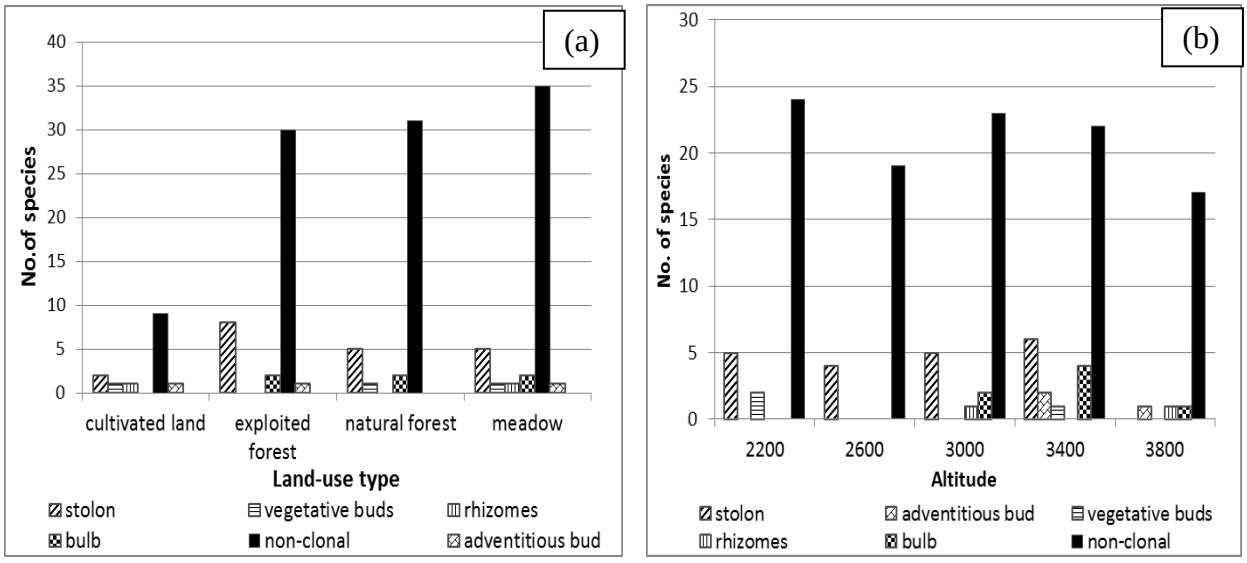


Figure 6: Distribution of different clonality categories along various (a) land-use types and, (b) altitudinal gradient

4.5 Spinescence

Among the investigated species only eight were found to consist of spines. The species with longer spines were found to be dominant mostly at the meadows (Fig 7.a). In comparison to lower altitude spine consisting species was found to decrease at highest altitude (Fig 7.b). Spinescence was observed in *Berberis aristata, Cotoneaster microphyllus, Dipsacus inermis, Rosa sericea,*and *Zanthoxylum*

armatum, which occurred at the meadow whereas some others including *Rubus ellipticus* and *Quercus semecarpifolia* occurred at the natural forests.

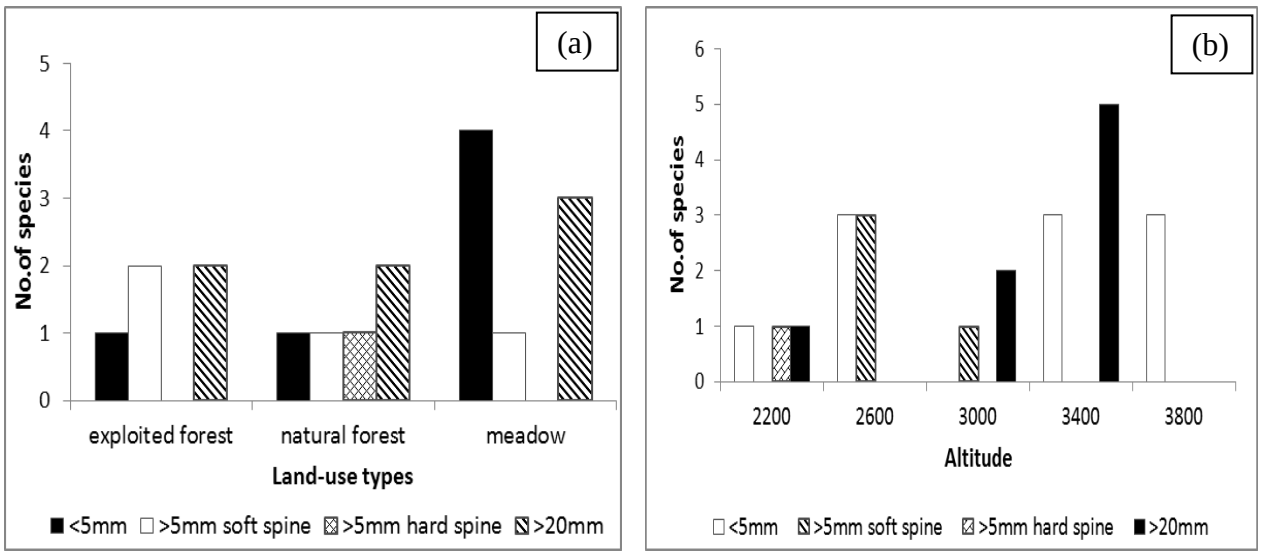


Figure 7: Distribution of spines in various (a) land-use types and, (b) altitudinal gradient

4.6 Leaf Dry Matter Content (LDMC)

The highest LDMC was recorded in *Rhododendron arboreum* i.e. 736.360mg/g, followed by *Pinus wallichiana, Quercus semecarpifolia and Abies spectabilis* while the lowest value was observed in *Pilea umbrosa* i.e. 35mg/g. Leaf dry matter content of herb was significant with land-use type but not significant with altitude (Table 2). From post hoc analysis significant difference ($p<0.01$) was seen in natural and exploited forest. LDMC measured by major life form such as shrub was found significantly different with altitude. Similarly, LDMC of trees have significant difference with land-use type and altitude (Table 2). Lowest LDMC was observed for tree in natural forest (Fig 8.a). Outliers were present in 2600m showing highest value of shrub LDMC and the lowest value was observed at 3400m (Fig 8.b). Highest value of herb LDMC was seen at 3400m and lowest was observed at 2200m along with the presence of outliers (Fig 8.c).

Table 2. Results of One-way ANOVA of LDMC of herbaceous, shrub and tree species

		Herbs		Shrubs		Trees	
	Df	F value	p value	F value	p value	F value	p value
Land-use type	3	3.5342	0.0150 *	0.5483	0.65	10.695	<0.001 ***
Altitude	4	0.9735	<0.001***	0	<0.001***	9.525	0.0027 **

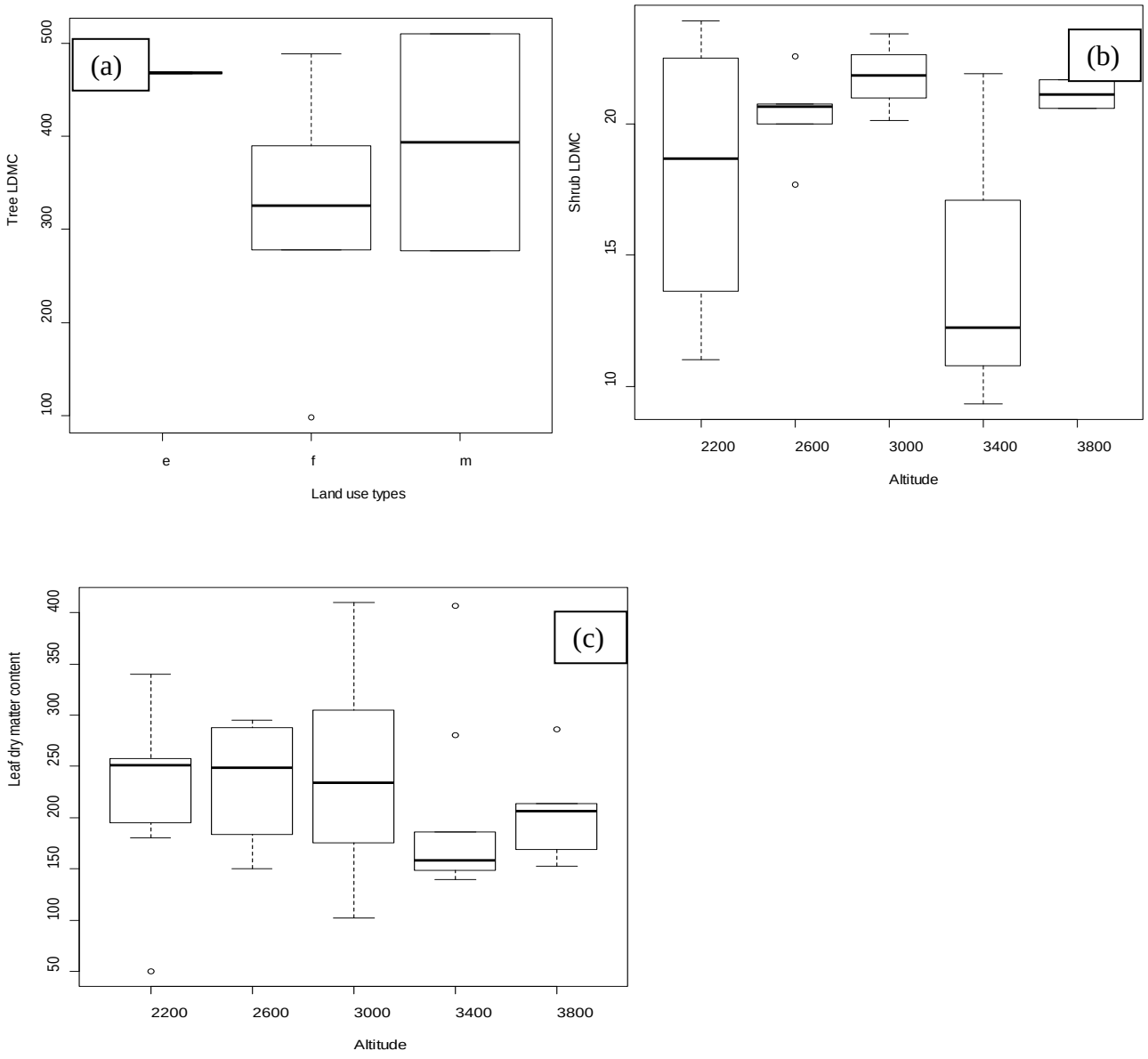


Figure 8: Box-plot showing relationship between (a) tree LDMC in different land use types (b) shrub LDMC along altitude and, (c) herb LDMC along altitude. e represents exploited forest, f for natural forest and m as meadow.

4.7 Stem Specific Density (SSD)

Altogether 27 trees and shrub species were collected and among them stem specific density of 15 shrubs was measured. The highest value of SSD was recorded in *Rhododendron lepidotum* (9.35mg/mm^3) while the lowest value was observed in *Anaphalis busua* (0.19mg/mm^3). Stem specific density for herbs showed significant difference with land-use type (Table 3). More difference was seen in between exploited forest and cultivated land ($p<0.001$) as well as natural forest and exploited forest ($p<0.001$) from posthoc analysis. Similar result was observed from boxplot showing lowest value of SSD at exploited and natural forest with presence of outliers and highest value at natural forest (Fig 9).

Table 3. Results of One-way ANOVA of SSD of herbaceous and shrub species

		Herbs		**Shrubs**	
	Df	F value	p value	F value	p value
Land-use type	3	10.100	<0.001***	1.5936	0.1979
Altitude	4	0.0875	0.7677	3.2544	0.0751 .

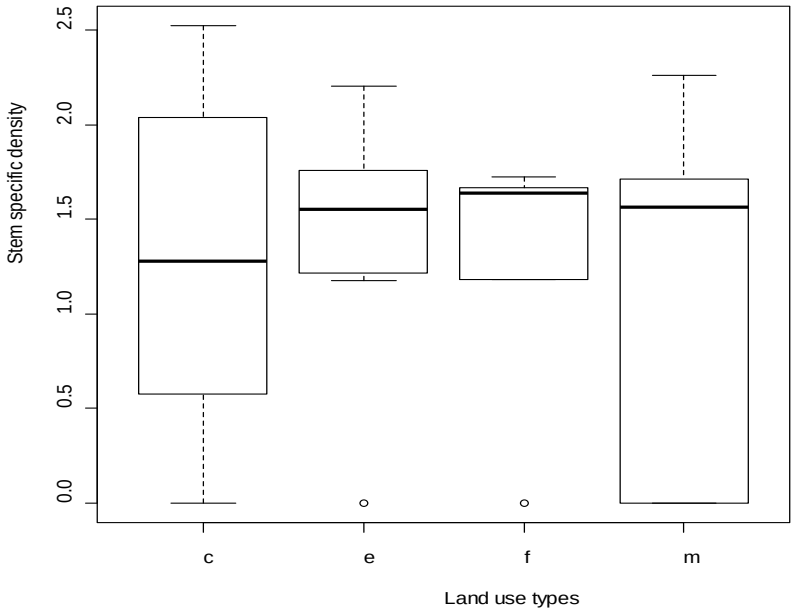


Figure 9: Box-plot showing relationship between stem specific density in different land use types. c represents cultivated land, e is exploited forest, f for natural forest and m as meadow.

4.8 Twig dry matter content (TDMC)

Twig dry matter content was calculated for tree and shrubs. The highest value of TDMC was 875mg/gm in *Gaultheria fragrantissima*, while the lowest was 251.57mg/gm in *Abies spectabilis*. TDMC of shrub species was found significant with land-use and altitude (Table 4). More difference was found between meadow and exploited forest. Similarly, twig dry matter content for trees showed significant difference with land-use type (Table 4). Outlier was present showing the highest value of tree TDMC at the natural forest and lowest mean value was observed at meadow (Fig 10).

Table 4. Results of One-way ANOVA of TDMC of shrub and tree species

		Shrubs		**Trees**	
	Df	F value	p value	F value	p value
Land-use type	3	6.6064	0.002**	9.5956	<0.001***
Altitude	4	11.999	0.001 **	1.6489	0.2058

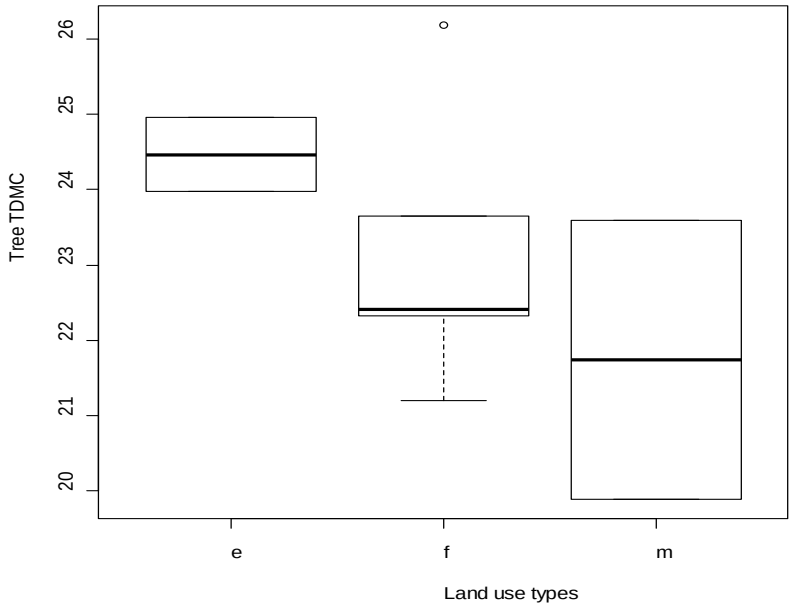


Figure 10: Box-plot showing relationship between tree TDMC in different land use types

4.9 Twig drying time

There was not much difference in the twig drying time of the plant species. TDT ranged from 2-4 days. The twigs of *Juniperus indica, Pieris formosa, Pinus wallichiana* and *Quercus semecarpifolia* dried in 4 days , while *Osbekia* took the lowest drying time i.e. 2 days. All the other remaining species took 3 days to dry out completely.

4.10 Bark thickness

Bark thickness was measured only in the tree species. Mostly the gymnosperms consisted of thick barks. In comparison to them *Rhododendron campanulatum, Alnus nepalensis,* etc. had much thinner bark. *Betula utilis* was found to have thin multilayered bark. The thickness of tree bark was found significant with landuse type and altitude (Table 5). From posthoc analysis significant difference was observed between meadow and natural forest ($p<0.01$).

Table 5. Results of One - way ANOVA of bark thickness of tree species

	Trees		
	Df	F value	p value
Land-use type	3	41.9043	0.02331 *
Altitude	4	38.7498	0.02485 *

4.11 Specific Root Length (SRL)

Specific root length was measured only for the herbaceous species. The highest value of SRL was 2.75m/gm in *Dipsacus inermis*, while the lowest was 0.013m/gm in *Roscoea purpurea*. Herbaceous species found at the meadows had much deeper roots. SRL of herbs was found to be highly significant difference with land-use type and altitude (Table 6). More difference was observed between species of meadow and cultivated land ($p<0.001$). Outlier was present at 2200m which showed the highest value of SRL and lowest value was observed at 3800m (Fig 11).

Table 6. Results of One-way ANOVA of SRL of herbaceous species

	Herbs		
	Df	F value	p value
Land-use type	3	5.6251	0.001 **
Altitude	4	26.952	<0.001***

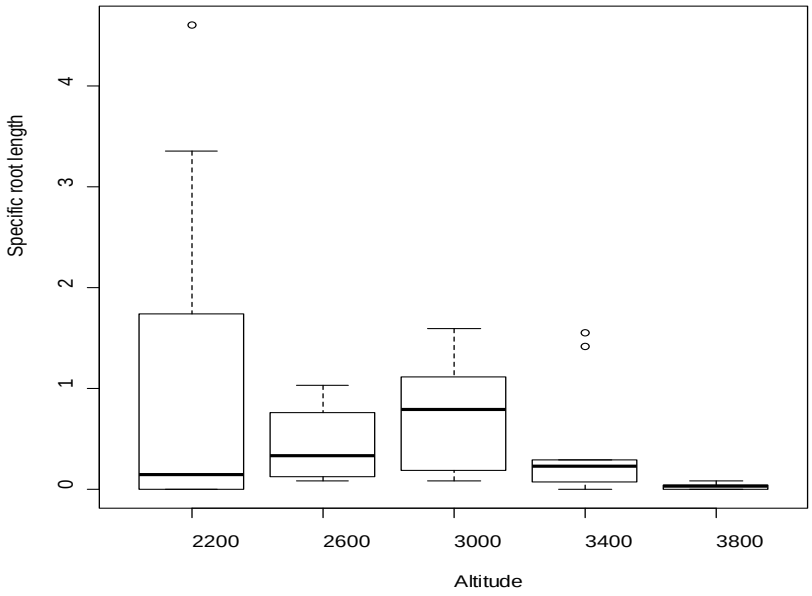


Figure 11: Box-plot showing relationship between specific root length along altitude (m).

4.12. Correlation between traits

The correlation coefficient was found to be significant between different traits. Plant height was positively correlated with LDMC, SSD and BT. TDMC and TDT was positively correlated with plant height, LDMC, SSD and BT while negatively correlated with clonality. All aboveground biomass representing traits (plant height, LDMC, SSD, BT, TDMC and TDT) showed negative correlation with belowground biomass (SRL) as shown in Table 7.

Table: 7. Correlation coefficient between different traits of overall altitudes (values with bold entries showed statistically significant).

	Plant height	LDMC	SSD	BT	TDMC	TDT	SRL
Plant height	1.000						
LDMC	**.553****	1.000					
SSD	**.462****	.236	1.000				
BT	**.577****	.229	-.156	1.000			
TDMC	**.802****	**.610****	**.371****	**.625****	1.000		
TDT	**.801****	**.598****	**.426****	**.546****	**.976****	1.000	
SRL	**-.568****	**-.394****	**-.428****	**-.352****	**-.613****	**-.624****	1.000

**Correlation significant at $p<0.01$, *significant at $p<0.05$.

LDMC: Leaf Dry Matter Content, SSD: Stem Specific Density, SRL: Specific Root Length, BT: Bark Thickness, TDMC: Twig Dry Matter Content, TDT: Twig Drying Time.

This correlation coefficient value showed significantly different result within same altitudes as well as other altitudes. Along each of the five altitudinal gradients, plant height showed positive correlation with TDMC and TDT. Higher significant correlation between traits was found in the lower altitude (2200m). Plant height was negatively correlated with SRL at 2200m, 2600m and 3000m. LDMC also showed positive correlation with TDMC and TDT at 2200m and 2600m (Appendix III).

CHAPTER 5. DISCUSSION

The result achieved shows variation in different traits along altitude as well as land-use types. Among the various growth forms, tree was dominant in natural forest while different categories of herbs were found to be less dominant. This might be because herbs do not grow well under canopy due to difficulty in light intensity much reaching to the ground (Whittaker *et al*. 2001; Panthi *et al*. 2007). Shrubs and erect leafy were found to be dominant at meadow and exploited forest which may be as an adaptation to grazing. The height and positioning of the foliage may be both adaptations and responses to grazing by different herbivores (Cornelissen *et al*. 2003). Along the altitudinal gradient, trees and erect leafy herbs decreased in number whereas other herbs and dwarf shrubs were found to be dominant along higher altitude. Similar result of increment in herbs at higher altitudes was found by Wana & Beierkuhnlein (2009) in southwest Ethiopian highlands. The distinction of growth forms informs us about the specific adaptations to environmental conditions such as climate and wind (Rowe & Speck 2005; Dalacho 2009), solar energy partitioning (Baldocchi *et al*. 2004), water use efficiency (Breshears & Barnes 1999) and resource partitioning (Cody 1991) in the ecosystem. Weeds and unpalatable or toxic herbs, shrubs were particularly abundant in the meadows and exploited forest that were mostly overgrazed areas present nearby villages (Bauer 1990; Boer & Smith 2003).

'Life form' classifies plants with respect to the location of the regeneration buds as strategy to survive cold winters (Raunkiaer 1934). One of the basic gradient along which life-forms change is altitude (Klimes 2003). Hemicryptophytes were found to be dominant in the higher altitude where as phanerophytes and chameophytes decreased with the gain of altitude. Dominance of hemicryptophytes at the higher altitudes has also been reported from Hindukush Himalaya (Agakhanyantz & Breckle 1995). Diversity of life-forms was found to decrease with increasing altitude similar to the finding of Klimes (2003), and only one or two life-forms remain at extreme altitudes (Pavon *et al*. 2000). The reason behind it can be smaller area in the higher elevation zones support more heterogeneous environments and provide wider geographical ranges for species (Lomolino 2001). Another reason may be because of low temperatures which cause organic matter to decay gradually and accumulate humus in the soils that may limit soil productivity (Sanchez-Gonzalez & Lopez-Mata 2005). In this study, hemicryptophytes were found to be dominant in the meadows which may be the result of disturbances such as periodic grazing, mowing and fire. The harsher the climate, the fewer plant

species are likely to have buds far above the ground surface, fully exposed to the cold or the drying power of the atmosphere (Cornelissen *et al*. 2003; Kahmen 2004).

Herb and shrub height showed significant difference with the altitude. A study by Bhattarai & Vetaas (2003) in the Himalayan range indicate that woody species display a uni-modal pattern of diversity while herbaceous species do not show any relationship to altitude which is different from the result of present study. The reason behind it could possibly be the effect of an incomplete gradient length because this study covers only an altitudinal range of 2200-3800m. Plant height in case of shrubs showed significant difference between natural forest and exploited forest as well as between meadow and exploited forest. Significant difference was observed with land-use type mainly between meadow and natural forest in case of tree height. It may be due to presence of very few trees in meadow of short stature, and low disturbance such as grazing, mowing, firing, etc in natural forest in comparison to the meadow. Short plants were found most dominant in the meadow because they have higher quality and growth rate, and are more tolerant to herbivory than taller plants (Cingolani 2005). There is interrelationship between plant height and tolerance or avoidance of environmental (climate, nutrient) stress. Some tall plants may successfully avoid fire reaching the green parts and meristems in the canopy (Cornelissen *et al*. 2003).

Rhizomes and other clonal species were dominant in high altitudes for adaptation to chilling and grazing, similar to the finding of Wana & Beierkuhnlein (2009). Increase of clonal species in the colder sites was also found by Klimesova *et al*. (2010) in East Ladakh, Western Himalayas. Diversity of clonal species was high in the meadows because they grow well in harsher environment (Klimes 2003) and nutrient-poor conditions (Klimes *et al*. 1997). In response to severe environments, plants either develop adaptations that enable protection of renewing buds and spread the risk of bud mortality by multiplying buds through clonal growth (Raunkiaer 1934). Clonality give plants competitive vigour and the ability to exploit patches rich in key resources (nutrient, water, light), while it may promote persistent after environmental disturbances. At higher nutrient levels a few highly competitive species become dominant supressing other species (Pausus and Austin 2001). Clonal organs, especially below ground ones, may also serve as storage organs. Clonal behavior may also be an effective means of short distance migration under circumstances of poor seed dispersal or seedling recruitment (Cornelissen *et al*. 2003).

Plant species with spines were mostly shrubs and were found to be dominant at the meadows because disturbance level is high due to grazing, trampling, etc. Another reason may be defense mechanism to protect them from herbivores. They can play an additional role in reducing heat or drought stress (Cornelissen *et al*. 2003) by dissipating heat loading on the surface of the leaves and steams or absorbing solar radiation, in addition to their role as a mechanical deterrence against vertebrate herbivory (Grime 2001). Thorns or spines were found to be more abundant in lower altitudinal ranges in response to drought and grazing which is similar to the findings of Dalacho (2009) and Wana & Beierkuhnlein (2009). Plants with spines were found to have edible fruits (e.g; *Berberis aristata, Rubus ellipticus, Zanthoxylum armatum*, etc.). They may have developed spines in order to save their fruit from herbivores and to reduce water loss.

Leaf dry matter content of tree was found to vary significantly with land-use type and altitude. Significant difference was seen between meadow and cultivated land as well as natural forest and cultivated land. In the natural forest, trees with high LDMC were present while in the cultivated and meadow more herbs with low LDMC were present. Species with low LDMC are associated with highly disturbed environments, intensive land-use and colder sites (Garnier *et al*. 2007). At higher altitude, fast-growing and shorter species also have low LDMC and lower toughness (Ryser 1996). Plants found in high light, less intensive land-use and warmer sites usually have thick leaves with high LDMC (Garnier *et al*. 2007; Xu *et al*. 2009). Leaves with high LDMC tend to be relatively tough and are more resistant to physical hazards (e.g. herbivory, wind, hail) than leaves with low LDMC. LDMC was significant with altitude in the herbaceous species. Spinescence, growth form, clonality, Twig drying time and plant height were positively correlated to LDMC.

Stem specific density for herbs showed significant difference with land-use type. More difference was observed in between exploited forest and cultivated ($p<0.001$) as well as natural forest and exploited ($p<0.001$). Trees present in the natural forest had more stem specific density than the ones present in the exploited forest. Best competitors for light are those plants that allocate large fractions of their biomass to aboveground organs i.e. stems and leaves (Minden 2010). SSD is correlated with plant height and TDMC. More the height of the plant higher is the stem density as well as twig dry matter content. A dense stem provides the structural strength that a plant needs to stand upright and the durability it needs to live sufficiently long. Lower the stem density higher is the plant growth rate.

Stem defenses against pathogens, herbivores or physical damage by abiotic factors is higher at high SSD. Stem plays an important role in the aboveground storage of carbon (Cornelissen *et al*. 2003).

Twig Dry Matter Content of tree differed significantly with altitude and land-use type. High significance was observed between meadow and exploited forest. Low TDMC may be positively correlated with high potential relative growth rate. Twig drying time was positively correlated to twig dry matter content in case of trees. Twigs with high dry matter are expected to dry out relatively quickly during the dry season in fire-prone regions (Cornelissen *et al*. 2003). Highest TDMC value in this study was recorded in *Gaultheria fragrantissima* which indicates that it has stronger avoidance characteristics than the others as reported by Olivero (2011).

Similarly, bark thickness was significant with land-use type and altitude. Significant difference was found between meadow and natural forest because trees with thick bark are present in the forest. Bark thickness increased with the increase in altitude. At higher altitude cold temperature persists so thicker bark provides protection of vital tissues against frost or drought. It also protects plant from attack by pathogens and herbivores. Thick bark insulate meristems and bud primordial from fire (Cornelissen *et al*. 2003). Lawes *et al*. (2011) also considered bark thickness as a predictor of resistance to cambial injury from fire.

SRL was significant with altitude and land-use type. More significance was in meadow and cultivated land. The reason may be because in meadow herbs were found to have thick and deep roots which hold the soil tightly, whereas in the cultivated land roots were much thinner. Thicker roots have been indicated to exert greater penetration force on the soil, better withstand low soil moisture and have higher rates of water transport within the root (Cornelissen *et al*. 2003). SRL decreased with the increase in altitude. Specific root length was observed to be negatively correlated with plant height, LDMC, TDMC and SSD. But positive relationship between belowground and aboveground dry mass was found by Enquist and Niklas (2002). Negative correlation is seen in this study because nutrient conserving species with large belowground storage organs allocate less aboveground mass (Grime 1974). Under low nutrient conditions plants increase their biomass allocation to roots at the expense of leaves and shoots to increase nutrient uptake (Ryser and Lambers 1995). Plants with high SRL are able to build longer roots for a given dry mass investment and this is achieved by constructing roots of thin diameter. Species of higher SRL have faster root elongation rates, higher rates of nutrient and water uptake.

Hence, from the result most of the traits were found to vary significantly with altitude and land-use types. Above discussion shows that there are various factors which are responsible for adaptation of plants by developing various traits. The major ones being climate, temperature, water use efficiency, nutrient availability, solar energy partitioning and disturbance level along altitude and land-use types. According to Dominguez *et al*. (2012), the main environmental filters that determine the patterns of functional traits in a forest stand are light availability, soil moisture and soil nutrients. Traits such as life form, canopy height have been identified as responsive to various types of disturbance, and especially grazing. The correlation coefficient between aboveground and belowground traits was found to be significant. As mentioned above, clonal species, small sized seed, short basal herbs were dominant in the higher altitude while spines, tall trees were observed at the lower altitude. Similarly, in case of land-use types, plants present in meadows and exploited forest showed more variation in traits due to more disturbance.

CHAPTER 6. CONCLUSION AND RECOMMENDATION

6.1. Conclusion

Overall, the result shown in this study is in line with many other works conducted to this related topics. From the above findings we can conclude that both quantative as well as qualitative traits show a great deal of variation along different environmental gradients, the ones focused in this study being the altitude and land–use types. Four different land-use types exhibited significant relationship with traits. Plant traits were found to vary significantly between disturbed (i.e. cultivated, exploited forest, and meadow) and less disturbed (i.e. natural forest). Some contrasting results found in this study pave the way towards a better understanding of how species cope with varying habitat conditions.

The study showed that both natural as well as anthropogenic disturbances are responsible in order to make the plant adapt to those conditions and show various traits for their defense against it. The main disturbances were grazing, fire, trampling, litter collection, etc. Grazing encourages species that are short-lived, herbaceous growth form and clonal. The study site being a Himalayan region, especially in the higher altitude more harsher environment persist due to cold climate as well as other disturbance factors which cause less diversity of growth forms, life forms and more variation in traits. Hence, the result supports our assumption that various traits are shown by the plants along land use types and altitudinal gradient. The variation in the abundance of certain plant functional traits at a particular habitat informs us about the strength of the dominant environmental constraint such as climate, resource availability and disturbance level in that ecosystem.

6.2. Recommendation

Based on the results of present study, following recommendations have been given

- Many studies have been conducted on the species distribution pattern but study related to their attributes in the context of different land-use types is not yet performed in Nepal. Hence, such kind of study is very necessary to be carried out in several other parts of Nepal.
- This study is limited to altitudinal range of 2200-3800m, study beyond this range would have definitely given a better result. So that altitudinal variation of trait could be better understood.

- Continuity of this study for long term is recommended to get a better picture of the global changes like climate change.
- Strategies should be developed to control both natural as well as anthropogenic disturbances which are responsible for biodiversity loss.

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Appendix I

General characterization of the investigated species:

Name of the species	Abbreviations	Family	Life form	Growth form
Abies spectabilis (D. Don) Mirb.	*Abie.spe*	Pinaceae	P	T
Aconogonum molle (D. Don) H. Hara	*Acon.mol*	Polygonaceae	C	S
Alnus nepalensis D.Don	*Alnu.nep*	Betulaceae	P	T
Anaphalis busua (Buch.-Ham. ex D. Don) DC.	*Anap.bus*	Compositae	He	H
Anaphalis triplinervis (Sims) C. B. Clarke	*Anap.tri*	Compositae	He	H
Androsace sarmentosa Wall.	*Andr.sp.*	Primulaceae	He	H
Artemisia indica Willd.	*Arte.vul*	Compositae	C	H
Arundinaria maling Gamble	*Arun.mal*	Graminae	P	S
Aster flaccidus Bunge	*Aste.fla*	Compositae	He	H
Avena sativa L	*Aven.sat*	Graminae	Th	H
Berberis aristata DC.	*Berb.sp.*	Berberidaceae	P	S
Betula utilis D. Don	*Betu.uti*	Betulaceae	P	T
Bistorta amplexicaulis (D. Don) Greene	*Bist.amp*	Polygonaceae	He	H
Capsella bursa-pastoris (L.) Medik.	*Caps,bur*	Brassicaceae	He	H
Commelina maculata Edgew.	*Comm.mac*	Commelinaceae	He	H
Cotoneaster microphyllus Wall. ex Lindl.	*Coto.sp.*	Rosaceae	C	S
Daphne bholua var. *glacialis* Buch.-Ham. ex D. Don	*Daph.bho*	Thymelaceae	P	S
Dipsacus inermis Wall	*Dips.ine*	Dipsacaceae	C	H
Elsholtzia fruticosa (D. Don) Rehder	*Elsh.fru*	Labiatae	P	H
Eupatorium adenophorum Spreng.	*Eupa.ade*	Compositae	C	H
Euphorbia sikkimensis Boiss.	*Euph.sik*	Euphorbiaceae	C	H
Fragaria indica Andrews.	*Frag.ind*	Rosaceae	He	H
Fragaria nubicola Lindl. ex Lacaita	*Frag.nub*	Rosaceae	He	H

Gaultheria fragrantissima Wall.	*Gaul.fra*	Ericaceae	P	S
Geranium pratense L.	*Gera.pra*	Geraniaceae	He	H
Geum elatum Wall. ex G. Don	*Geum.ela*	Rosaceae	He	H
Hedera nepalensis K. Koch	*Hede.hel*	Araliaceae	He	H
Heracleum nepalense D. Don	*Hera.sp.*	Umbeliferae	He	H
Impatiens urticifolia Wall.	*Impa.urt*	Balsaminaceae	He	H
Inula cappa (Buch.-Ham. ex D. Don) DC.	*Innu.cup*	Compositae	C	S
Iris clarkei Baker ex Hook. f.	*Iris.alp*	Iridaceae	G	H
Juniperus indica Bertol.	*Juni.ind*	Cupressaceae	P	T
Juniperus recurva Buch.Ham. ex D. Don	*Juni.rec*	Cupressaceae	P	S
Lonicera angustifolia Wall. ex DC.	*Loni.sp.*	Caprifoliaceae	P	S
Lyonia ovalifolia (Wall.) Drude	*Lyon.ova*	Ericaceae	P	T
Malaxis cylindrostachya (Lindl.)Kuntze	*Mala.cyl*	Orchidaceae	G	H
Osbeckia stellata Buch.-Ham. ex D. Don	*Osbe.ste*	Melastomataceae	P	S
Pedicularis siphonantha D.Don	*Pedi.sp.*	Scrophulariaceae	He	H
Phlomis rotata Benth. ex Hook. f.	*Phlo.ro*	Labiatae	P	H
Pieris formosa (Wall.) D. Don	*Pier.for*	Ericaceae	P	S
Pilea umbrosa Blume	*Pile.umb*	Urticaceae	C	H
Pinus wallichiana A. B. Jacks.	*Pinu.wal*	Pinaceae	P	T
Plantago major L.	*Plan.sp.*	Plantaginaceae	He	H
Potentilla fructicosa var. *rigida* L.	*Pote.fru*	Rosaceae	He	H
Primula denticulata Sm.	*Prim.den*	Primulaceae	He	H
Quercus semecarpifolia Sm.	*Quer.sem*	Fagaceae	P	T
Rhododendron arboreum Sm.	*Rhod.arb*	Ericaceae	P	T
Rhododendron campanulatum D. Don	*Rhod.cam*	Ericaceae	P	T
Rhododendron lepidotum Wall. ex G. Don	*Rhod.lep*	Ericaceae	P	S
Rhododendron setosum D.Don	*Rhod.set*	Ericaceae	P	S

Rosa sericea Lindl.	*Rosa.ser*	Rosaceae	P	S
Roscoea purpurea Sm.	*Rosc.pur*	Zingeberaceae	G	H
Rubus ellipticus Sm.	*Rubu.ell*	Rosaceae	P	S
Rumex nepalensis Spreng.	*Rume.nep*	Polygonaceae	He	H
Salvia campanulata Wall. ex Benth.	*Salv.sp.*	Labiatae	C	H
Saxifraga parnassifolia D. Don	*Saxi.par*	Saxifragaceae	He	H
Senecio cappa Buch.-Ham. ex D. Don	*Sene.cap*	Compositae	C	H
Senecio diversifolius Wall. ex DC	*Sene.div*	Compositae	C	H
Tsuga dumosa (D. Don) Eichler	*Tsug.dum*	Pinaceae	P	T
Zanthoxylum armatum DC.	*Zant.ala*	Rutaceae	P	T

Growth forms: T=Tree; S=Shrub; DS= Dwarf Shrub; H= Herb

Life forms: Th=Therophyte; He= Hemicryptophyte; P= Phanerophyte; C= Chameophyte; G= Geophyte; NA= not available

Appendix II:

Altitude wise anova of all continuous traits according to difference in Land-use types:

Altitude	Traits	Df	F value	Pr(>F)
2200	TDMC	3	1.5239	0.268
	SSD	3	0.736	0.548
	LDMC	3	0.7958	0.5237
	Plant height	1	6.190	**0.026 ***
	SRL	3	3.715	**0.0497***
2600	TDMC	2	0.757	0.526
	SSD	2	0.8562	0.4903
	LDMC	2	0.327	0.738
	Plant height	2	0.713	0.543
	SRL	2	0.305	0.752
3000	TDMC	3	0.5922	0.677
	SSD	3	0.4017	0.769
	LDMC	3	0.5874	0.679
	Plant height	3	0.577	0.684
	SRL	1	15.534	0.058
	TDT	3	0.7111	0.629
3400	TDMC	2	0.7688	0.5044
	SSD	2	0.1968	0.8264
	LDMC	2	10.244	**0.011 ***
	Plant height	2	0.917	0.449
	SRL	2	0.1771	0.842
3800	TDMC	3	3.2229	0.1439
	SSD	3	2.4116	0.2073
	LDMC	3	0.9964	0.4802
	Plant height	3	16.804	**0.0098 ****
	SRL	3	0.8508	0.5342

Appendix III: Correlation among different traits in different altitudes.

A. Correlation coefficient between different traits along 1st altitude i.e., 2200m.

	plant height	LDMC	SSD	BT	TDMC	TDT	SRL
plant height	1.000						
LDMC	**.548***	1.000					
SSD	.329	.250	1.000				
BT	**.542***	.334	**-.479***	1.000			
TDMC	**.788****	**.673****	.136	**.585***	1.000		
TDT	**.790****	**.669****	.150	**.571***	**.993****	1.000	
SRL	**-.522***	-.418	-.244	-.299	-.347	-.351	1.000

B. Correlation coefficient between different traits of 2nd altitude i.e., 2600m.

	plant height	LDMC	SSD	BT	TDMC	TDT	SRL
plant height	1.000						
LDMC	.806**	1.000					
SSD	.274	.383	1.000				
BT	.522	.406	-.466	1.000			
TDMC	**.832****	**.919****	.279	.539	1.000		
TDT	**.895****	**.934****	.345	.497	**.964****	1.000	
SRL	**-.765****	**-.860****	-.586	-.261	**-.845****	**-.877****	1.000

C. Correlation coefficient between different traits of 3rd altitude i.e. 3000m.

	plant height	LDMC	SSD	BT	TDMC	TDT	SRL
plant height	1.000						
LDMC	.830**	1.000					
SSD	.389	.638*	1.000				
BT	.522	.058	-.466	1.000			
TDMC	.785**	.615	.318	.588	1.000		
TDT	**.782****	**.711***	.463	.408	**.961****	1.000	
SRL	**-.725***	**-.694***	-.304	-.359	**-.845****	**-.880****	1.000

D. Correlation coefficient between different traits of 4th altitude i.e. 3400m.

	plant height	LDMC	SSD	TDMC	TDT	SRL
plant height	1.000					
LDMC	.070	1.000				
PP	-.044	.131				
SSD	**.817****	-.141	1.000			
TDMC	**.650***	.059	.574	1.000		
TDT	**.648***	.000	**.587***	**.996****	1.000	
SRL	-.057	.292	-.362	-.525	-.528	1.000

E. Correlation coefficient between different traits of highest altitude i.e. 3800m.

	plant height	LDMC	SSD	BT	TDMC	TDT	SRL
plant height	1.000						
LDMC	.200	1.000					
SSD	.523	-.043	1.000				
BT	**.874****	.246	.277	1.000			
TDMC	**.756***	.537	.486	**.721***	1.000		
TDT	**.871****	.241	.635*	**.774****	**.893****	1.000	
SRL	-.425	-.425	-.471	-.504	-.597	-.618	1.000

****Correlation significant at p<0.01, *significant at p<0.05.**

LDMC: Leaf Dry Matter Content, PP: Photosynthetic Pathway, SSD: Stem Specific Density, SRL: Specific Root Length, WD: Wood Density, BT: Bark Thickness, DM: Dispersive Mode.

Appendix IV: Photo Plates

Photo plate 1: Investigating a plant in the field for trait measurement

Photo plate 2: Laying a transect and at work in the field

Photo plate 3: Working in the field.

Photo plate 4: Winged seeds of *Abies spectabilis* for wind dispersal

Photo plate 5: Taking measurement of Leaf dry matter content.

Photo plate 6: Measuring leaf length by using graph sheet and measuring scale