Chapter 1

INTRODUCTION

1.1 Background

The mountain forests in Himalaya are ideal sites for the comparative study of vegetation zonation in humid monsoonal climates because of their essentially continuous extension of mountain topography from tropical to alpine regions. The Himalayan mountain range exhibits the largest elevation gradient in the world and a very wide range of climatic zone (Dobremez, 1976), from 60 m a.s.l. at the Gangetic plains (Tarai in south Nepal) to the Himalayan peaks above 8000 m a.s.l. The ecological variation associated with an elevation range of 800 m is equivalent to a latitudinal distance of approximately 6000 km. Variation in species diversity along elevation gradients and available soil moisture shows the similar pattern as latitudinal variations (Simpson, 1964; Cook, 1969).

The Mountains are therefore considered as the place having several ecotones between different habitat types under steep climatic gradients. This large environmental variation within a small geographic area makes elevational gradients ideal for investigating patterns in species richness (Körner, 2000). Generally, species richness is lower at higher altitudes (Ohlemuller & Wilson, 2000), just as the number of species decreases progressively in cooler climates as one moves from tropical to polar region.

Alpine ecosystems tend to support many species at their physiological, and thus distributional, limits. With increasing concerns as to the possible effects of global climate change, particularly higher temperatures, alpine ecosystems and the species and communities they support, may serve as obvious signals of environmental change (Mark *et al*., 2000). Increasing temperatures are likely to result in changes in the altitudinal limits of species, making it important, to understand the contemporary vegetation and species patterns of the alpine zone (Messerli & Ives, 1997; Körner, 1999).

Study of species richness with elevation has been known for over a century and found a different trend with elevation (Wallace, 1878; Pianka, 1966; Lomolino, 2001). With increasing elevation Yoda (1967), Hamilton (1975), Gentry (1988), Stevens (1992), and Fossa (2004) have found a decreasing trend in species richness, whereas others have found a hump shaped relationship between species richness and elevation (Whittaker & Niering, 1975; Rahbek, 1995; Lieberman *et al* 1996; Odland & Birks, 1999; Grytnes & Vetaas, 2002, Carpenter, 2005; Nogues-Bravo *et al.*, 2009).

Rahbek (1995 & 1997), review of literature on species richness and elevation gradients, found that about 50% studies show a hump trend in species richness with a maximum species at mid elevation, another 25% show a monotonic decline in species richness from low elevation to high elevation and remaining shows nearly constant from the lowlands to mid-elevation and strong decline further i.e. diversity plateau at low elevations. More recent studies show maximum species richness at middle elevations for insects (Fleishman *et al*., 1998; Sanders, 2002; Sander *et al*., 2003), small mammals (Lomolino, 2001), birds (Rahbek, 1997) and vascular plants (Lieberman *et al*., 1996; Austrhein, 2002; Grytnes & Vetaas, 2002; Vetaas & Grytnes, 2002), pteridophytes (Bhattarai *et al*., 2004a; Kluge *et al*., 2006) however, the monotonic decline in species richness as the elevation increase is also found (Stevens 1992; Rahbek 1995 & 2005; Vazquez & Givnish, 1998; Grytnes, 2003; Nagy *et al.*, 2003; Fosaa, 2004).

To describe variation in vascular plant richness and species composition along altitudinal gradients in different climates, and vegetation types, different approach have been postulated like number of species with lower and upper distribution limits i.e. species turnover (van Steenis, 1984; Vazquez & Givnish, 1998), similarity or dissimilarity indices (Beals, 1969; Hamilton, 1975; Hamilton & Perrott, 1981; Baruch, 1984; Kirkpatrick & Brown, 1987; Ohsawa, 1991; Itow, 1991; Vazquez & Givnish, 1998), ordination and classification techniques (Baruch, 1984; Kirkpatrick & Brown, 1987; Druitt *et al.*, 1990; Kitayama, 1992; Boyce, 1998).

In ecology, it has been long recognized about the importance of scale in resolution of geographical patterns of species richness (Ricklefs, 1987 & 2004; Levin, 1992; Schneider, 1994). The observed patterns of species richness at different spatial scales required mechanistic explanations. The attempts to account for such explanations have taken mainly in two directions: i) the deterministic aspect of the physical environment and ii) historical-evolutionary processes (Brown & Lomolino, 1998; Gaston, 2000; Ricklefs, 2006). The physical environment considers variations in the physical environment as the primary determinant of species richness across spatial scales (Willig *et al*., 2003). The general notion here is the variation in the number of species is an outcome of species interactions at particular environmental settings (Ricklefs, 2006). Thus, the biological processes (e.g competition, predation) are inherently thought to be guided by particular environmental settings and play a key role to determine the species richness in a particular community.

The historical-evolutionary process refers to the importance of history and evolutionary mechanisms such as speciation and extinction as the processes to create and maintain richness. Historical and evolutionary process is believed not only play an important role in large scale patterns of richness (Whittaker, 2004) but also controls external drivers for local scale (Keddy, 1992). However, recently there is a consensus that both processes work together for the pattern of species richness at different spatial scales, although, the relative importance of one over the other is still dependent on the scale of observation (Whittaker, 2004).

Processes driving global scale richness patterns could be a result of evolutionary processes, interacting with large scale and long term climatic conditions (Willis & Whittaker, 2002; Whittaker, 2004). In regard to latitudinal variation in species richness, a number of hypothesis were forwarded such as energy availability, water-energy dynamics, environmental stability, habitat heterogeneity, species-area relationship, Rapoport´s rule (species range size), and time (Gaston, 2000). Nonetheless each of these could lend only a part when explaining the gradient in richness from tropics to temperate latitudes. Yet, the general consensus is that the tropics had a constantly high environmental temperature compared to temperate regions and a long evolutionary time was available for species to accumulate (Willig *et al.*, 2003; Kreft & Jetz, 2007). These two factors together or independently may have led to the accumulation of species, niche specialization and other biological processes to generate higher species richness in the tropics compared to temperate latitudes, which had observed different cycles of climatic oscillations and shorter time for accumulation of species (Brown & Lomolino, 1998).

The formation of the highland systems provided wide ranges of environmental templates along altitudinal gradients for species to shift up and down during past climate changes (Bobe, 2006). Concerning the mechanisms explaining altitudinal gradients of richness, there were a number of factors considered to be important for elevational clines of richness (Lomolino, 2001). Some of these may include climatic factors mainly rainfall and temperature, area effect, and increased isolation with elevation (Brown & Lomolino, 1998). In regard to climatic factors, mainly temperature and rainfall, temperature decreases with increasing altitude while rainfall increases non-linearly with altitude in the tropics and hence produce a double complex gradient and affect the abundance, diversity and richness of species along the mid altitudinal gradient (Brown & Lomolino, 1998).

The other factor, which was thought to affect the pattern of species richness along altitudinal gradient, is the effect of area. As altitude increases the total area decreases towards the top of a mountain (Körner, 2000). This small area effect with increasing isolation of habitats at higher altitudes would result in lower number of species at the upper end of the gradient (Lomolino, 2001). As tops of mountains tend to be isolated, it is highly probable that species dispersal and exchange events will be lower there (Brown & Lomolino, 1998; Lomolino, 2001).

Topographic and other environmental heterogeneity gains more importance in explaining the variation in species richness at landscape scales (O'Brien *et al.,* 2000). Topographic heterogeneity owing to the effect of slope, aspect and altitude affects the distribution of individual plants and communities by indirectly regulating the distribution of moisture, nutrients and through the influence of micro-climatic and hydrological processes in the site (Parker & Bendix, 1996).

Various researches have been carried out in Nepalese Himalaya to show a relationship between species and elevation at both regional and local sale. All the studies came to the similar conclusion that species richness shows a unimodal relationship with elevation

(Grytnes & Vetaas, 2002; Vetaas & Grytnes, 2002; Bhattarai *et al*., 2004a; Carpenter, 2005; Grau *et al*., 2007; Baniya *et al*., 2010; Acharya *et al*., 2011). Grytnes & Vetaas (2002) and Vetaas & Grytnes (2002) used the secondary data from the literature to show the relationship between species and elevation, showed the unimodal relationship forming peak between 1500 m and 2500 m and plateau between 3000 m and 4000 m. Similarly, the interpolated richness peak for ferns was observed at 1900 m (Bhattarai *et al.*, 2004a), for liverworts and mosses show richness peaks at 2800 and 2500 m (Grau *et al*., 2007), for lichens was observed between 3100-3400 m (Baniya *et al*., 2010), while orchids show richness peaks at 1600 m (Acharya *et al*., 2011).

The empirical study on species density and elevation from the eastern Nepal shows a unimodal pattern for understory plants and trees (Carpenter, 2005), while a high elevation plateau in richness was found in central Nepal (Panthi *et al*., 2007). Bhattarai & Vetaas (2003) used empirical data for vascular plants from eastern Nepal between 100 and 1500 m and found a hump shape pattern for all spermatophytes, shrubs and trees, while, woody climbers and ferns showed a positive monotonic trend with elevation. Climbers, herbaceous climbers, all herbaceous plants and grasses have no significant relationship with elevation (Bhattarai & Vetaas, 2003).

The species richness pattern along an elevation gradient at local–scale in the Nepalese Himalaya was observed from the eastern Nepal (Carpenter, 2005; Bhattarai & Vetaas, 2003), however, some works cover the central Nepal (Panthi *et al*., 2007; Rijal, 2009). None of them cover western Nepal. It is found a lacuna to observe a species relation with elevation along with different environmental parameter in sub-alpine and alpine areas from the western part of the country for assessing their upward shift in the future. Thus there is an immediate need to observe the pattern of species richness in the Nepalese Himalayas focusing specially in western region of the country that consist both subalpine and alpine vegetation. The pattern observed here along with the pattern observed in Central Nepal and Eastern Nepal collectively tells the pattern of species richness of subalpine and alpine region for Nepalese Himalayas.

The present research tries to address issues of pattern of species richness with altitude at fine scale in western Nepal by avoiding sampling biases as suggested by Lomolino (2001) and Whittaker *et al.* (2001).

1.2 Research Questions

Following research questions were designated:

- What is the general pattern of vascular plant species richness with altitude at local scale?
- What is the role of altitude in determining pattern of different functional groups?
- Is there any role of environmental parameter like moisture, pH, grazing and rock cover in shaping the richness pattern?

1.3 Hypothesis

The hypothesis are:

- There is a monotonic decline in vascular plant species richness along with altitudinal gradient in a local scale.
- All the functional group of vascular plant follows the same pattern as shown by vascular plant species.

1.4 Objectives

The overall aim of the study is to test the hypothesis based on the objectives. The general objective of the study is to understand species richness pattern along the altitudinal gradient. The specific objectives are as follows.

1. Make models of vascular plant species richness along the elevation gradient from subalpine to alpine region by means of empirical study.
2. Relate the empirical richness pattern to quantitative environmental variables, such as grazing, rock cover, relative radiation index, soil moisture and soil pH.

Chapter 2

MATERIALS AND METHODS

2.1 Study Area

2.1.1 Biogeographical location

Humla district is situated in the north western corner of Nepal. The district belongs to the *Karnali* region, and administratively, to the Mid-Western Development Region (MWDR) of Nepal. It stretches between 29° 35' to 30° 70' north latitude and 81° 18' to 82°10' east longitude, and spans an area of 5,655 km^2. The terrain of Humla is rugged with elevations ranging from 1,220 to 7,336 m a.s.l. (meters above sea level). It borders with *Mugu* district in the east; *Bajhang* district in the west; *Bajura* district in the south and the Tibetan autonomous region of China in the north (DDC, 2004). *Simikot* is the district headquarters of Humla district, which is situated at elevation of 2,945 m a.s.l., and located at latitude of 29° 58' N latitude and 81° 50' E longitude. Humla has been divided into three regions namely lower, middle and upper Humla. The division is based on the location from the district headquarters – *Simikot*. Lower Humla is situated in the south of *Simikot* which consists of 13 VDCs. The 8 VDCs at the north and north east of *Simikot* are known as middle Humla, Upper Humla, which lies north-west of *Simikot*, consists of 6 VDCs (Roy, 2010).

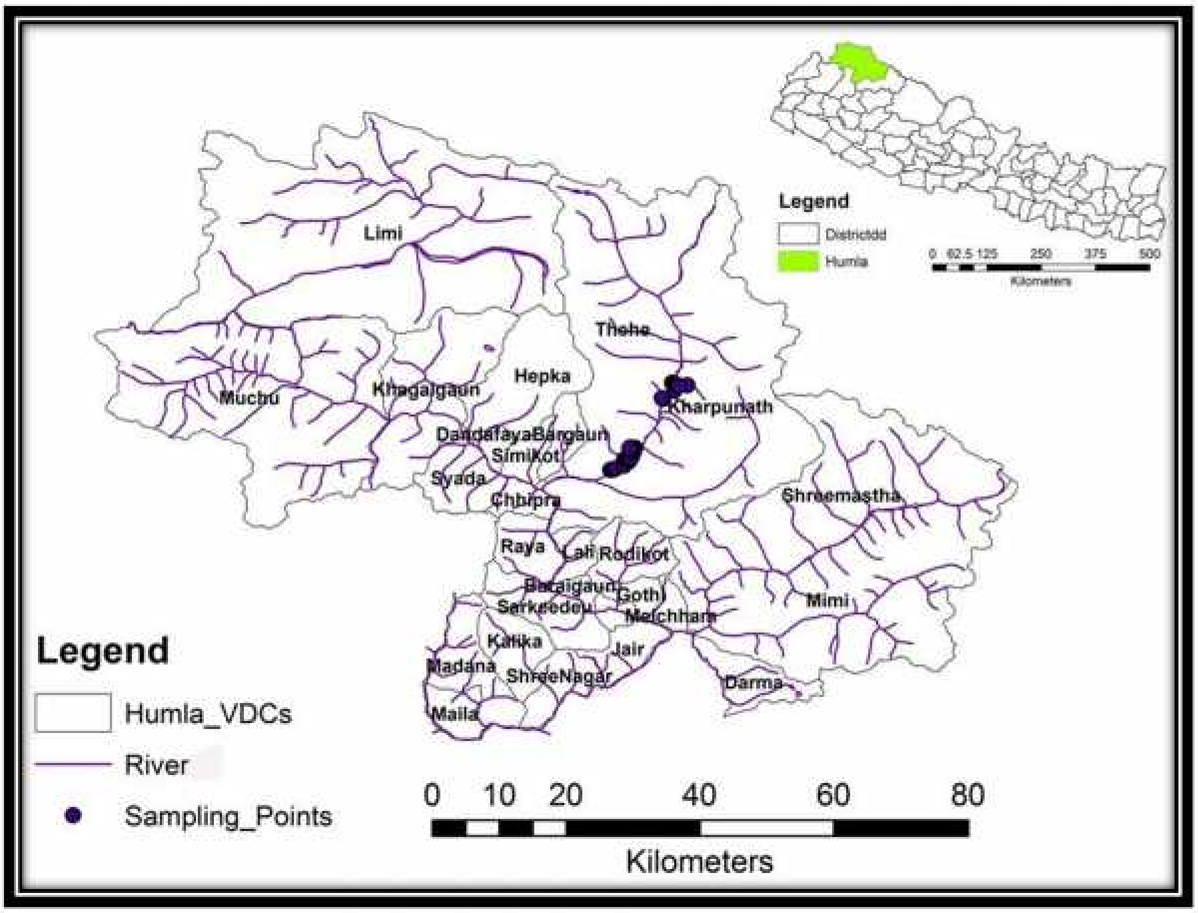


Fig 1. Location of the study area and sampling plots

2.1.2 Demography and Ethnicity

Humla district host the population of 40,749 of which 21,016 (51.57%) is male and 19,633 (48.43%) is female. This population is distributed in 6,974 households and an average household size is 5.8. The population density is 7.21 persons per sq. km. The larger share of population falls under age group 5-9 years and the population of age group 70-74 years is lower (CBS, 2001).

The people of Humla are known as *Humlis*.

The district has following ethnic composition: *Chhetri* (44.2%), *Thakuri* (19.5%), Lama (16.1%), *Brahmin* (6.2%), and the occupational casts such as *Kami* (Black Smiths-5.66%), *Damai* (Tailors-2.36%) and *Sarki* (Cobblers-1.2%). In addition, remaining 4.78% of population represents other ethnic group.

The Language spoken in the district is *Humli Khas* spoken by 84.38% of total population, while *Lama Kham* by 15.32% and others by 0.3% population. It is believe that Nepali language, a national language of Nepal, is originated from *Humli Khas* (Roy, 2010). Similarly, 78.2% and 20.2% of population devote in Hindu and Buddhist religion respectively. In addition, remaining 1.6% of population does not specify their religion during census 2001.

The Lama ethnic groups practice polyandry system, which is now disintegrating gradually due to various internal and external factors such as modernization, education, social and cultural-mixed with other caste group/s and so on. However, this system is good in terms of economic aspect and make family bond strong. In contrary, *Chhetri* and *Thakuri* caste generally separated from the parent family after they get married. They prefer nuclear family. This is how, Lama ethnic group seems to be wealthy than *Chhetri* and *Thakuri*.

The Dalits (locally called *Dom*) such as *Kami*, *Sarki* and *Damai* are still socially discriminated. This community is also economically vulnerable.

2.1.3 Climate

The altitude and topography varies greatly in Humla district. The climate of the region varies widely from subtropical to alpine type. Climate of the area is generally characterized by high rainfall and humidity; whereas some part of district is drier (Zomer & Oli, 2011). In north, most part is covered with snow and the climate is alpine. In the Southern part and valleys the climate is subtropical, and in middle hill region climate is a temperate type. The average maximum temperature is 25 ºC and the minimum temperature is –12 ^{o}C, and rainfall ranges from 25.4-146.9 mm, with nearly 80% of the total annual rainfall falling during the four months of monsoons from June to September. All areas experience very high rainfall intensities, while upper part of Humla is relatively much drier. Within its elevation range up to 2,000 m there are limited subtropical valleys in the southern margin although most of the area is physiographically temperate or highland. A cold, generally dry climate exists in the high alpine valleys just north of the southern arm of the Himalaya that cuts across the bottom of Humla. The climatic data was obtained from Department of Hydrology and Metrology, Babarmahal which was recorded from the station of district headquater, *Simikot*.

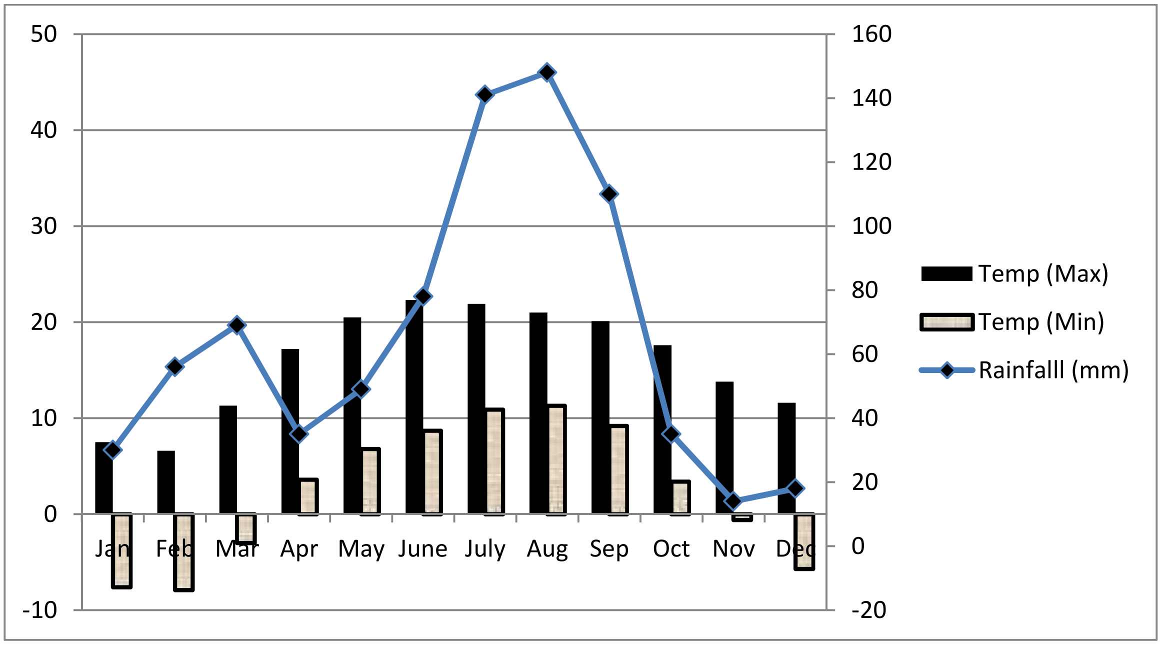


Fig 2. Average maximum and minimum temperature (^{0}C) and average rainfall recorded at *Simikot* station (1989-2006). *Source*: Department of Hydrology and Meterology, Kathmandu, Nepal.

2.1.4 Soil

In the High Himalayan region fine particles of stony soil exit in cracks of larger rock while in high mountains stony soil is found. In the Middle Mountain soil is moderately to high acidic, medium to light textured coarse grained sand and gravel. Soils of the lower region are predominantly fine to coarse loam; and alluvial and coarse textured in irrigated field. Soils in the middle mountains are moderately acidic, medium- to light- textured coarse grained sand and gravel (Field survey, 2010).

2.1.5 Vegetation

Altogether 25 forest types ranging from Chir Pine forest (1000-2700 m) to Caragana Steppe (4000-4500 m) (Source: Stainton, 1972; Appendix 1) are found in the region, however, the vegetation of our sampling area can broadly categorized within three vegetation zones:

i) Upper temperate zone (2800-3000m asl)

The most dominant tree species of the region are *Juglans regia, Acer oblongum, Picea smithiana, Pinus wallichiana, Prunus rufa,, Ulmus wallichiana*. Similarly, the dominant shrubby vegetation is represented by *Rosa brunonii, Rosa macrophylla, Principea utilis, Pyracantha crenulata, Viburnum cotinifolium, Elsholtzia fructicosa* and herbs by *Urtica dioica, Gerardiana diversifolia, Polygonatum verticillatum, Viola biflora, Valeriana hardwickii, Origanum vulgare, Thalictrum foliolosum* and *Astilbe rivularis.*

ii) Subalpine zone (3000-4000m asl)

Most of the woody species found in this zone are the tree line forming species. The dominant tree species are *Abies spectabilis, Betula Utilis, Rhododendron campanulatum, Taxus wallichiana* with understory shrubs like *Rhododendron lepidotum, Ribes griffithii, Ribes gracile, Lonicera rupicola, Spiraea bella, Rosa sericea, Sorbus cuspidata* and herbs like *Primula atrodentata, Fritillaria cirrhosa, Dactylorhiza hatagirea, Polygonatum hookeri, Rheum australe, Oxyria digyna* and *Meconopsis horridula*.

iii) Alpine zone (Above 4000m asl)

This zone is mostly represented by bushy species like *Caragana bravifolia, Rhododendron anthopogon, Hippophae tibetana, Spiraea arcuata* and the meadow species like *Primula aureata, Neopicrorhiza scrophulariiflora, Nardostachys grandiflora, Leontopodium jacotianum, Saxifraga andersonii, Saussurea* species and *Thalictrum alpinum*.

2.1.6 People and Forest resources

Humla is rich in natural resources especially in forest products, Non-Timber Forests Products (NTFPs) and Medicinal and Aromatic Plants (MAPs). In Nepal, NTFPs are used in subsistence livelihood such as foods, spices, herbal medicine, tannins, natural dye, gums, resins, incenses, oils, fibers and construction materials (Edward, 1996 cited in Roy, 2010). The NTFPs play a remarkable role in the family. Different species of NTFPs have been used in the daily household chores in the remote and mountainous regions of Nepal for food and medicine where Humla district is no exception. They are directly linked with the everyday livelihood of the people. Trading of NTFPs species is a major source of income for people living in remote and mountainous regions where people are poor. In this context, collection, transportation and selling of NTFPs species can be a regular source of income as off-farm employment. NTFPs species are important source of income for subsistence livelihood at household level in Humla district.

2.1.7 Animal husbandry

The livestock available in Humla are: Yak (*Bos grunniens)*, *Jhhupaa*, *Jhhumaa*, Horse (*Equus ferus)*, Donkey (*Equus africanus asinus*), Mule, Ox (*Bos primigenius)*, Cow (*Bos primigenius)*, Goat (*Capra aegagrus*) and Sheep (*Ovis aries*). Male animals especially yak, *Jhhupaa*, horse, donkey, goat and sheep are used as pack animals. Other purposes of keeping animals are for milk and milk products (ghee and *Chhurpi*), meat and wool.

Humli take their livestock specially *Jhhupaa*, *Jhhumaa*, and ox to the *Lek* which is commonly known as *goth*. Transhumance starts around mid March and ends around mid November. This eight months rotation of moving livestock to the higher altitude in summer and bringing them back to the lower elevation in winter is a part of the livelihood activities of *Humli*. For the remaining four months in winter, *Humli* keep livestock at *goth* starting from mid December to mid March. The herds of livestock are taken to higher elevations gradually. The livestock stop at every station for two to three weeks. There are three to five stations from the settlement to the pasture land – last station of *Lek*. Every station has agricultural land except the last station, which is not suitable for cultivation of agricultural crops. However, green grass and water are adequately available in the last station of *Lek* for the livestock. Generally, livestock reach the last station of pasture land in between the second and third week of July. Livestock graze there for nearly four to eight weeks and return back to settlement in between the first and second week of September. During these periods, people, who are staying in the pasture land, produce ghee and *Chhurpi* (dried smoke cheese) from *Jhhumaa* milk.

2.2 Sampling Design and Data collection

2.2.1 Sampling Design

The present study was conducted in the month of May 2010. Prior to detail sampling of plots, the sampling site was selected by KSLCI team. A semi-systematic representative sampling was used for data collection to cover all the possible habitat and vegetation types. All the sampling plots were located on the southern slope of the southern Himalayan main range. The sampling method was designed to include all the habitat types and vegetation zones within 2800 to 4400 m. a.s.l. Five plots of 10 × 10 m were sampled in each 100 m elevation band (Rijal, 2009) i.e. a total of 80 plots between 2800-4400 m a.s.l. Each plot was divided into four sub-plots of size 5 × 5 m and species presences were recorded for each subplot separately. The first plot was laid by observing the tallest tree in the altitudinal range in the forest while in open shrub and grass land the plot was lead randomly by altitude observation. The distance between two plots is not less than 20 m (walking distance) to avoid the clustering of the plots. To avoid biasness the direction of next plot from the earlier one was determined by lottery. The sampling design in a hypothetical mountain slope is shown in figure 3.

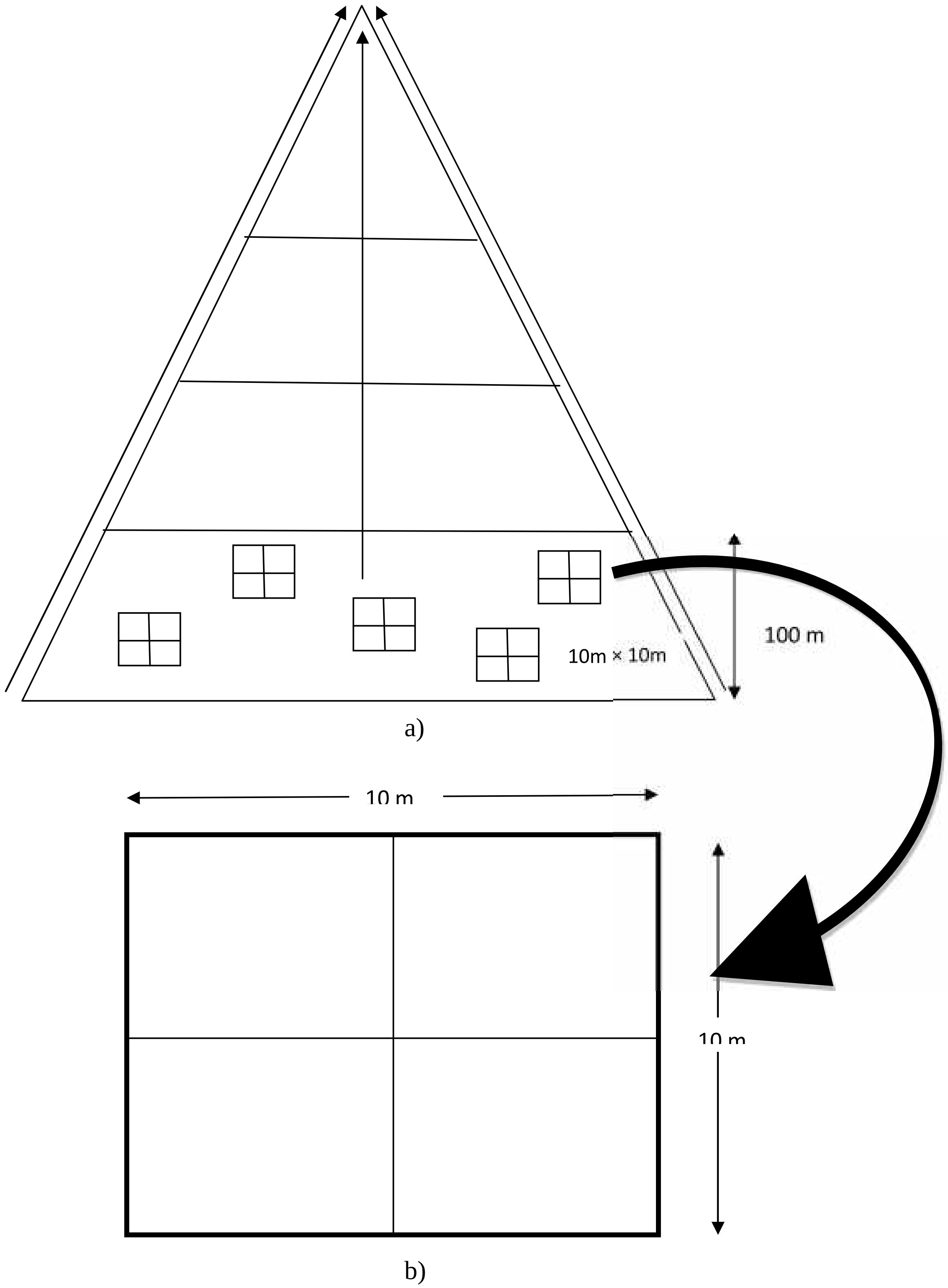


Fig 3. Sampling design in a hypothetical mountain slope: (a) sampling strategy for each 100 m belt and (b) sampling strategy for each plot.

2.2.2 Environmental Parametres

Longitude, latitude, and elevation of each sample plot were recorded by global positioning system (GPS, eTrex Garmin) and elevation was cross-checked with a standardized altimeter. Slope and aspect of each plot were recorded by a clinometer compass. Soil moisture and pH of each sub-plot were recorded by using a gauge (Soil pH and moisture Tester; Model DM 15) with a default scale of 1 to 8 for both parameters. Dung deposition and location of the plot from goat-sheds were combined to evaluate the grazing gradient. Grazing was graded on a zero to four scale starting from zero for no sign of grazing and four for the plot where dung were present in all subplots. Plots very near to goat-sheds were assigned level four and farthest as level one and zero for no goat-shed within the territory. The average value of both was considered in the analysis. The rock cover was estimated by visual observation. The average of three people's estimation was used for analysis. The numerical value of zero to four was given, where one was given if the exposed surface area consists about 25% of rock of the total 10 x 10 m plot whereas four was given if whole exposed surface area was covered by rocks.

2.2.3 Data Preparation

The field data sheet were further elaborated and filled in MS excel for numerical analysis. Presence-absence data was used for the calculation. The total Vascular plant species were further classified into various lifeforms or functional groups as Dicot, Monocot, Herbs, Shrubs and Trees using the *Annotated Checklist of the Flowering Plants of Nepal (*Press *et al.*, 2000). Soil pH, moisture, grazing intensity, rock cover, relative radiation index (rri) along with altitude itself was mainly considered as environmental variables. For the interpolated empirical richness, species list was taken from the empirical field data while *An Annotated Checklist of Flowering Plants of Nepal* (Press *et al.*, 2000) was used for the elevation ranges of the species.

2.3 Specimens collection and identification

Most of the plant species were identified in the field at the time of data collection using the floristic literatures Polunin and Stantion (1984) and Stantion (1988). Experts from the Central Department of Botany were helpful in the field for plant identification. Species that could not be identified in the field were collected, tagged, made dry and brought to Central Department of Botany for further identification. Digital photographs of live plant species were taken in the field and the photo number and tag number were noted. The unidentified specimens were identified by comparing the specimens with relevant specimens deposited at Tribhuvan University Central Herbarium (TUCH) and National Herbarium and Plant Laboratories (KATH). Experts from the Central Department of Botany and KATH were consulted for identifying species along with the photographs. Tag number and photo number were used for correct naming of species. Monocots were identified with the help of *Flora of Bhutan*. Press *et al*. (2000) was followed for the nomenclature. Some of the species identified to the genus level were also incorporated in the analysis. Voucher specimens are housed at TUCH.

2.4 Numerical Analysis

Species density is defined as the total number of species encountered within a quadrat or in 100m^2 plots. Species richness (*gamma* diversity) refers to the total number of individual species within a community (Lomolino, 2001) or in other words it is the total number of individual species present in all the five plots of 100m^2 or 0.01 ha at 100m elevation range. Interpolated empirical richness was calculated for each species which occur in 100m elevation band between 2800-4400 m a.s.l. in the study. The term species richness has been used for gamma diversity (band richness and interpolated empirical richness) for generality. Species density and species richness were treated as the response variables and regressed against altitude. Flowering plants were further splitted into different life-forms and were also used to evaluate their richness patterns (Bhattarai & Vetaas, 2003).

Species density of total vascular plants, dicots, monocots, herbs, shrubs and trees were individually regressed against altitude while total species density was also regressed with soil moisture, soil pH, grazing, rock cover and relative radiation index (RRI). RRI was calculated for each plot (Ôke, 1987) and its value ranges from +1 to -1. A Generalised Linear Model (GLM: McCullagh & Nelder, 1989; Dobson 1990) was used to elucidate the pattern of species richness along the altitudinal gradient. A log linear model with a Poisson error distribution was used for the analysis due to the count nature of the response variables. The Chi square-test statistics was used for analysis. A quasi- Poison error distribution with F- test was used where the data showed the over dispersion to handle the over dispersion of the deviance (Crawley, 2007). The significance of each model was tested against the null model as well as with each other up to the third-order polynomials. Forward selection of model was done. The model with higher F-value and highly significance value of Chi square test was selected for the model fitting and graphical representation. R version 2.10.1 (R Development Core Team 2010) was used for regression analyses and graphical representation.

Chapter 3

RESULTS

3.1 Species composition

A total of 199 vascular plant species were recorded from 80 sampling plots within a range between 2800m-4400m asl. The vascular plant species were further categorised into the different functional group in which dicots were found dominant over monocot. The dicot plant species were represented by 165 plant species whereas monocots were represented by only 23 plant species. In comparison of different functional group the herbaceous species were dominant over woody species (include both trees and shrubs) where the former were represented by 145 species whereas the later by 56 plant species. 21 species of trees, 35 species of shrubs, only 7 species of gymnosperms and 4 species of pteridophytes were present within a range between 2800-4400 m a.s.l. (Appendix 2).

3.2 Species richness pattern

The species richness pattern in this case was shown in the form of species density and species richness as defined earlier. The species density pattern was represented by empirical field data whereas species richness pattern was represented by both empirical as well as interpolation of species. The patterns observed by different functional group were also shown. Both the species density and species richness were regressed against altitude and environmental parameters.

3.2.1 Species richness pattern and altitude

3.2.1.1 Species density

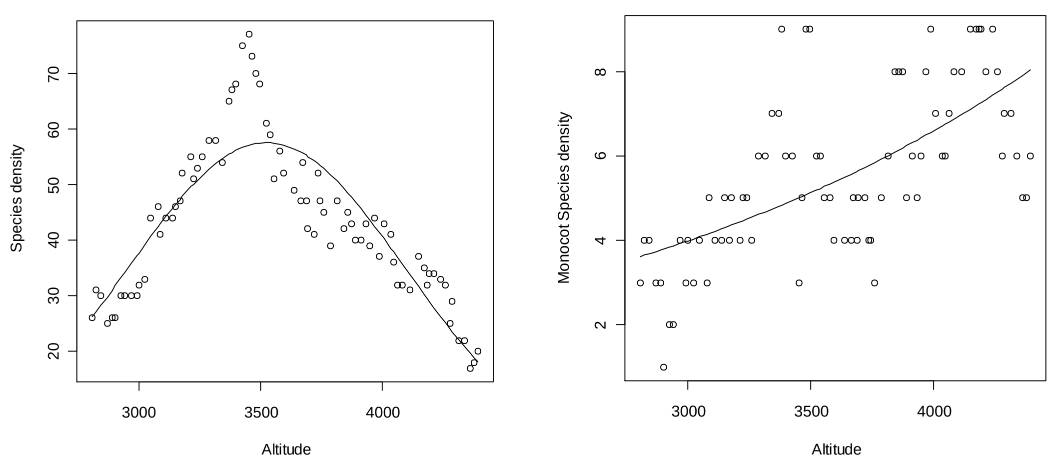
Species density pattern of total vascular plants

A unimodal relationship was observed between species density when regressed against altitude (fig.4a). Statistically both 1st and 2nd order polynomial was found significant but second order polynomial was the most appropriate model that fit the pattern (Appendix

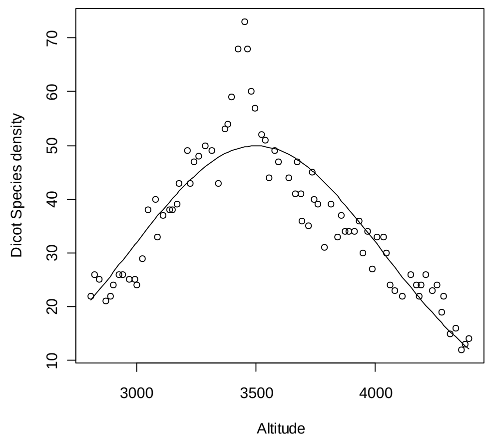
4a.). Here, the species density was low at lower and upper altitude while the more species were accumulated at the mid altitude forming a hump shaped pattern. The highest species density occurred at an altitude of 3455m represented by 77 species whereas the lowest species density was encountered at an altitude of 4362 m represented by only 17 plant species.

Species density pattern of different functional group

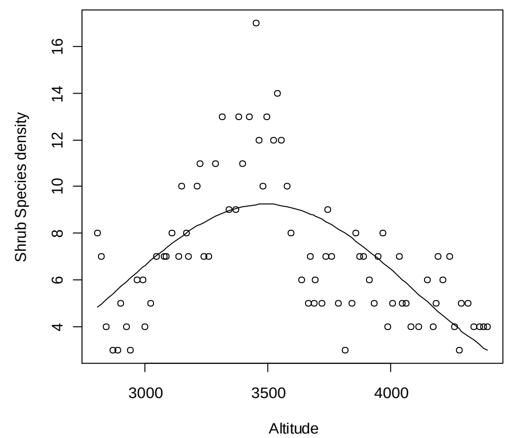
The pattern observed above was also found in case of species density of different functional group when regressed against altitude in most of the cases. It was common to dicots, herbs, shrubs and trees (fig. 4 c,d,e,f ; Appendix 3a) but in case of monocot there was a linear increase of species density with altitude (fig 4b). The dicots, herbs, shrubs and trees species peaked at an altitude of about 3500 m, 3500-3600 m, 3500 m and 3400 m respectively, formed a unimodal pattern while the monocot species have a highest species density at an altitude of 4100 m- 4200 m forming a linear pattern. The shrubs and trees species density shows the richness plateau at an altitude between 3300 m- 3800 m and 3200 m – 3700 m respectively. The Generalised Linear modal was used where the first and second order polynomial was found significant and second as the most appropriate model for dicots, herbs, shrubs and trees while the first order polynomial for monocots species.



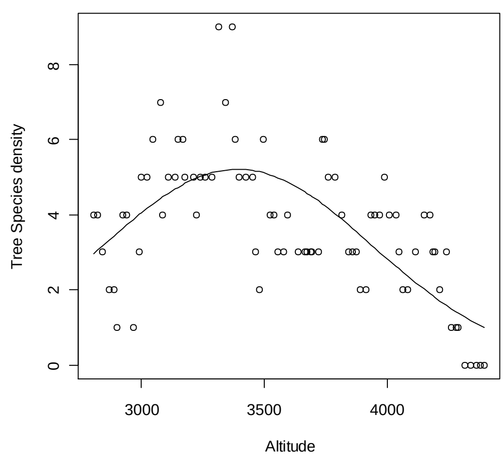
a) b)



c)



d)



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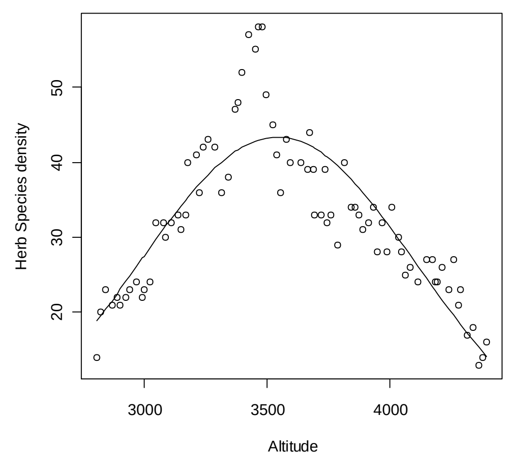


f)

Fig. 4. Relationship between plant species density of total vascular plants and different functional group with altitude (lines are fitted with GLM, 2^{nd} order for species density of total vascular plants, dicots, herbs, shrubs, trees and 1^{st} order for monocot) ; See Appendix 3a for regression statistics.

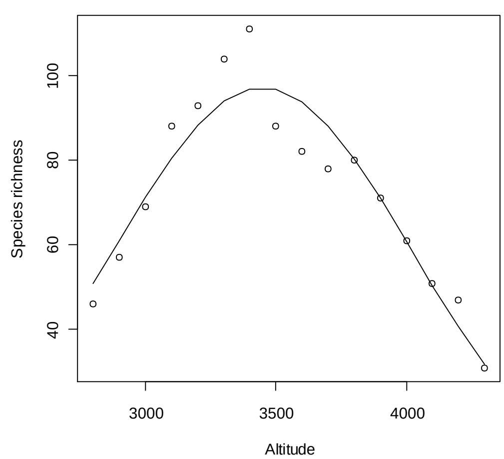
3.2.1.2 Species richness

Species richness pattern of total vascular plant

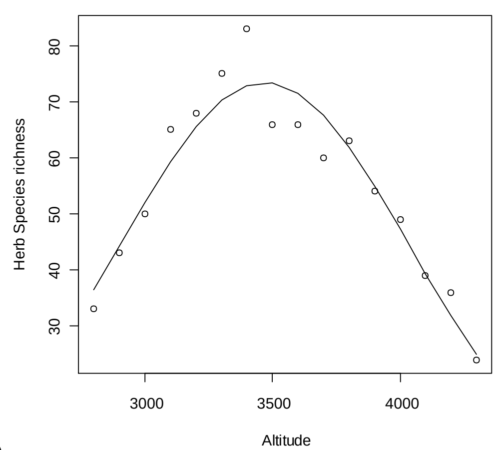
The species richness of all the vascular plants showed a unimodal pattern with altitude (fig 5a; Appendix 3b). The 1st and the 2nd order polynomial were significant statistically and the second order polynomial as the best fit model. The species was accumulated at mid elevation at an altitude between 3400-3600 m and decrease in both directions afterwards forming a unimodal pattern.

Species richness pattern of different functional group

Species richness pattern of all functional group i.e. dicots, herbs, shrubs and trees showed a unimodal pattern with altitude. The richness peak was found at an altitude approximately between 3400-3600 m, 3400-3600 m, 3300-3500 m and 3200-3500 m respectively (fig 5 b,c,d,e; Appendix 3b.). The trees species richness shows the richness plateau at an altitude between 3100 m – 3600 m. The monocots species richness was not found significance with altitude. GLM of both first and second order polynomial were found significance for all functional group but the second order polynomial was the most appropriate model to fit the data. (See Appendix 3b for regression statistics).



a)



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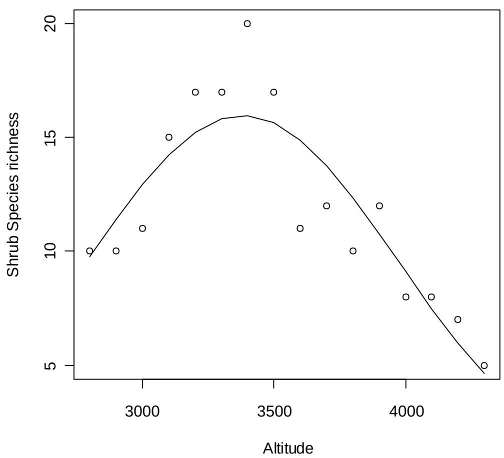

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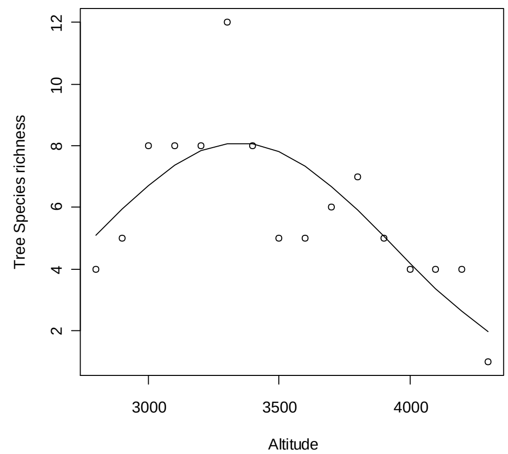

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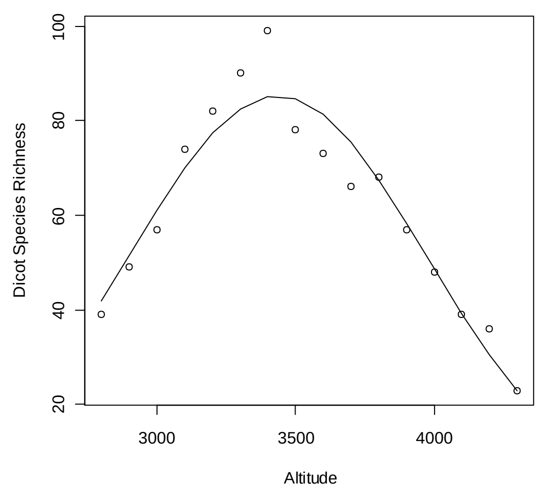


e)

Fig. 5. Relation between species richness with altitude of different functional groups (all the functional group are fitted with 2nd order polynomial) ; see Appendix 3b. for regression statistics.

Interpolated empirical species richness

Species richness calculated by interpolation when regressed with altitude, a hump shaped pattern was observed. A richness pattern showed a peak at an altitude of approximately 2900-3600 m (fig 6) and decreased both at lower and higher altitude. A GLM with both 1st and 2nd order polynomial were strongly but the second order polynomial was the best fit model (See Appendix 3b for regression statistics).

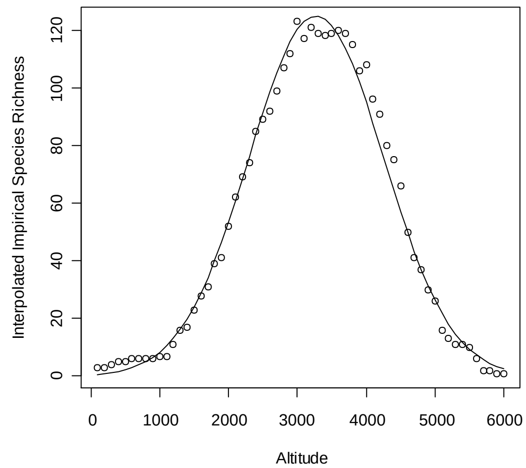


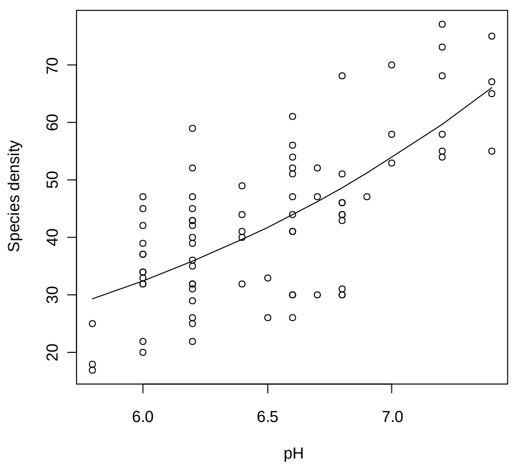
Fig. 6. Relationship between interpolation empirical species richness with altitude (lines are fitted with GLM 2nd order); see Appendix 3b for regression statistics.

3.2.2 Species richness pattern and environmental variables

Species density and environmental variables

Species density of each plot was regressed against different environmental parameters to show the pattern. The environmental parameter in the study area includes soil pH, soil moisture, rock cover, grazing intensity and Relative Radiation Index (RRI). The species density of total vascular plants was regressed against each environmental parameter separately and found a different pattern. Soil pH and grazing intensity showed a linear increase in species density from acidic to alkaline soil (Fig 7a; Appendix 3c.) and low to high grazing respectively (Fig 7d; Appendix 3c.). The maximum species occurred at soil pH 7.5 (Fig. 7a) and high grazing scale of 4 (Fig 7d). Both soil pH and grazing intensity was significant over the 1st order GLM (Fig 7 for pattern and Appendix 3c. for regression statistics.)

The species density decrease linearly with Relative Radiation Index (Fig 7b) and rock cover (Fig 7c). Statistically 1st order polynomial GLM was significant in both case (Appendix 3c for regression analysis). The species density showed a unique pattern with moisture content. A hump back- shaped curved was observed (Fig 7e; Appendix 3c for regression analysis). The species density is high at lower and higher moisture. The species density decrease from lower moisture content to higher moisture to some extent and increased further up forming a hump back- shape curve. Both the first and second order polynomial was significant when species density was regressed against moisture content but second order polynomial model best fit the data.



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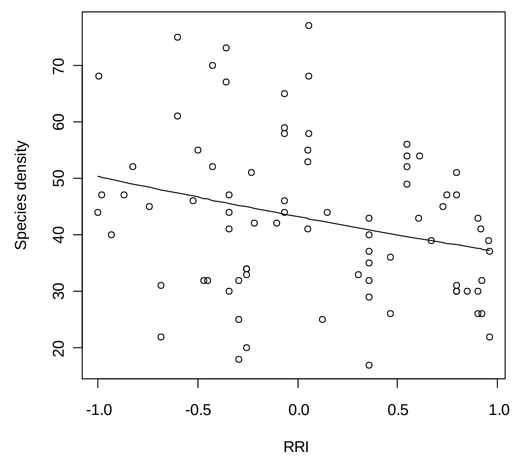

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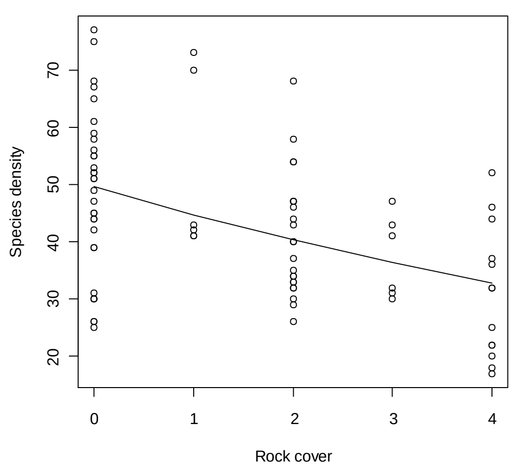

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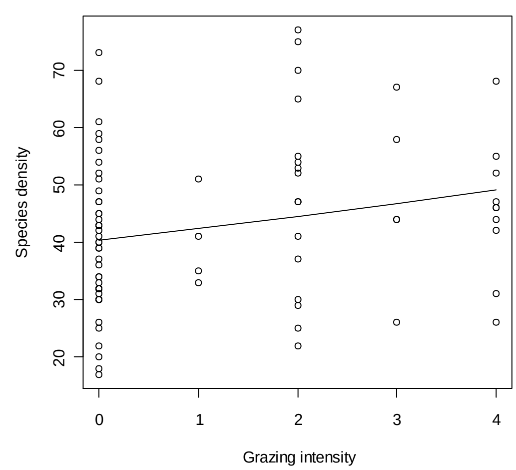

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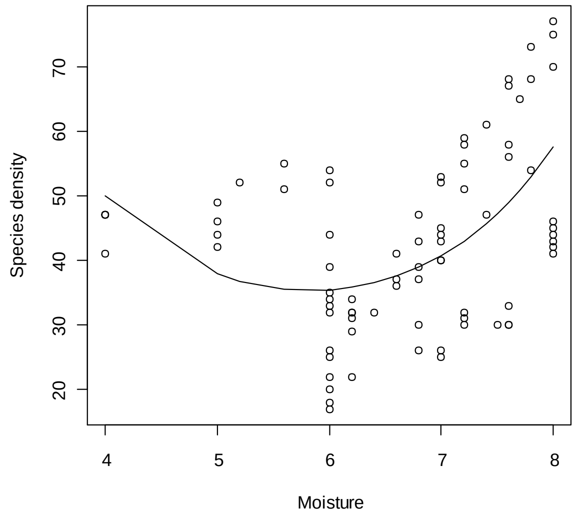

e)

Fig. 7. Relationship between species density and environmental variables (lines are fitted with 1st order GLM (fig. a, b, c and d) and 2nd order GLM (fig. e); see Appendix 3c for regression statistics).

Chapter 4

DISCUSSION

4.1 Species richness and altitude

4.1.1 Species density and richness of total vascular plant

Most of the species richness studies suggest that the highest species richness appears at the mid-altitudinal zones forming a unimodal pattern (Sanders, 2002; Grytnes & Vetaas, 2002; Bhattarai & Vetaas, 2003; McCain, 2004; Carpenter, 2005; Oommen & Shanker, 2005) but monotonic decrease in species richness with increasing elevation is not uncommon (Stevens, 1992). In this study, richness and densities of all the vascular plants showed hump-shaped patterns across a broad altitudinal range (fig. 4a, 5a and 6). The pattern observed above in this study was similar with a pattern observed by several author from different part of the world as Rahbek (1995 & 1997), Brown (2001), Lomolino (2001), Grytness & Vetaas (2002), Carpenter (2005), Nogues-Bravo *et al*. (2009) and Rowe & Lidgard (2009) but Grytness & Vetaas (2002) also found a plateau around 4000 m a.s.l. which was not found in this study.

The reasons for this situation are complex. The characteristics of biodiversity generally result from two factors, evolutionary history and contemporary ecological conditions (Whittaker *et al*., 2001; Ricklefs, 2004). If we assume that evolutionary history is identical, we can infer that the species groups that have the same or similar ecological requirement and ways of adapting or responding to the environment may also exhibit the same or similar distribution of diversity in space.

Ecological phenomena are hierarchically structured, which is related closely to the scale of observation (Meentemeyer, 1989; Whittaker *et al*., 2001). It is increasingly acknowledged that traditional statistics have severe limitations in describing ecological patterns and determining relationships among ecological factors, in particular by not allowing for the scale dependence of spatial data (Legendre & Fortin, 1989; Legendre, 1993). Thus, the challenge to contemporary ecology and biogeography is to document scale dependence or independence in different systems.

The factor for unimodal pattern observed from this study was also may be due to the combination of climate related water energy-dynamics, species area-relationships and local environmental factors which have direct effects on plants physiological performance. The unimodal structure of richness along altitude is primarily related to water energy dynamics or productivity (O'Brien, 1998; Rahbek, 2005)**.** The evapotranspiration affect the biological processes and competitive interaction among species and thereby affected species richness along the gradient (O'Brien *et al.*, 2000).

It has been widely observed that species richness increases as a function of area (He *et al*., 1996; Rahbek, 1997). Lomolino (2001) argued that total number of species should be higher in the lower elevation zones because of species-area relationships. Along mountain slopes area tends to decrease with altitude. Hence, larger area in the lower elevation zones would be expected to support more heterogeneous environments, provide wider geographical ranges for species, and a lesser degree of isolation for potential immigrants (Lomolino, 2001). By contrast the elevation zones in the higher altitude were smaller in area and characterized by a high degree of isolation and dispersal limitations. This might be the result of a unimodal pattern of species richness found in this study. Romdal & Grytnes (2007) discussed the potential influence of surrounding elevation zone area as a regional pool of species on the local level richness. They found out a high correlation between the area within elevation band and species richness. The increase in the number of species especially above 3100 m a.s.l. coincides with the high richness. Thus, it suggests that biotic interactions (e.g. competition and facilitation) could also play an important role in affecting the pattern of richness and would also be the possible region of determining the unimodal pattern in this study.

The hump-shaped pattern for interpolated empirical richness observed in this study was due to the interpolation of species presence between lower and upper extremes of a given altitudinal range (fig 6), although it has been commonly applied in previous studies (Rahbek, 1997; Sanders, 2002; Vetaas & Grytnes, 2002) .The hump shaped pattern observed in this case was because the richness towards the endpoints consists only of observed species, whereas at the central regions the richness consists of the observed species and those added by interpolation.

The mid domain effect and the ecotone effect was also the main factor for creating the observed pattern of species richness. The mid domain effect (MDE) due to geometric constraints for species distributions was possible cause for such hump-shaped curves (Colwell & Lees, 2000; Colwell *et al*., 2004). The MDE was a contributor to the relationship between plant species richness and elevation in Nepalese Himalaya (Grytnes & Vetaas, 2002). Similarly to this, the MDE predictions of the null models fitted the empirical patterns well for both species richness and density for total vascular plants in this study.

An ecotone effect (high diversity in the ecotone due to significant overlap between communities) has been proposed in the context of elevational gradients and source–sink dynamics (Lomolino, 2001). The proportion of species shared and the amount of overlap between communities can play a significant role in determining the unimodal pattern of species richness by shifting of species towards the center of the elevational range. This study showed unimodal pattern at local scale (fig 4a and 5a). This can be explored further by looking at the contribution of marginal/sink species to the richness dynamics in the zones of overlap. Along a local gradient, richness in the ecotone was likely to be composed of ecotone specialists and a number of low abundance sink species contributed by spillover from adjoining biomes as shown by rescue effect hypothesis (Brown & Kodric-Brown, 1977) or by mass effects (Shmida & Wilson, 1985).

4.1.2 Species density and richness of different functional group

The patterns of species richness may be clarified if disaggregated into different functional types or life forms (Pausas & Austin, 2001) however, the studies focused too much in particular environmental factor (e.g. temperature, moisture, or soil nutrients). Comparing diversity patterns of different species groups, it was found that total plant species richness showed a unimodal pattern with altitude (fig 5a). Herbs, shrubs, trees, dicots and monocots displayed parallel diversity patterns for species density with elevation. The species density of herbs, shrubs, trees and dicots showed a hump shaped pattern that peak at mid- altitude (fig 4c,d,e and f) whereas monocot species density decrease monotonically with increasing elevation (fig 4b). The dicots, shrubs, trees and herbs species density shows the similar pattern as shown by Carpenter (2005) where as the monocot species density shows the linear trend with altitude which didn't match the finding with Carpenter (2005) where he showed the unimodal pattern for monocots species.

The species richness of all the functional group except monocots also showed a hump shaped pattern with altitude (fig 5 b, c, d and e) while monocots species richness did not have any significant relationship with altitude. This result showed the similar pattern with Bhattarai & Vetaas (2004a). The insignificant relationship of monocots species richness and altitude was might be due to the incomplete gradient length. Some studies (Rahbek, 1995; Bruun *et al.*, 2006) pointed out that different patterns would be observed if an incomplete gradient length was studied compared to the whole gradient which covers the full length of species responses.

These results suggest that changes in herb and dicots species density with elevation result mainly from local mean variation with altitude. The elevation pattern of total vascular species richness and density was greatly influenced by herbs and dicots species richness, owing to both of them being a major component of total plant species richness. From the comparisons above, it is suggested that species groups with similar ecological features have similar spatially structured characteristics of species richness when detailed patterns of species richness are revealed at different spatial scales.

In classical plant synecology, it is well known that plants can be divided by life form into trees, shrubs, and herbs based on ways they adapt to environmental stresses (Li, 1993), each of which uses similar resources and responds to the environment in similar ways (Pausas & Austin, 2001). Moreover, both trees and shrubs are woody plants, with similar requirements and responses to environmental conditions. Thus, the results from the present study suggest that species groups with the same or similar ecological features bear the same or similar patterns with altitude (fig 4d & e and fig 5c & d)

Patterson *et al.* (1998) contrasted elevation patterns for birds and mammals found that, although both bats and mice are mammals, they showed pronounced distinctions in their elevation species richness patterns. Conversely, bats and birds, although very different taxa, had very similar species richness distributions with altitude owing to their similar ecological characteristics. These results were similar to the findings of the present study, suggesting that biodiversity research may benefit by partitioning species into groups of ecologically similar species. Ma *et al.* (1995) investigated the distribution of herb species richness with altitude and concluded that herb species richness decreased monotonically with increasing elevation, showing an opposite pattern from that obtained in the present study (fig 5b). This discrepancy may arises from the fact that Ma *et al.* (1995) focused on elevation ranges of 1500–2300 m a.s.l., whereas the present study area ranged from 2800 to 4400 m a.s.l.

The mid domain effect was possible cause for creating hump-shaped curves (Colwell & Lees, 2000; Colwell *et al*., 2004). The MDE was a contributor to the relationship between plant species richness and elevation in Nepalese Himalaya (Grytnes & Vetaas, 2002) and also might be the factor for creating hump shaped pattern for different life forms observed in this study. The notable thing was that monocots species density showed linear decrease with altitude, thus, if the mid domain effect cause the unimodal pattern it should be followed for all life forms.

An ecotone effect has been proposed in the context of elevation gradient for the pattern of species richness. The proportion of species shared and the amount of overlap between communities can play a significant role in determining the unimodal pattern of species richness by shifting of species towards the center of the elevation range and was the factor in creating hump shaped pattern of species richness and density and could be considered as the most strong factor for creating such observed pattern.

4.2 Species richness and Environmental variables

Patterns of plant species richness at both local and broad scale result from a number of environmental and non-environmental processes act individually or together. Environmental determinants were the important factors proposed to explain species richness patterns (Brown & Sax, 2004). Here in this study the species density was separately regressed against different environmental factors (pH, moisture, grazing and rock cover).

Grime (1979) showed the presence of greater number of species in high pH soil. Partel (2002) showed a positive relationships between species density and pH where the pool of species suited for high pH soil is larger than the pool of species suited for low pH soil, and that negative relationships occur between species density and pH where the pool of species suited for low pH soil is larger than the pool of species suited for high pH soil. In particular, the prediction of Partel (2002) is that species density should be maximal on low pH sites where the flora has evolved in a low soil pH which was not supported by this result. This study showed the resemblance with Grime (1979) where species density increases linearly with increase in soil pH (fig 7a).

Soil moisture was an important factor affecting the pattern of richness (Peet, 1978; de Lafontaine & Houle, 2007). Bhattarai & Vetaas (2003) observed a positive linear trend in species density for total species and different life forms (shrubs, trees and climbers) with moisture but this study did not follow the pattern as shown by them and found the hump back-shaped when species density was regressed against moisture (fig 7e).

The general consensus of species richness should peak at moderate disturbance (grazing) (Lomolino, 2001; Bhattarai *et al.*, 2004b; Nogués-Bravo *et al.*, 2009) but this results did not match with this finding and found the gradual increase in richness pattern with grazing (fig 7d). The anomalous pattern of this study with previous finding was because the cattle spend more time in over graze area and thus helped to make the soil more nutritive. Despite that the cattle also helped in seed dispersal (Panthi *et al.*, 2007）of plant species forming more species at the region.

From biological perspective, topographic variables are indirect factors, which do not necessarily have a physiological influence on species, in contrast to direct factors such as temperature and soil nutrients (Austin *et al*., 1984; Austin, 1985; Austin & Smith, 1989). This study here focused on the important of topographic factor which are measurable to show the pattern of species richness. On a local-scale, topography facilitates the compression of biotic communities into relatively constricted vertical spaces and produces rapid species turnover (McLaughlin, 1994) that may be the cause of different pattern of species density. In this study RRI and the stone cover was used to show the species density pattern. The RRI and stone cover both showed the linear pattern. This study showed that the species density had a negative relation with RRI (fig 7b) which was also observed in previous study (Klimek, *et al*., 2007). The reason behind it may be due to the increasing radiation and slope with altitude. The rock covered by the expose surface area also had the negative relation with species density (fig 7c). This was because in such area the land was barren and less nutritive. Beside that the area decreased when the rock covered increased.

Chapter 5

Conclusion

Hump-shaped species richness patterns were observed for a total vascular plant species as well as several growth forms. The pattern was same for empirical and interpolation. The pattern of richness observed in our study also varied with several categories of growth forms. Generally, however, hump-shaped richness patterns were observed for several categories. Thus from this study it can be concluded that the richness pattern is similar for both empirical and interpolation. Besides that the pattern is also similar for different life forms or functional group i.e. hump-shaped richness pattern except for monocot (linear pattern).

Several factors such as climate related water energy-dynamics, species area relationships, and local environmental factors may work in concert to produce such observed patterns. In addition, altitude represents composite gradients of several environmental variables which at times are inter-correlated. A number of other environmental variables play a dominant role to explain the pattern of richness at the local scale. At the local scale topographic and substrate heterogeneity, as well as soil properties capture the patterns of species richness along elevation gradients. Disturbance regimes, may also play a considerable role in structuring the pattern of diversity distributions in anthropogenically modified landscapes. Thus, considering multiple gradients would help to reveal better pictures of richness patterns and the potential mechanisms that structure the distributions of biodiversity in high mountainous region.

The study area here represents a part of western region of Nepal or Western Himalaya. From this study it can be concluded that the species richness pattern of vascular plants is unimodal with hump shaped structure for western Nepal.

Finally, from this study the hypothesis set were rejected since the richness pattern of total vascular plants and different life forms (functional group) except monocot showed the unimodal pattern. Like that the species number in the given altitude was determined by the environmental parametres.

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Appendix 1.

Forest types found in the Humla district (Source: Stainton, 1972)

S.No	Forest Type	Altitudinal range (m asl)
1.	Chir pine forest	1000-2700
2.	*Alnus* forest	500-2700
3.	Oak (*Quercus incana, Q. lanuginosa*)- chir pine forest	2000-2400
4.	Oak (*Q. dilata*) forest	2100-2750
5.	Oak (*Q. semecarpifolia*)- blue pine forest	2450-3000
6.	Oak forest (*Quercus semecarpifolia*) forest	2450-3100
7.	Pine (*Pinus excelsa*) forest	2000-3200
8.	Lower temperate mixed forest (*Michelia kisopa, Lithocarpus spicata, Castanopsis tribuloides*)	2000-2500
9.	*Aesculus- Juglans-Acer* forest	2000-2900
10.	*Tsuga- Pinus excelsa* forest	2100-3200
11.	*Cupressus torulosa-Abies pindrow* forest	2100-2900
12.	*Picea smithiana* forest	2150-3200
13.	*Abies pindrow* forest	2150-2900
14.	*Cedrus deodara* forest	2000-2600
15.	*Cupressus torulosa* forest	2150-2900
16.	*Populus ciliata* forest	2150-3200
17.	Mixed coniferous (*Pinus-Picea-Abies*) forest	2800-3500
18.	*Abies-Juniper* forest	3000-3500
19.	*Betula utilis* forest	2900-3800
20.	*Abies spectabilis* forest	3050-3950
21.	*Abies-Betula* forest	3000-4000
22.	Birch-Rhododendron forest	3500-4000
23.	Moist alpine shrub forest	3650-4400
24.	Upper alpine meadows	4500-5000
25.	Caragana Steppe	4000-4500

Appendix 2.

List of plant species recorded from sampling plots.

Plant Species	Family	Life forms	Altitudanal ran (Press *et al.* 200
Abies spectabilis (D. Don) Mirb	Pinaceae	Tree (Gynmosperm)	3000-4000
Acer acuminatum Wall. ex D.Don	Aceraceae	Tree (Dicot)	2200-3200
Acer caesium Wall. ex Brandis	Aceraceae	Tree (Dicot)	2000-3000
Achyranthes aspera L.	Amayranthaceae	Herb (Dicot)	100-2900
Aconitum heterophyllum Wall. ex Royle	Ranunculaceae	Herb (Dicot)	3200-3700
Aconitum spicatum (Bruhl) Stapf.	Ranunculaceae	Herb (Dicot)	1800-4200
Aconogonum molle (D. Don) H. Hara	Polygonaceae	Herb (Dicot)	2100-4000
Aconogonum rumicifolium (Royle .ex Bab) H. Hara	Polygonaceae	Herb (Dicot)	3300-4400
Actaea spicata (Wall. ex Royle) H. Hara	Ranunculaceae	Herb (Dicot)	2500-3700
Adiantum species	Pteridaceae	Herb (Pteridophyte)	
Aesculus indica (Colebr.Ex Cambess) Hook.	Hippocastanaceae	Tree (Dicot)	1900-2400
Allium wallichii Kunth	Amarylliidaceae	Herb (Monocot)	2400-4700
Ampelocissus rugosa (Wall.) Planch	Vitaceae	Shrub (Dicot)	1000-2400
Anaphalis triplinervis (Sims) C.B. Clarke	Asteraceae	Herb (Dicot)	2900-4100
Androsace robusta (Kunth) Hand.-Mazz	Primulaceae	Herb (Dicot)	3100-5600
Androsace sarmentosa Wall.	Primulaceae	Herb (Dicot)	2500-4000
Androsace strigillosa Franch.	Primulaceae	Herb (Dicot)	2400-4400
Anemone rupestris Wall. ex Hook.	Ranunculaceae	Herb (Dicot)	3000-4800
Anemone rupicola Cambess.	Ranunculaceae	Herb (Dicot)	2700-4800
Anemone tetracephala Royle	Ranunculaceae	Herb (Dicot)	
Arabidopsis himaliaca (Edgew.) O.E. Schulz	Cruciferae	Herb (Dicot)	3000-4800
Arabis pterosperma Edgew.	Cruciferae	Herb (Dicot)	2300-4400
Arisaema flavum (Forssk.) Schott	Aceraceae	Herb (Monocot)	2400-3800
Arisaema tortuosum (Wall.) Schott	Aceraceae	Herb (Monocot)	1300-2900
Arnebia benthamii (Wall. ex G. Don) I.M. Johnst.	Boraginaceae	Herb (Dicot)	2800-3800
Artemisia biennis Willd.	Asteraceae	Herb (Dicot)	3700-4600

Artemisia vulgaris Willd.	Asteraceae	Herb (Dicot)	300-2400
Asparagus filicinus Buch.-Ham. ex D.Don	Liliaceae	Herb (Monocot)	2100-2900
Aster albescens (DC.) Hand.-Mazz.	Asteraceae	Herb (Monocot)	1500-4200
Astilbe rivularis Buch.-Ham. ex D. Don	Saxifragaceae	Herb (Dicot)	2000-3600
Berberis aristata DC.	Berberidaceae	Shrub (Dicot)	1800-3000
Berberis glaucocarpa Stapf	Berberidaceae	Shrub (Dicot)	2400-3000
Berberis hamiltoniana Ahrendt	Berberidaceae	Shrub (Dicot)	2700-4200
Berberis kumaonensis C.K. Schneid.	Berberidaceae	Shrub (Dicot)	1800-3300
Bergenia ciliata (Haw.) Sternb.	Saxifragaceae	Herb (Dicot)	1600-3200
Betula utilis D. Don	Betulaceae	Tree (Dicot)	2700-4200
Bistrota affinis (D. Don) Greene	Polygonaceae	Herb (Dicot)	3500-4800
Bistrota macrophylla (D. Don) Sojak	Polygonaceae	Herb (Dicot)	2700-4500
Capsella bursa-pastoris (L.) Medic.	Cruciferae	Herb (Dicot)	1800-4500
Caragana brevispina Royle	Fabaceae	Shrub (Dicot)	2400-3200
Caragana brevispina subsp. *tenzingii* Vassilcz	Fabaceae	Shrub (Dicot)	
Caragana sukiensis C.K. Schneid.	Fabaceae	Shrub (Dicot)	3000-3700
Cardamine loxostemonoides O.E. Schulz	Cruciferae	Herb (Dicot)	2900-5500
Carex atrata L.	Cyperaceae	Herb (Monocot)	3500-4400
Carex atrofusca (Boott) T. Koyama	Cyperaceae	Herb (Monocot)	4000-5600
Carex cruenta Nees	Cyperaceae	Herb (Monocot)	4000-5600
Cassiope fastigiata (Wall.) D. Don	Ericaceae	Shrub (Dicot)	2800-5000
Chenopodium album subsp. *album* L.	Chenopodiaceae	Herb (Dicot)	2000-4000
Chesneya nubigena (D. Don) Ali	Leguminosae	Herb (Dicot)	3600-5200
Cicerbita macrorhiza (Edgew.) P.	Asteraceae	Herb (Dicot)	1300-4500
Clematis Montana Buch.-Ham. ex DC.	Ranunculaceae	Herb (Dicot)	100-4000
Clematis species	Ranunculaceae	Herb (Dicot)	
Clinopodium umbrosum (M. Bieb.) K. Koch	Lamiaceae	Herb (Dicot)	100-3400
Coleus forskohlii Briq.	Lamiaceae	Herb (Dicot)	

Corydalis govaniana Wall.	Papaveraceae	Herb (Dicot)	3000-4800
Cotoneaster affinis Lindl.	Rosaceae	Shrub (Dicot)	2200-2800
Cotoneaster frigidus Wall. ex Lindl.	Rosaceae	Shrub (Dicot)	2200-3400
Cotoneaster microphyllus Wall. ex Lindl.	Rosaceae	Shrub (Dicot)	2000-5400
Cremanthodium arnicoides (DC. ex Royle) R. Good	Asteraceae	Herb (Dicot)	3100-4900
Cremanthodium ellisii (Hook. f.) Kitam. ex Kitam & Gould.	Asteraceae	Herb (Dicot)	3600-5500
Cremanthodium oblangatum C.B. Clarke	Asteraceae	Herb (Dicot)	2900-5000
Cynanchum auriculatum Royle. ex Hook. f.	Asclepiadaceae	Herb (Dicot)	2000-3700
Cynanchum canescens (Willd.) K. Schum.	Asclepiadaceae	Herb (Dicot)	-
Cynoglosum species	Boraginaceae	Herb (Dicot)	-
Dactylorhiza hatagirea (D. Don) Soo	Orchidaceae	Herb (Monocot)	2800-4000
Delphinium brunonianum Royle	Ranunculaceae	Herb (Dicot)	3500-6000
Delphinium himalayai Munz	Ranunculaceae	Herb (Dicot)	3000-4500
Desmodium elegans DC.	Leguminosae	Shrub (Dicot)	1200-3000
Dioscorea deltoidea Wall. ex Griseb.	Dioscoreaceae	Herb (Monocot)	400-3100
Dipsacus inermis var. mitis (D. Don) Y. J. Nasir	Dipsacaceae	Herb (Monocot)	1400-4100
Dryopteris barbigera	Dryopteridaceae	Herb (Pteridophyte)	-
Elaeagnus parvifolia Wall. ex Royle	Elaeagnaceae	Shrub (Dicot)	1300-3000
Elsholtzia fruticosa (D. Don)Rehder	Lamiaceae	Herb (Dicot)	1800-4200
Ephedra gerardiana Wall. ex Stapf	Ephedraceae	Shrub (Gymnosperm)	2300-5200
Epipactis royleana Lindl.	Orchidaceae	Herb (Monocot)	1600-3500
Eskemukerjea megacarpum (H. Hara) H. Hara	Polygonaceae	Herb (Dicot)	2400-3000
Euphorbia longifolia D. Don	Euphorbiaceae	Herb (Dicot)	1700-2900
Fragaria nubicola Lindl. ex Lacaita	Rosaceae	Herb (Dicot)	1600-4000
Fritillaria cirrhosa D. Don	Liliaceae	Herb (Dicot)	3000-4600
Galium aparine L.	Rubiaceae	Herb (Dicot)	2700-3600

Galium asperifolium Wall.	Rubiaceae	Herb (Dicot)	1500-3000
Galium paradoxum Maxim.	Rubiaceae	Herb (Dicot)	2500-3800
Gentiana nubigena Edgew.	Gentianaceae	Herb (Dicot)	-
Gentiana robusta King. ex Hook. f.	Gentianaceae	Herb (Dicot)	3500
Geranium donianum Sweet	Geraniaceae	Herb (Dicot)	3200-4800
Geranium pretense L.	Geraniaceae	Herb (Dicot)	2200-3500
Gerbera kunzeana A. Br. & Asch.	Asteraceae	Herb (Dicot)	-
Gervera nivea (DC.) Sch.Bip	Asteraceae	Herb (Dicot)	2800-4500
Gueldenstaedtia himalaica Baker	Leguminosae	Herb (Dicot)	3300-4600
Halenia elliptica D. Don	Gentianaceae	Herb (Dicot)	2000-4500
Hedera nepalensis K. Koch	Araliaceae	Shrub (Dicot)	2000-3200
Hemiphragma heterophyllum Wall.	Scrophularaceae	Herb (Dicot)	1800-3500
Heracleum candicans Wall. ex DC.	Apiaceae	Herb (Dicot)	2200-3800
Hippophae salicifolia D. Don	Elaeagnaceae	Tree (Dicot)	2200-3500
Hippophae tibetana Schltdl.	Elaeagnaceae	Tree (Dicot)	3800-4500
Impatiens sulcata Wall.	Balsaminaceae	Herb (Dicot)	1700-4100
Iris kemaonensis D. Don ex Royle	Iridaceae	Herb (Monocot)	2500-4300
Jasminum humile L.	Oleaceae	Herb (Dicot)	1600-3400
Juglans regia C. DC.	Juglandiaceae	Tree (Dicot)	1200-2100
Juniperus indica Bertol.	Cupressaceae	Tree (Gymnosperm)	3700-4100
Jurinea dolomiaea Boiss.	Asteraceae	Herb (Dicot)	3200-4300
Kobresia species *1*	Cyperaceae	Herb (Monocot)	-
Kobresia species *2*	Cyperaceae	Herb (Monocot)	-
Lamium album L.	Lamiaceae	Herb (Dicot)	1500-3700
Lamium tuberosum Hedge	Lamiaceae	Herb (Dicot)	3900-4800
Lancea tibetica Hook. f. & Thomson	Scrophularaceae	Herb (Dicot)	3300-4400
Lepisorus species	Drynariaceae	Herb (Pteridophyte)	-
Ligularia sibirica (DC.) Kitam	Asteraceae	Herb (Dicot)	-
Lindelofia longiflora (Benth.) Baill	Boraginaceae	Herb (Dicot)	3300-4600
Lloydia longiscapa Hook.	Liliaceae	Herb (Monocot)	4000-5000
Lomatogonium graciliflorum H. Sm.	Gentianaceae	Herb (Dicot)	3000-4500
Lonicera angustifolia Wall. ex DC.	Caprifoliaceae	Shrub (Dicot)	2600-3800
Lonicera obovata Royle ex Hook. f.	Caprifoliaceae	Shrub (Dicot)	3600-4400

Lonicera webbiana Wall. ex DC.	Caprifoliaceae	Shrub (Dicot)	2600-4300
Maharanga emodi (Wall.) A. DC.	Boraginaceae	Herb (Dicot)	2200-4500
Mandragora caulescens C.B. Clarke	Solanaceae	Herb (Dicot)	3600-4400
Meconopsis horridula Hook. f. & Thomson	Papaveraceae	Herb (Dicot)	3000-5800
Megacarpaea polyandra Benth.	Cruciferae	Herb (Dicot)	2700-4600
Morina longifolia Wall. ex DC.	Dypsacaceae	Herb (Dicot)	3000-4200
Morina polyphylla Wall. ex DC.	Dypsacaceae	Herb (Dicot)	3000-4300
Nardostachys grandiflora DC.	Valerinaceae	Herb (Dicot)	3200-5000
Neopicrorhiza scrophulariiflora (Pennell) Hong	Scrophularaceae	Herb (Dicot)	3500-4800
Ophioglosum species	Ophioglossaceae	Herb (Pteridophyte)	-
Origanum vulgare L.	Lamiaceae	Herb (Dicot)	600-4000
Oxyria digyna (L.) Hill	Polygonaceae	Herb (Dicot)	2400-5000
Oxytropis duthieana Ali	Fabaceae	Herb (Dicot)	3500-5000
Paris polyphylla Sm.	Liliaceae	Herb (Monocot)	1800-3300
Parnassia nubicola Wall. ex Royle	Parnassiaceae	Herb (Dicot)	2900-4200
Pedicularis species	Scrophularaceae	Herb (Dicot)	-
Pedicularis hoffmeisteri Koltzschii	Scrophularaceae	Herb (Dicot)	2300-3900
Picea smithiana (Wall.)Boiss.	Pinaceae	Tree (Gymnosperm)	2300-3600
Pilea symmeria Wedd.	Uticaceae	Herb (Dicot)	2100-3300
Pinus wallichiana A.B. Jacks.	Pinaceae	Tree (Gymnosperm)	1900-4100
Piptanthus nepalensis (Hook.) D. Don	Leguminosae	Shrub (Dicot)	2000-3800
Plantago himalaica Pilg.	Plantagenaceae	Herb (Dicot)	2900
Pleurospermum benthamii (DC.) C.B. Clarke	Umbelliferae	Herb (Dicot)	3500-4000
Podophyllum hexandrum Royle	Berberidaceae	Herb (Dicot)	3000-4500
Polygonatum cirrhifolium (Wall.) Royle	Liliaceae	Herb (Monocot)	1700-4600
Polygonatum hookeri Baker	Liliaceae	Herb (Monocot)	2900-4500
Polygonatum verticillatum (L.) All.	Liliaceae	Herb (Monocot)	2400-4700
Populus ciliata Wall. ex Royle	Salicaceae	Tree (Dicot)	2000-3200
Potentilla fructicosa Hook. f.	Rosaceae	Shrub (Dicot)	3700-4600
Potentilla microphylla D. Don	Rosaceae	Herb (Dicot)	3800-5100
Potentilla saundersiana Royle	Rosaceae	Herb (Dicot)	3100-4900
Primula atrodentata W.W. Sm.	Primulaceae	Herb (Dicot)	3500-4900

Primula macrophylla D. Don	Primulaceae	Herb (Dicot)	3400-5600
Prinsepia utilis Royle	Rosaceae	Shrub (Dicot)	1500-2900
Prunus napaulensis (Ser.) Steud.	Rosaceae	Tree (Dicot)	1600-2600
Prunus rufa Hook. f.	Rosaceae	Tree (Dicot)	3000-3800
Ranunculus brotherusii Freyn	Ranunculaceae	Herb (Dicot)	3000-5000
Ranunculus hirtellus Royle ex D. Don	Ranunculaceae	Herb (Dicot)	2800-5500
Rheum austral D. Don	Polygonaceae	Herb (Dicot)	3200-4200
Rheum moorcroftianum Royle	Polygonaceae	Herb (Dicot)	3600-4400
Rhodiola himalensis (D. Don) S.H. Fu	Crassulaceae	Herb (Dicot)	3700-4600
Rhododendron anthopogan D. Don	Ericaceae	Shrub (Dicot)	3300-5100
Rhododendron campanulatum D. Don	Ericaceae	Tree (Dicot)	2800-4400
Rhododendron lepidotum Wall. ex G. Don	Ericaceae	Herb (Dicot)	2100-4700
Ribes acuminatum	Grossulariaceae	Shrub (Dicot)	-
Ribes species	Grossulariaceae	Shrub (Dicot)	-
Rosa macrophylla Lindl.	Rosaceae	Shrub (Dicot)	2100-3800
Rosa sericea Lindl.	Rosaceae	Shrub (Dicot)	2200-4600
Rubus paniculatus Sm.	Rosaceae	Shrub (Dicot)	2100-2900
Rumex nepalensis Spreng.	Polygonaceae	Herb (Dicot)	1200-4200
Salix calyculata Hook. f. ex Andersson	Salicaceae	Shrub (Dicot)	3600-4500
Salix species	Salicaceae	Tree (Dicot)	-
Salvia lanata Roxb.	Lamiaceae	Herb (Dicot)	1500-3000
Saussurea species	Asteraceae	Herb (Dicot)	-
Saxifraga andersonii Engl.	Saxifragaceae	Herb (Dicot)	3400-5500
Sedum multicaule Wall. ex Lindl.	Crassulaceae	Herb (Dicot)	1500-3200
Selinum candollei DC.	Apiaceae	Herb (Dicot)	3000-3800
Silene indica Roxb. ex Otth	Caryophyllaceae	Herb (Dicot)	2000-4500
Smilacina oleracea (Baker) Hook. f.	Smilacaceae	Shrub (Dicot)	2500-3400
Smilax menispermoidea A. DC.	Smilacaceae	Shrub (Dicot)	1800-3400
Sorbus cuspidata (Spach) Hedl.	Rosaceae	Tree (Dicot)	2700-3700
Sorbus lanata (D. Don) Schauer	Rosaceae	Tree (Dicot)	2500-3400
Soroseris species	Asteraceae	Herb (Dicot)	-
Spiraea arcuata Hook. f.	Rosaceae	Shrub (Dicot)	3500-4900
Stellera chamaejasme L.	Caryophyllaceae	Herb (Dicot)	2700-4200
Stipa sibirica (L.) Lam.	Poaceae	Herb (Monocot)	2600-3200

Swertia ciliata (D. Don ex G. Don) B.L. Burtt	Gentianaceae	Herb (Dicot)	2800-4000
Swertia racemosa (Griseb.) C.B. Clarke	Gentianaceae	Herb (Dicot)	3000-5000
Syringa emodi Wall. ex Royle	Oleaceae	Shrub (Dicot)	2500-3600
Tanacetum dolichophyllum (Kitam.) Kitam. ex Kitam. & Gould.	Asteraceae	Herb (Dicot)	3000-4400
Taraxacum officinale F.H. Wigg.	Asteraceae	Herb (Dicot)	-
Taxus wallichiana Zucc.	Taxaceae	Tree (Gymnosperm)	2300-3400
Thalictrum alpinum L.	Ranunculaceae	Herb (Dicot)	2800-5000
Thalictrum cultratum Wall.	Ranunculaceae	Herb (Dicot)	2400-4200
Thalictrum foliolosum DC.	Ranunculaceae	Herb (Dicot)	1300-3400
Thesium himalense Royle ex Edgew.	Santalaceae	Herb (Dicot)	1300-4000
Thlaspi arvense L.	Cruciferae	Herb (Dicot)	2100-4500
Thymus linearis Benth.	Labiateae	Herb (Dicot)	2400-4500
Tsuga dumosa (D. Don)Eichler	Pinaceae	Tree (Gymnosperm)	2100-4000
Typhonium diversifolium Wall. ex Schott	Araceae	Herb (Monocot)	2400-4300
Ulmus wallichiana Planch.	Ulmaceae	Tree (Dicot)	2000-3000
Urtica dioica L.	Urticaceae	Herb (Dicot)	3000-4500
Urtica hyperborea Jacquem. ex Wedd.	Urticaceae	Herb (Dicot)	4100-5100
Valeriana hardwickii Wall.	Valerianaceae	Herb (Dicot)	1200-4000
Viburnum cotinifolium D. Don	Sambucaceae	Herb (Dicot)	2100-3600
Viola biflora L.	Violaceae	Herb (Dicot)	2100-4500

Appendix 3

a) Regression statistics for Species density: GLM model are significant over 1st & 2nd order (Altitude is Predictor)

Response Variables	Model	Polynomial order	Res degree of freedom	Residual deviance	DF	Deviance	F-Value	Pr(>F)
Species density of Vascular Plant	Null	0	79	354.34				
	GLM	1	78	331.48	1	22.854	5.4158	< 0.05
	GLM	2	77	71.34	2	283.00	150.51	< 0.001
Species density of Monocot	Null	0	79	57.973				
	GLM	1	78	34.167	1	23.806	54.221	< 0.001
	GLM	2	77	31.514	2	26.459	32.701	< 0.001
Species density of Dicot	Null	0	79	389.51				
	GLM	1	78	348.53	1	40.879	9.0835	< 0.01
	GLM	2	77	66.90	2	322.51	180.03	< 0.001
Species density of Tree	Null	0	79	91.584				
	GLM	1	78	74.987	1	16.561	20.686	< 0.001
	GLM	2	77	50.089	2	41.459	35.721	< 0.001
Species density of Shrub	Null	0	79	96.321				
	GLM	1	78	89.471	1	6.8499	5.7039	< 0.05
	GLM	2	77	53.900	2	42.42	30.332	< 0.001
Species density of Herb	Null	0	79	263.46				
	GLM	1	78	253.24	1	10.229	3.1544	< 0.1
	GLM	2	77	54.615	2	208.85	143.84	< 0.001

b) Regression statistics for Species richness: GLM model are significant over 1st & 2nd order (Altitude is Predictor).

Response Variables	Model	Polynomial order	Res degree of freedom	Residual deviance	DF	Deviance	Pr(>Chi)
Species richness	Null	0	15				
of Vascular	GLM	1	14	93.969	1	14.056	< 0.001
Plant	GLM	2	13	9.301	2	98.724	< 0.001
Species	Null	0	15	78.201			
Richness of	GLM	1	14	71.256	1	6.9449	< 0.001
Herb	GLM	2	13	5.458	2	72.743	< 0.001
Species	Null	0	15	22.590			
Richness of	GLM	1	14	16.621	1	5.9694	< 0.05
Shrub	GLM	2	13	4.2019	2	18.389	< 0.001
Species	Null	0	15	17.312			
Richness of	GLM	1	14	12.772	1	4.5403	< 0.05
Tree	GLM	2	13	5.9641	2	11.348	< 0.01
Species	Null	0	15	116.182			
Richness of	GLM	1	14	97.948	1	18.233	< 0.001
Dicot	GLM	2	13	7.574	2	108.64	< 0.001
Empirical							
Interpolated	Null	0	59	2559.1			
Species	GLM	1	58	2501.8	1	49.3	< 0.001
Richness	GLM	2	57	49.99	2	2509.1	< 0.001

c) Regression statistics for environmental variables against species density: GLM model are significant ov

1st & 2nd order (Species density is response variable).

Predictor	Model	Polynomial order	Res. Degree of freedom	Residual deviance	DF	Deviance	F- Value	P (>F)
RRI	Null	0	79	354.34				
	GLM	1	78	327.79	1	26.551	6.402	< 0.05
	GLM	2	77	324.22	2	30.122	3.6564	ns*
pH	Null	0	79	354.34				
	GLM	1	78	184.37	1	169.97	73.192	< 0.001
	GLM	2	77	183.93	2	170.41	36.282	ns*
Rock	Null	0	79	354.34				
Cover	GLM	1	78	277.88	1	76.46	21.485	< 0.001
	GLM	2	77	266.01	2	80.839	11.323	ns*
Grazing	Null	0	79	354.34				
Intensity	GLM	1	78	336.37	1	17.696	4.1522	< 0.05
	GLM	2	77	329.35	2	24.986	2.9334	ns*
Moisture	Null	0	79	354.34				
	GLM	1	78	322.97	1	31.37	7.7088	< 0.001
	GLM	2	77	255.33	2	99.006	15.185	< 0.001

*ns – not significant

Appendix 4

Plot wise species density along with environmental variables

Altitude (m asl)	Species density	Longitude(°)	Latitude(°)	Aspect(°)	Slope(°)	RRI	pH	Moisture (1-8)	Rock (1-4)
2810	26	81.952	29.967	220	25	0.9028	6.5	7	0
2825	31	81.956	29.967	230	25	0.7949	6.8	7.2	0
2845	30	81.958	29.968	230	25	0.7949	6.6	7.2	0
2870	25	81.959	29.969	235	30	0.1227	6.2	7	0
2890	26	81.970	29.972	240	25	0.9216	6.2	6.8	0
2905	26	81.971	29.981	220	30	0.4629	6.6	6	2
2928	30	81.974	29.981	210	25	0.8483	6.6	6.8	3
2943	30	81.975	29.979	220	25	0.9027	6.8	7.6	0
2970	30	81.977	29.978	230	30	-0.3428	6.8	7.5	2
2995	30	81.977	29.978	230	25	0.7947	6.7	7.6	0
3000	32	81.978	29.980	240	10	-0.4678	6.2	7.2	3
3025	33	81.979	29.982	260	20	0.3031	6.5	7.6	2
3050	44	81.980	29.984	180	10	-0.9987	6.8	8	0
3080	46	81.980	29.984	200	15	-0.5254	6.8	8	2
3090	41	81.980	29.984	220	20	0.0491	6.6	8	1
3112	44	81.979	29.982	200	30	-0.0679	6.4	6	2
3139	44	81.983	29.990	230	30	-0.3430	6.6	5	4
3150	46	81.983	29.992	200	30	-0.0680	6.8	5	4
3169	47	81.983	29.992	230	30	-0.3431	6.9	4	2
3180	52	81.983	29.992	200	40	-0.4256	6.7	5.2	4
3215	55	81.985	29.996	160	5	0.0500	7.4	5.6	0
3225	51	81.984	29.996	180	5	-0.2338	6.8	5.6	0
3240	53	81.984	29.996	160	5	0.0500	7	7	0
3260	55	81.984	29.996	170	10	-0.4984	7.2	7.2	0
3290	58	81.984	29.996	150	30	0.0574	7.2	7.2	0
3315	58	81.984	29.996	160	30	-0.0680	7	7.6	2
3343	54	81.983	29.996	170	30	0.5481	7.2	7.8	2
3373	65	81.983	29.996	160	30	0.0680	7.4	7.7	0
3382	67	81.983	29.996	180	30	-0.3604	7.4	7.6	0
3398	68	81.982	29.996	180	35	-0.9967	7.2	7.8	0
3425	75	81.980	29.996	170	35	-0.6030	7.4	8	0
3455	77	81.980	29.996	150	30	0.0574	7.2	8	0
3467	73	81.979	29.996	180	30	-0.3604	7.2	7.8	1
3480	70	81.979	29.996	160	40	-0.4255	7	8	1
3498	68	81.979	29.996	150	30	0.0574	6.8	7.6	2
3526	61	81.978	29.996	170	35	-0.6030	6.6	7.4	0
3540	59	81.978	29.996	160	30	-0.0680	6.2	7.2	0
3558	51	81.978	29.996	180	25	0.7922	6.6	7.2	0
3580	56	81.978	29.996	190	30	0.5481	6.6	7.6	0
3595	52	81.977	29.996	190	30	0.5481	6.2	7	0

3640	49	82.023	30.062	190	30	0.5488	6.4	5	0
3667	47	82.023	30.062	200	22	-0.8672	6.6	4	3
3675	54	82.023	30.062	208	30	0.6100	6.6	6	2
3689	47	82.023	30.063	190	24	0.7478	6.7	4	0
3696	42	82.022	30.063	230	5	-0.2181	6.2	5	0
3720	41	82.022	30.063	145	25	0.9178	6.6	4	1
3738	52	82.022	30.063	170	21	-0.8257	6.6	6	0
3745	47	82.022	30.063	190	19	0.7927	6	7.4	2
3761	45	82.022	30.063	220	38	0.7275	6	7	0
3789	39	82.021	30.063	220	24	0.6697	6.2	6	0
3815	47	82.035	30.084	290	15	-0.9830	6.2	6.8	2
3843	42	82.035	30.083	290	20	-0.1041	6	8	1
3861	45	82.036	30.083	270	40	-0.7444	6.2	8	0
3875	43	82.036	30.083	270	30	0.3554	6.2	8	1
3892	40	82.036	30.083	240	40	-0.9328	6.4	7	2
3915	40	82.037	30.083	270	30	0.3554	6.2	7	2
3935	43	82.037	30.079	240	30	0.6052	6.2	7	2
3950	39	82.037	30.082	280	38	0.9545	6	6.8	0
3971	44	82.038	30.082	270	20	0.1480	6.8	7	0
3989	37	82.038	30.073	270	30	0.3554	6	6.6	4
4008	43	82.038	30.081	220	25	0.9019	6.8	6.8	3
4038	41	82.038	30.081	230	30	-0.3445	6.4	6.6	3
4048	36	82.039	30.081	220	30	0.4638	6.2	6.6	4
4064	32	82.056	30.080	250	15	-0.4509	6.2	6.4	4
4084	32	82.039	30.080	240	25	0.9209	6.4	6.2	4
4116	31	82.043	30.080	270	35	-0.6858	6.2	6.2	3
4150	37	82.043	30.080	280	32	0.9602	6	6.8	2
4175	35	82.044	30.080	270	30	0.3554	6.2	6	2
4186	32	82.044	30.080	280	30	-0.2936	6	6	2
4195	34	82.044	30.080	280	40	-0.2550	6	6	2
4215	34	82.041	30.080	280	40	-0.2550	6	6.2	2
4241	33	82.042	30.080	280	40	-0.2550	6	6	2
4260	32	82.042	30.080	270	30	0.3554	6	6.2	2
4280	25	82.042	30.080	280	30	-0.2936	5.8	6	4
4290	29	82.042	30.081	270	30	0.3554	6.2	6.2	2
4316	22	82.043	30.080	270	35	-0.6858	6	6	4
4338	22	82.043	30.080	280	32	0.9602	6.2	6.2	4
4362	17	82.044	30.080	270	30	0.3554	5.8	6	4
4380	18	82.044	30.080	280	30	-0.2936	5.8	6	4
4395	20	82.044	30.080	280	40	-0.2550	6	6	4