1. INTRODUCTION

1.1 Background

Biological diversity refers to the variety and variability among living organisms and the ecological complexes in which they occur (Huston and Huston 1994; Rosenzweig 1995). Ecologists have found species diversity difficult to define and measure; may in fact reflect the possibility that it is a 'non-concept' (Hurlbert 1971). At present, there have been two approaches to measuring species diversity i.e. species richness and species evenness; both of them combinely incorporate the number of species (species richness) and the relative abundances of individuals within each species (species abundance). Thus, species diversity is a measure of the diversity within an ecological community that incorporates both species richness and the evenness (Hill 1973).

Whittaker (1972) distinguished three level of diversity: alpha diversity is the diversity within habitat or intracommunity diversity; beta diversity is defined as the change in species composition along the environmental gradients; gamma diversity is the diversity on entire landscape and can be considered as composite of alpha and beta diversity.

Species richness is the number of total species present in an ecological community (Colwell 2009). Species richness is currently the most widely used measure of diversity (Stirling and Wilsey 2001). It is a simple and easily interpretable indicator of biological diversity (Peet 1974; Whittaker 1977).

Variation of species diversity with forest types and elevation has been known for a long time.Forest is a complex ecological system in which trees are dominant life forms. Forest is one of the important renewable resources providing services and products to people and environment which meets the basic needs of people and a major source of world for livelihood and cash income (Vaalverde and Silvertown 1997).

Species composition of forests has been documented for Nepal over several decades (Hara 1966; Shrestha 1982).The structure of tree species diversity in hill forests varies greatly from place to place due to variation of altitude, orientation of slope, nature of soil, and type and intensity of disturbance (Stainton 1972; Vetaas 2000). Natural disturbances such as forest fire, landslide, volcanic activity, and climatic change, determine forest dynamics and tree diversity (Burslem and Whitmore 1999; Masaki *et al*. 1999). Anthropogenic disturbance may regulate the regeneration dynamics; structure and floristic composition of forest (Ewel *et al*. 1981; Hong *et al*. 1995). Disturbance may increase species richness in old growth forest (Sheil 1999) and may maintain species diversity (Huston 1979; Petraitis *et al*. 1989). Frequent and low intensity disturbances like grazing and extraction of firewood and fodder strongly affects forest structure and the succession of tree species in the forest (Ramirez-Marcial *et al*. 2001).

The forest canopy modifies the availability of understory resources such as light, water, and soil nutrients (Gracia *et al.* 2006) hence affect plant growth and consequently influence the richness and composition of understory vegetation. A mature forest canopy facilitates the survival of shade tolerant understory species (Moore *et al.* 2011). Canopy cover determines availability of light for the understory species and their composition of any ecosystem. Canopy structure controls the quality and quantity of ecosystem differed both in spatial and temporal availability of light (Jennings *et al.* 1999).

Human disturbance is the main cause of change in land use type, which severely threatens the biodiversity. People harvest plants for timber, fodder, firewood, and so on. At high level of disturbance, due to human impacts like deforestation, many species are at risk of extinction (Lalfkawma *et al.* 2009). These disturbances cause change in land cover of area. Disturbance favors the growth of herbaceous species rather than woody species (Matima *et al.* 2009). Herbaceous species were found more in openland than forest (Bhattarai and Vetaas 2013) whereas tree species found more in undisturbed natural forest (Bobo *et al.* 2006).

The distribution and diversity of plant species in forests depend on the size of the forest or habitat area along with different factors. It is generally assumed that larger the size of the forest the more will be the number of species (Rosenzweig 1995). Hill and Curran (2001) studied species composition in fragmented forest and they proposed that large forests contain the greatest number of tree species.

The elevation represents a complex gradient along which many environmental variables change simultaneously (Austin *et al.* 1996). Many studies reported a decline in the number of species with increasing elevation (Brown 1988;Stevens 1992; Begon *et al*. 1996; Lomolino 2001).However, Rahbek (1995) showed a mid-altitude peak in species richness. Other studies, that found humped relationship between species richness and altitude, include Whittaker and Niering (1975), Liberman *et al*. (1996), Grytnes and Vetaas (2002), Carpenter (2005), Grau *et al*.(2007), Nogués-Bravo *et al.*(2009), Baniya *et al*.(2010), Acharya *et al*.(2011), Chhetri and Bhattarai (2013) and Bhattarai *et al.* (2014).

Species richness along elevation gradient is controlled by a series of interacting biological, climatic and historical factors (Colwell and Lees 2000). It is assumed that tree species are more influenced by climatic factors than herbaceous species. In fact, trees are most susceptive climatic factors than herbs (Bhattarai and Vetaas 2003).

Climatic factors, environmental stability and habitat heterogeneity are the factors often discussed as determinants of variability in species richness (Spies and Turner 1999). Altitudinal gradient creates varied climates along with resultant soil differentiation and promots the diversification of plant species (Brown 2001 and Lomolino 2001). Environmental stress including climatic factors, such as temperature, duration of snow cover, disturbances, light duration, competition and other factors may change with altitude that affect species richness patterns (Baniya *et al.* 2010). Species richness normally decreases with increasing elevation. However, a hump and a plateau have been documented in species richness curves in the Nepal Himalaya (Panthi *et al*. 2007). The species richness of tree species shows a significant linear pattern along the elevation gradient (Mahato 2006).

An ecotone is the zone of transition between adjacent ecological systems, having a set of characteristics uniquely defined by space and time scales and by the strength of the interactions between the systems (Holland 1988; Risser 1993). The term ecotone is widely used in ecology (Holland et al. 1991; Schilthuizen 2000). Clements (1907, cited in Harris 1988) first described the junction between two adjacent communities as a stress line or ecotone. More recently, the concept has been broadened to include biotic and abiotic factors at various scales (Holland and Risser 1991; Risser 1995).

One consequence of ecotone has been described as the edge effect, the tendency for increased population density and species richness at the junction zone between two communities (Odum 1958). The ecotone contains not only species common to the communities on both sides; it may also include a number of highly adaptable species that tend to colonize such transitional areas (Smith 1974). The phenomenon of increased variety of plants as well as animals at the community junction is called the edge effect and is essentially due to a locally broader range of suitable environmental conditions or ecological niches.

Scale is a very important factor to measure biodiversity (Whittaker 1977; Blake and Loiselle 2000; Rahbek and Graves 2001; Baniya 2010). Small scale measures the local influences (Blake and Loiselle 2000) whereas larger scale measures the larger temporal and spatial phenomena (Rahbek and Graves 2001). Scale also determines the size of the study area and sampling unit for the study (Wiens 1989).

1.2 Justification of the study

The study of species diversity, or at least species richness, gives ecologists insights into the stability of communities (Walker 1988). Species richness is one of the most studied measures of Plant species diversity. In the context of Nepal species richness along elevation gradient have been studied in different parts of the country. Still there are huge areas in Nepal yet to be explored by science. Very few empirical studies have been done in ecotone forests of Gulmi district. Hence, present study has been conducted to find out the current status and diversity of woody species, and vegetation composition with forest types along elevation gradient in subtropical- temperate ecotone forest. It will be helpful for management and conservation of plant resources, realizing their importance in the livelihood of local people.

1.3 Hypothesis

Woody plant species diversity varies wih elevational gradient in subtropical-temperate ecotone forest.

1.4 Objectives

General objective of present research is to study the species diversity of woody species in relation to different forest types and elevation gradients.

Specific objectives

- To assess the community structure of woody plant species in the study area.
- To assess the species diversity of woody species in subtropical-temperate ecotone forest.
- To asses the species richness patterns along elevation gradients.
- To assess the species composition and distribution pattern of woody species in the study area.

1.5 Limitation of the study

This study was carried out on the northern slope of subtropical-temperate ecotone forest in Resunga region extending 1700 m asl to the top of the hill 2347 m asl and could not cover additional forest area. Species richness pattern is assessed for woody species only. Few specimens which were found in vegetative stage could not be identified to the species level.

2. LITERATURE REVIEW

2.1 Elevation and species richness pattern

Species richness changes pattern with elevation characterizes the vegetation in simple but powerful way (Baniya *et al.* 2010). Several researches have been carried out in elevational gradients in various parts of the world and found specific patterns for different plants. General concept about the species richness with the elevation is gradual decrease in species richness as the elevation increases (Brown and lomolino 1998; Körner 2002; Fossa 2004; Baniya *et al.* 2010). In general there are three main patterns of species richness pattern: a monotonic increase with elevation, a monotonic decrease with elevation and unimodal pattern (Rahbek 1995, 1997). The most dominant pattern of species richness along elevation is the unimodal pattern (Rahbek 1995; Brown 2001; Vetaas and Grytnes 2002; Carpenter 2005; Rowe and Lidgard 2009). Differences between organisms and between life forms of plants (Bhattarai and Vetaas 2003), geographic factors, factors correlated with latitude, biotic factors, spatially varying factors (productivity and resource richness, spatial heterogeneity and environmental harshness), temporally varying factors (climatic variation, environmental age), habitat area and remoteness (Rosenzweig 1995; Rahbek 1995, 1997; Lomolino 2001; Brown *et al.*2004), scale (Whittaker 1997) historical and evolutionary factors (Lomolino 2001; Bhattarai and Vetaas 2003; Grytnes 2003; Rahbek 2005), elevational gradient itself (Grytnes 2003) are responsible for species richness along the elevational gradient. Other causes of species richness are the mid-domain effect (MDE) (Colwell and Hurtt 1994; Colwell and Lees 2000) and Rapoport's elevation rules (Stevens 1992).

The first paper on elevational species gradient in Nepal was published by Yoda (1967). Hunter and Yonzon (1993) published the second elevational species gradient pattern on animal and mammals of Nepal. Later more studies have been done based on interpolation (Vetaas and Grytnes 2002; Baniya *et al.* 2010), and empirical studies (Bhattarai and Vetaas 2003; Carpenter 2005). Interpolation studies showed hump shaped species richness pattern, peak for flowering plants of Nepal was found between 1500 m – 2500 m asl and a plateau between 3000 m asl and 4000 m asl for endemic species richness. Likewise, species richness for ferns peaked at 1900 m asl (Bhattarai *et al.* 2004), bryophytes and mosses at 2800 m asl and 2500 m asl respectively (Grau *et al.* 2007), lichens at 3100 m -3400 m asl (Baniya *et al.* 2010) and orchids at 1600 m asl (Acharya *et al.* 2011).

Several authors, such as Gosz (1993) and Risser (1995) have suggested that transitional areas not only share the two types of environments of the habitats that coincide in the ecotone, but also have a unique ecotonal environment. Odum (1953) proposed that transition zones often support a unique community with characteristics additional to those of the communities that adjoin the ecotone. In addition, ecotones tend to shift in space and time over several spatial scales (Gosz 1993), (Kent *et al*. 1997), as a response to climatic variation, other environmental changes (Crumley 1993; Kent *et al*. 1997; Neilson 1993), and human activity (Gehrig *et al*. 2007). Ecotones show high spatial and temporal heterogeneity, which may serve as important factors contributing to their high genetic and species diversity (Risser 1995). Ecotones, comprising meeting areas between adjoining communities, include a combination of species from two or more community types (Risser 1995). Ecotonal areas often comprise the edge of the range for species on both sides where many peripheral populations occur (Kark and van Rensburg 2006; Shmida and Wilson 1985). Shmida and Wilson (1985) proposed that the high number of species in transitional areas could be due to a process they called the mass effect, which is the flow of individuals from favorable to unfavorable areas.

Nepal (2001) conducted quantitative analysis of vegetation (trees and shrubs) along the altitudinal gradient on the north east slope and south west slope on Kaski district. He found variation in species composition in two different slopes of study area.

Shrestha (2001) studied species diversity and distribution along altitudinal gradient in Landruk village of Annapurna region Nepal. He found prominent variation of vegetation along altitudinal gradient.

Grytnes and Vetaas (2002) analyzed plant species richness along the Himalayan altitudinal gradient in Nepal. They concluded that interpolated species richness in the Himalaya showed a hump-shaped structure. The maximum richness of flowering plants of Nepal has been found between 1500 m and 2500 m asl.

Bhattarai and Vetaas (2003) evaluated the relation between species richness of plant in different life forms with different climatic variables such as potential evapo-transpiration (PET), mean annual rainfall (MAR) and moisture index (MI). They used empirical data of all vascular plants from eastern Nepal between 100 and 1500 m and total species (excluding ferns), shrubs and trees showed hump-shaped patterns with elevation. Woody climbers and ferns showed a positive monotonic trend with elevation. Climbers, herbaceous climbers, all herbaceous plants, grasses and forbs showed no significant relation with elevation.

Carpenter (2005) studied the species richness pattern for trees and understory plants of eastern Nepal. Stand basal area, tree leafing phenology and taxonomic composition (angiosperm vs. gymnosperm) showed non-random change with elevation. Understory plant and tree species density both have a humped, unimodal trend with more species near the bottom of the gradient and fewest at the top. These trends were consistent with expected effects of the climatically active water and energy variables. After curve-fitting, significant spatial structure in the residuals suggested that tree communities within the 1750–2250 m elevation range did not realize their climatic potential species richness.

Gautam and Watanabe (2005) compared species composition, distribution and diversity of tree species in three forest stands in the Bharse area, Gulmi District, Nepal. The distribution of species showed clump behavior in the grazing forests whereas mixed (clump and regular) distribution occurred in the controlled-cutting forest. Trees with small diameter size were more in the controlled-cutting forest than the forests used for grazing and/or cutting. Species richness was highest in forest opened for cattle grazing. Moderately disturbed forest showed the highest species richness of the three forests. However, values of tree species diversity and evenness were higher in the controlled-cutting forest than in the forests with grazing and/ or cutting.

Bhattarai and Vetaas (2006) studied the distribution of 614 tree species to test Rapoport's elevational rule along a gradient from 100 to 4300 m asl, in the Nepalese Himalaya. The widest elevation ranges were observed at mid-elevations, and narrow elevation ranges were observed at both ends of the gradient. This did not support Rapoport's elevation rule, as proposed by Stevens. There was a peak in species richness between 900 and 1000 m, and not in the tropical lowland as projected by

Rapoport's elevation rule. This study found a peak tree richness in the lower half of the elevational gradient. This study did not find monotonically decreasing tree species richness with increasing elevation, as suggested by Stevens (1992) and estimated by Yoda (1967) for the Himalayas. The tree species richness shows positive correlation with elevation up to 1500 m asl and then shows negative correlation beyond 1500 m. But their result does not support this rule because Nepalese vascular plants follow hump shaped pattern of species richness.

Subedi (2006) studied the distribution pattern of plant species of Manang along whole Himalayan elevation gradient of Nepal. He recorded 303 species using primary and secondary data. The study showed that hump shaped distribution with optimum species at 3500 m asl.

Panthi *et al.* (2007) sampled species richness and composition in the north and south aspects of the dry valley of Manang between 3000 and 4000 m asl. A plateau in total species richness was observed between 3000and 4000 m aslat the local level. Species richness was significantly higher on the north facing slope than on the south facing slope. They also determined that moisture and factors influencing evaporation (i.e. canopy and aspect) are the main environmental factors influencing species composition and richness in the dry inner valley of the trans-Himalaya.

Rijal (2009) studied the species richness along the elevation gradient in Langtang National Park from 3000 to 4700 m asl elevation. He found species richness linearly decreases for dicot and herbs whereas gentle decreases for all the life-forms with increases elevation.

Baniya *et al.* (2010) used published data of 525 species of lichens to compare the distribution pattern along elevational gradient. They found the hump-shaped species richness for lichen peaked at 3100 -3400 m, and for endemic lichens peaked at 4000-4100 m. They found the species richness peak of lichen is higher than other groups of plants.

McCain and Grytnes (2010) discussed the history of elevational richness studies and overviewed the various hypotheses thought to be important in richness trends, including climatic, spatial, biotic and evolutionary factors. They described how abiotic factors change with elevation, how flora and fauna respond to these changes and how elevational species richness patterns have been studied to uncover drivers of biodiversity. They described four main trends in elevational species richness: decreasing richness with increasing elevation, plateaus in richness across low elevations then decreasing with or without a mid-elevation peak and a unimodal pattern with a mid-elevational peak.

Bhattarai (2011) studied the vascular plant species richness along the elevation gradient in Karnali river valley. He found unimodal pattern of species richness with elevational gradient for all life-forms except monocots.

Acharya *et al.* (2011) interpolated the published data of orchids of Nepal and Bhutan (100–5200 m asl), and adjacent regions of India, i.e. Sikkim and Darjeeling. A hump-shaped relationship between orchid species richness and elevation was observed in Nepal and Bhutan, with maximum richness at 1600 m asl.

Sharma (2012) studied the species richness pattern along the elevational gradient and different land use types in Manaslu Conservation Area and Sagarmatha National Park, Buffer zone of Nepal. She found linear decreasing pattern of species richness pattern along elevational gradient. She found higher species richness at exploited forest than other land use types, cropland, meadow and natural forest.

Chhetri and Bhattari (2013) studiedthe floristic composition pattern of Manaslu Conservation Area (MCA), Central Nepal. The DCA analysis of the floristic composition of the area showed the unimodal Relationship with altitude representing more species abundance at the mid-altitudes.

Thakali (2013) studied the species richness pattern for angiosperms, pteridophytes, bryophytes, mushrooms and lichens along elevational gradient in Manaslu Conservation Area, Central Nepal. In his study total species richness and angiosperms species richness showed unimodal pattern with elevation peaked at 3200 m asl. Bryophytes and lichen species showed monotonic increasing pattern while pteridophytes and mushrooms showed monotonic decreasing pattern with elevation.

Bhattarai and Vetaas (2013) studied on variation of herbaceous species richness across different land types: open, shrub and close forest, in eastern Nepal, from 100-1500 m asl. They recorded all species and grouped them into shrub, trees and herbaceous species. Herbaceous species were further divided into forbs and grasses (graminoides) and used analysis of variation to check, whether three land types were significantly different on mean herbaceous species richness. They hypothesized that forest canopy cover influences herbaceous species richness. They ordinate the trees and shrub species data by CCA, using land type as an environmental variable. The land type was significantly different on mean herbaceous species richness. The site linearly significant for forbs, grass and combined (forbs plus grass), indicated a pattern on herbaceous species richness along the gradient of open to close forest.

Bhattarai *et al*. (2014) checked the species richness pattern with elevation gradient and compared the empirical study with regional pattern and regressed with different environmental parameter including all the habitat types and vegetation. They regressed total vascular plants along with the life forms against the altitude and between species richness and different environmental parameters. Species richness of total vascular plants and all life forms showed a unimodal pattern with altitude having a peak at an altitude of 3500 m asl.

2.2 Species richness and forest types

Nepal is a small attractive package of nature embracing the rich biological diversity. One of the nature's gifts to Nepal is its vegetation. The narrow band of land holds over 170 parcels of vegetation. It lies just outside of the tropics in the global climatic zonation therefore bioclimatic tropicality extends into it up to an elevation of 1000 m altitude (Shrestha 2008). The subtropical zone (1000-2000 m asl), the temperate zone (2000-3000 m asl), the sub-alpine zone (3000-4000 m asl), the alpine zone (4000-5000 m asl) and the nival zone (5000 m asl and above) appear juxtaposed along the mountain slopes (Shrestha 2008). Stainton (1972) divided forests of Nepal in thirty five types under four major headings, tropical and subtropical, temperate and alpine broad leaved, temperate and alpine conifer and minor temperate and alpine association.

Nepal comprises around 4.27 million hectares (29% of total land area) of forest, 1.56 million hectares (10.6%) of scrubland and degraded forest, 1.7 million hectares (12%) of grassland, 3.0 million hectares (21%) of farmland, and about 1.0 million hectares (7%) of uncultivated lands (NBS 2002). Tropical to alpine climatic variation and their interaction form diverse ecosystems.

3. MATERIALS AND METHODS

3.1 Bio geographical location

Gulmi, one of the six districts of Lumbini zone, is a hilly region of western Nepal. It is situated in between 27º55' north to 28º27' north latitude and 83º10' east to 83º35" east longitude. Most of the area of Gulmi district belongs to the Mahabharat range.

Resunga Region is one of the historical place with cultural, environmental, recreational and tourist value. Tamghas, headquarter of Gulmi district, lies on the lap of Resunga hill. The Resunga Region occupies an area of 34 hectare surrounding 11 VDCs. Elevation of Resunga region ranges from 800 m asl to 2347 m asl.

This hill is named Resunga after Rishya Shringa, where the sage is supposed to have meditation in ancient time and as the time passed on the word 'Rishya Shringa' changed to Resunga (Subedi 1998). However no evidences in its support have been found and it is only people belief (Panthi 1984). The region is rich in biological diversity and seems to be historically, culturally, environmentally and socio-economically important.

The study site lies on the northern slope of Resunga Region including subtropical-temperate ecotone forest in the elevation range 1700 m asl to the top of the Resunga hill 2347 m asl comprising subtropical vegetation zone up to 2000 m asl and temperate vegetation zone 2000 – 2347 m asl. Almost half of the lower belt of study site is managed by a community and upper half, the religious forest is managed by government of Nepal. Location map of study area, showing position of Gulmi district and studied sampling plots in Resunga forest is shown below (Figure 1).

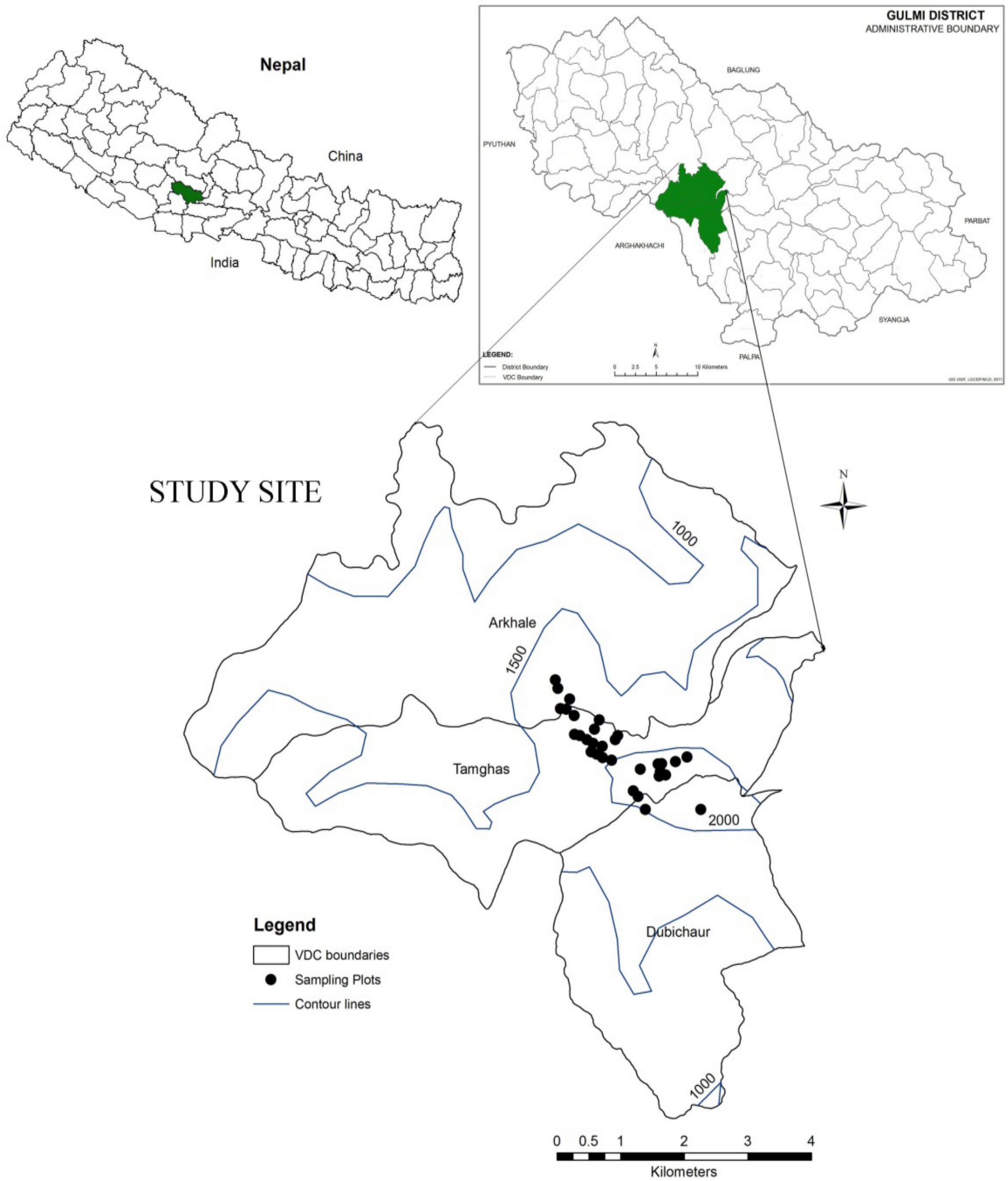

Figure 1: Location map of study area, showing position of Gulmi district and studied sampling plots in Resunga forest.(Sourse: Department of Survey,Kathmandu).

3.2 Climate

Climatic data from 2002 to 2011 showed that the monthly average maximum and minimum temperatures were 26.5ºC and 3.9ºC in the months of June and January respectively (Figure 2). Mean annual rainfall was 2207 mm, with the highest monthly rainfall in July-August and the lowest rainfall in November-December. The monsoon starts from June and most of the precipitation occurs during June, July, August and September. (Source: Department of Hydrology and Meteorology, Kathmandu).

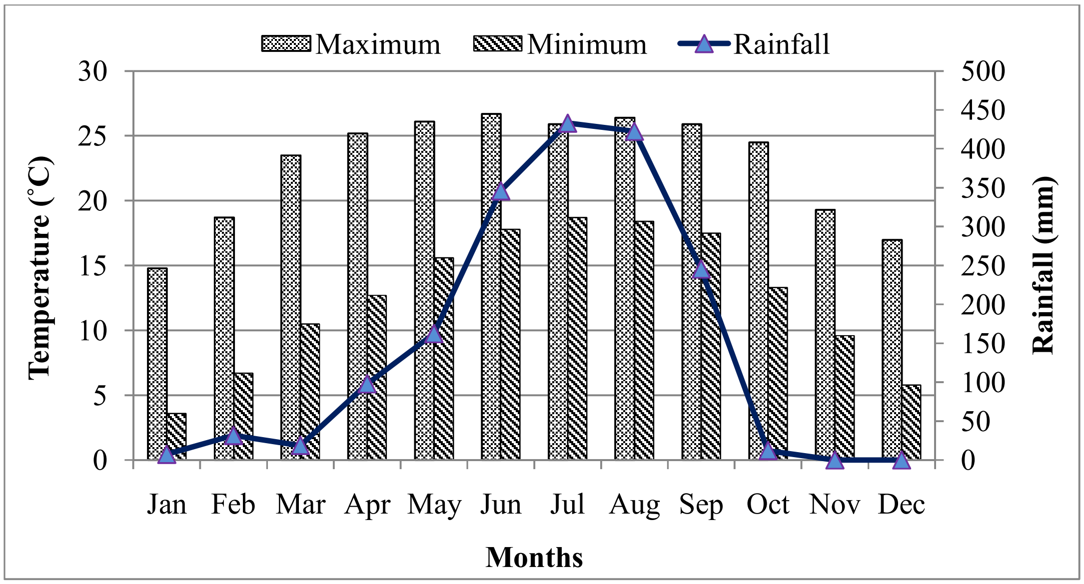

Figure 2: Ten years average (2002-2011) monthly minimum-maximum temperature and rainfall recorded at Tamghas weather station (1530 m asl). (Source: Department of Hydrology and Meteorology, Kathmandu).

3.3 Vegetation

Study area covers subtropical and temperate vegetation zones. Subtropical elements are chiefly composed of *Pinus roxburghii, Schima wallichii, Myrica esculenta, Castanopsis indica, Pyrus pashia, Rhus javanica, Lyonia ovalifolia, Aesculus indica, Cinnamomum glanduliferum, Ilex excelsa, Viburnum erubescens, Neolitsea pallens, Alnus nepalensis, Eurya acuminata , Prunus cersasoides* and understory of *Viburnum mullaha, Berberis asiatica, Maesa chisia, Osbeckia stellata, Phyllanthus parvifolius, Pyracantha crenulata, Randia tetrasperma, Rubus ellipticus, Smilax aspera, Viburnum cylindricum* and *Xanthoxylum armatum.*

Temperare elements are chiefly composed of *Symplocos lucida, Symplocos ramosissima, Rhododendron arboreum, Quercus semecarpifolia, Quercus lanata, Neolitsea pallens, Lindera pulcherrima* and understory of *Berberis aristata, Berberis asiatica, Daphne papyracea, Elaeognus parvifolia, Ilex dipyrena, Lindera pulcherrima, Persea gamblei, Rosa sericea, Sarcococca coriacea,* and *Rubus paniculatus*.

3.3.1 General forest types

The distribution of forest types depend on site specific physiography (Kunwar *et al.*2008). On the basis of dominant tree species and group of species the Resunga forest was categorized as follows following Stainton (1972).

i. Pine forest: This forest predominates mostly on south facing slopes up to 1900 m asl. *Pinus roxburghii* is the dominant species. The top canopy is composed of pine. Pure pine forest is found in patches and often it is mixed with broad leaved species like *Lyonia ovalifolia, Schima wallichii, Pyrus pashia* and *Rhododendron arboreum.* Understoryis formed by *Maesa chisia, Phyllanthus parvifolius, Osbeckia stellata* and *Berberis asiatica*.

ii. Subtropical semi-evergreen hill forest: This type of forest extends up to 2000 m asl mostly on northern slope. Canopy is mostly formed by *Aesculus indica, Schima wallichii, Lyonia ovalifolia, Rhododendron arboreum, Myrica esculenta* and *Pyrus pashia*. There is not any single dominant species. This type forest is mostly evergreen. Understory is composed of *Phyllanthus parvifolius, Berberis asiatica, Maesa chisia, Xanthoxylum armatum* and *Rubus ellipticus*.

iii. Lower temperate mixed broadleaved forest: This type of forest is found in the wetter parts of the study area between 2000 m -2200 m asl, usually on north or west facing slope. This forest is evergreen and trees of lauraceae and symplocaceae are prominent. Dominant species are *Rhododendron arboreum, Neolitsea pallens, Symplocus ramosissima, Lyonia ovalifolia* and *Cinnamomum glanduliferum.* Understory is composed of *Berberis aristata, Myrsine semiserrata, Eurya acuminata, Persea odoratissima* and *Viburnum erubescens.*

iv. Quercus forest: This type of forest is recorded on the higher elevation of Resunga extending from 2100 m asl to the top of the Resunga hill. *Quercus semecarpifolia* is the dominant species and most of the canopy is formed by *Quercus*. Other species are *Symplocus ramosissima, Rhododendron arboreum, Neolitsea pallens* and *Ilex dipyrena.* Understory is composed of *Berberis aristata, Myrsine semiserrata, Eurya acuminata and Daphne papyracea.*

3.4 Wildlife (Fauna)

Resunga hill shows diversity in vegetation and supports various types of birds and animals. Some interesting wildlife found in the area are – Kalij pheasant (*Lophura leucomellana*), Red jungle fowl (*Gallus gallus*), Barking deer (*Muntiacus muntjack*), Leopard (*Panthera pardus*), Fox (*Vulpes vulpes*), Monkey (*Macaca mulatta*), Common longoor (*Semnopithecus schistaceus*), Jacal (*Canis aureus*), Porcupine (*Hystrix indica*), Common mongoose (*Herpestes edwardsii)*, Squirrel (*Funambulus pennaii*), Rabbit (*Lepus nigricollis)* (K.C. 2006).

3.5 People and socio-economic condition

People living around the Resunga forest are of different ethnic groups like *Brahmin, Chhetri, Magar, Newar, Kumal, Kami, Damai* and *Sarki.* The main occupation of most of the people is agriculture and animal husbandry. Some of the people are traders and businessman, some are engaged in foreign employment and some others are involved on civil service. Economy of most of the people is based on agriculture. Some people collect medicinal herbs and wild edible fruits and sell them in local market or to the traders. Some families collect firewood from the forest and sell them in the local market (K.C. 2006).

3.6 Field sampling

The study area was first visited on July 2012 and repeated visits were made on subsequent months. Systematic sampling method was used for locating the sampling plots. The forest block was horizontally divided into seven elevation bands extending 100 m altitude in each. In each elevation band, five quadrats of 10×10 m^2 were located randomly at least 100m apart from each other.

At each location a square quadrat of 10 m ×10 m was defined with the help of iron peg and nylon rope. All the woody species present within the quadrat were recorded. Plants having diameter more than 10 cm at breast height (137 cm) were considered as trees and other woody plants were considered as understory shrubs. Diameter at breast height (DBH) was measured for all individuals of trees.

Geographic location i.e. latitude, longitude and elevation of each quadrat (10 m × 10 m) was recorded using Global Posioning System (GPS, Garmin eTrex® 10) from the centre of the quadrat. Canopy cover and ground vegetation cover was estimated visually. Disturbances like trampling, grazing, cutting were also recorded.

Based on vegetation and elevation, the whole sampling forest was divided into two zones – Subtropical forest and Temperate forest. Subtropical forest ranges up to 2000 m asl and Temperate forest ranges 2000 m asl to the top of the Resunga hill, 2347 m asl.

3.7 Plant collection, Herbarium preparation and Identification

Herbarium specimen of woody plant species occurring inside the quadrats were collected, tagged, pressed and dried. Herbs were collected from both inside and outside the quadrats along the elevation bands. Digital photographs of live plant specimens were taken in the field. Special characters of plant were documented as field notes. Consulting the local inhabitants, local names of the specimens were recorded. Some of the specimens were identified in the field with the help of 'Flowers of the Himalaya' (Polunin and Stainton 1984) and its supplement (Stainton 1988).The other specimens were identified in National Herbarium and Plant Laboratory (KATH) and Tribhuvan University Central Herbarium (TUCH) tallying with the specimens deposited in the herbaria.Annotated Checklist of the Flowering Plants of Nepal (Press *et al.* 2000) was followed for author citation. Herbarium specimens are deposited in the TUCH.

3.8 Data Analysis

3.8.1 Community Structure

Quantitative data were gathered with the help of field data sheet and analyzed for abundance, density and frequency according to Curtis and McIntosh (1950) and Mishra (1968). Importance value index (IVI) was calculated as Curtis (1959) reported. The diversity index (H') was calculated by using Shannon-Wiener's index. The concentration of dominance (CD) was calculated by Simpson's Index (Simpson 1949).Simpson's index (C) and Shannon-Wiener's index (H') was calculated following Barbour *et al.* (1999).For trees, basal area was calculated and for understory shrubs, cover was calculated. The formulae used for the calculation of these attributes are given below:

$$\text{Frequency (\%)} = \frac{\text{Number of Quadrats in which individual species occured}}{\text{Total number of quadrats studied}} \times 100$$

$$\text{Density (ind ha}^{-1}\text{)} = \frac{\text{Total number of individuals of a species}}{\text{Total number of quadrats studied} \times \text{Area of quadrat}} \times 10000$$

$$\text{Basal Area (m}^2\text{)} = \frac{\Pi}{4} \times (\text{DBH})^2$$

Where, DBH = diameter of the tree at breast height.

$$\text{Basal Area (m}^2\text{ha}^{-1}\text{)} = \frac{\text{Total Basal Area of a species}}{\text{Total number of quadrats studied} \times \text{Area of a quadrat}} \times 10000$$

Basal area of a species in each sampling plot was obtained by the summation of BA of all individuals of a species.

$$\text{Relative Frequency (\%)} = \frac{\text{Frequency of individual species}}{\text{Sum of the frequencies for all species}} \times 100$$

$$\text{Relative Density (\%)} = \frac{\text{Density of individual species}}{\text{Total Density of all species}} \times 100$$

$$\text{Relative Basal Area (\%)} = \frac{\text{Basal area of individual species}}{\text{Total Basal area of all species}} \times 100$$

Importance Value Index (IVI) gives the overall importance of each species in the community structures. It was calculated as the sum of relative values of density, frequency and basal area for tree and relative values of density, frequency and cover for understory shrubs.

Importance Value Index (IVI) = Relative frequency + Relative density + Relative basal area.

Simpson's index (C) $=\sum_{i=1}^{s}(pi)^2$

Shannon- Wiener's index (H') = $-\sum_{i=1}^{s}(pi \ln pi)$

Where, S = total number of species

pi= proportion of all individuals in the sample that belongs to species i.

$\ln pi$ = natural logarithm of pi.

Similarity index was calculated using the following formula (Magurran 2004).

Sorenson's similarity index (ISs) $= \frac{2C}{A+B} \times 100$

Where, IS = index of similarity

A = total number of species in one community (subtropical community)

B = total number of species in another community (temperate community)

C = total number of species which occur in both community

The similarity index ranges from 0 – 100% to quantify the range from dissimilarity to complete similarity.

Size class distribution diagram was used to predict regeneration behavior of trees. All the trees were divided into DBH classes of 10 cm interval and density of trees in each diameter class was calculated. Size class distribution diagram was prepared by plotting diameter class on x-axis and density on y-axis (Barbour *et al.* 1999).

3.8.2 Regression analysis

Linear regression analysis was carried out to evaluate the effect of altitude on plant density. In regression analysis, altitude levels were used as predictor variables. The woody vegetation (trees and shrubs) found in study areas were categorized in to seven different altitudinal levels, from 1700-2300 m asl. The number of shrubs species, trees species and total woody species in each level of altitude were treated individually. The data was normalized by log transformation before the analysis.

3.8.3 Ordination

Detrended Correspondence Analysis (DCA)

Detrended Correspondence Analysis (DCA), an indirect gradient analysis (Hill and Gauch 1980) was used to analyze the species composition to test the turnover rate or axis length. The SD units of first two ordination axes (axis I and axis II) together with the eigenvalues were used to evaluate the dispersion pattern with the species composition. Eigenvalues are the shrinkage values in weighted averages (Oksanen 1996). The axes explain percentages of the variance in the species data and eigenvalues are good measurement of the main variation in samples and species along the ordination axes (Jongman*et al.* 1995).

Canonical Correspondence Analysis (CCA)

Canonical Correspondence Analysis (CCA) is a direct gradient analysis (ter Braak 1986). The gradient length obtained from DCA greater than 2 SD units are allowed to use Canonical Correspondence Analysis (CCA) to relate the species composition to the elevation. CCA displays three pieces of information simultaneously samples as plots, species as symbols and environmental variable as arrows or points (Palmer 2007).

3.8.4 Software used

R version 2.15.1 (R Core Team 2013) was used for ordination analyses. *SPSS* 16.0 (Statistical Package for Social Science) (SPSS Inc. 2007) was used for linear regression.

4. RESULTS

4.1 Species composition

Altogether 236 species of plants under 79 families and 191 genera were identified from the study area. Among them, 196 species of Dicotyledonae belong to 155 genera and 68 families; 39 species of Monocotyledonae belong to 34 genera and 10 families; single species of Gymnospermae belongs to single genus and single family (Figure 3).

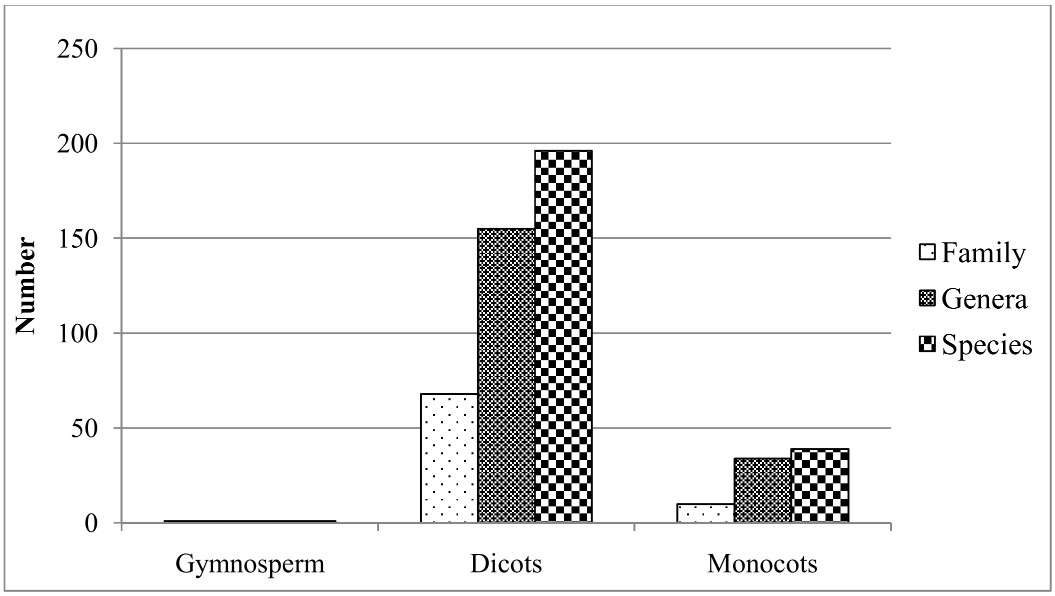

Figure 3: Distribution pattern of family genera and species.

4.1.1 Family and Genera composition

Based on number of species recorded from study area, ten largest families were Asteraceae (25 species), Lamiaceae (15 species), Leguminosae (12 species), Rosaceae (11 species), Poaceae (10 species), Polygonaceae (8 species), Ranunculaceae (7 species), Urticaceae (7 species), Liliaceae (7 species) and Orchidaceae (7 species) (Figure 4). Ten larger families represent 46.2% diversity of all recorded species. Similarly, ten largest genera were *Persicaria* (5 species), *Anaphalis* (4 species), *Desmodium* (4 species), *Clematis* (3 species), *Galium* (3 species), *Geranium* (3 species), *Potentilla* (3 species), *Rubus* (3 species), *Symplocos* (3 species) and *Viburnum* (3 species) (Figure 5).

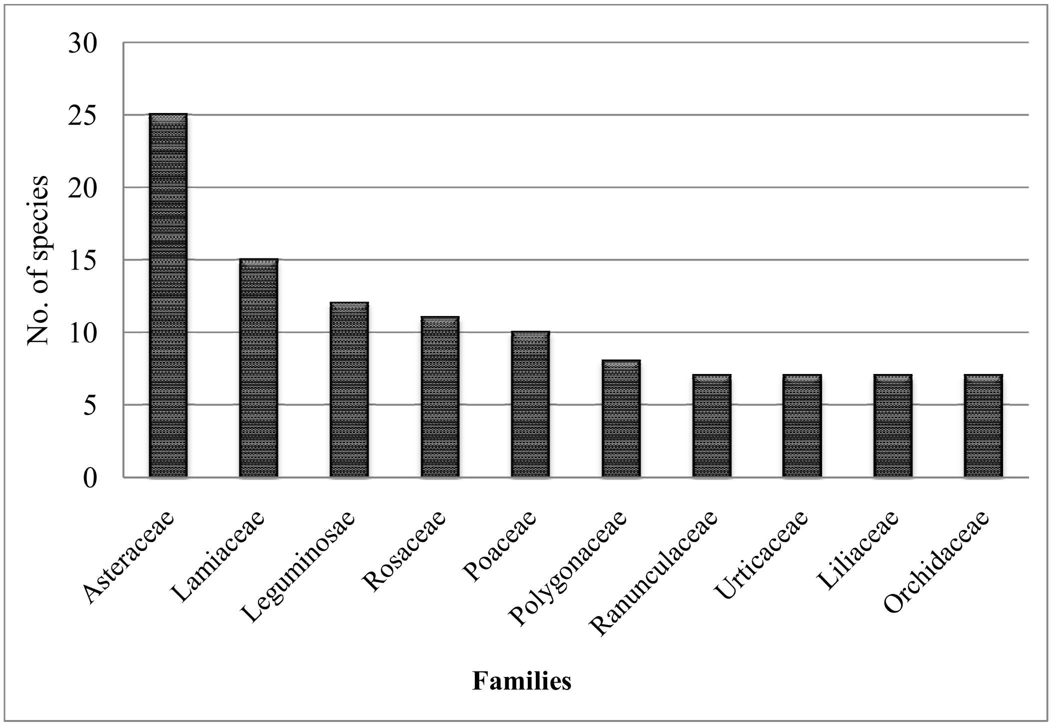

Figure 4: Ten largest families with their species number.

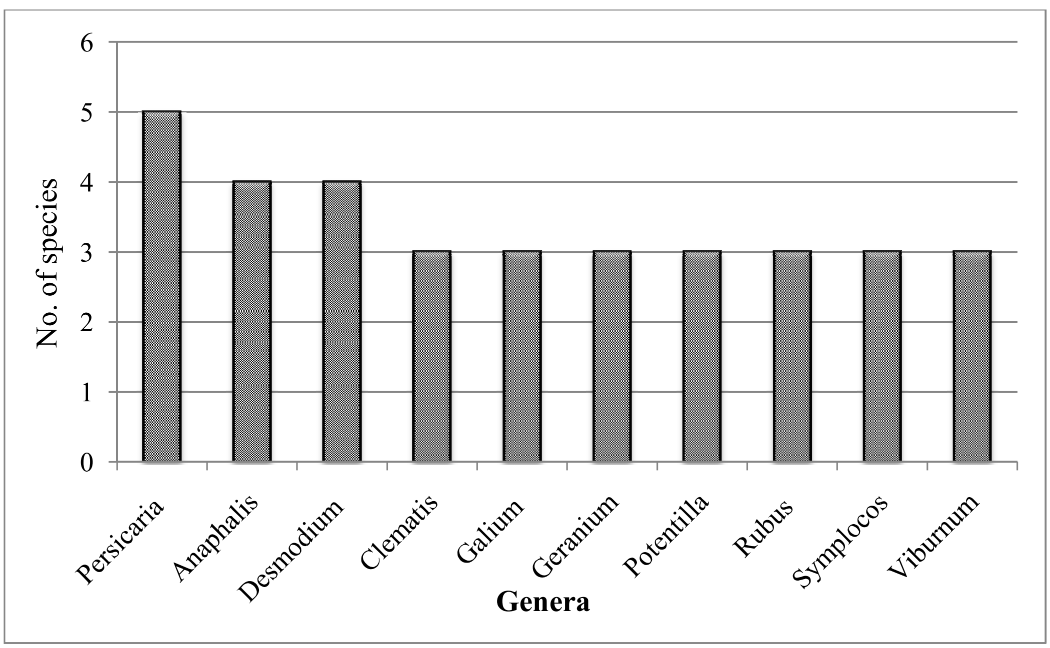

Figure 5: Ten largest genera with their species number.

4.2 Community structure of woody plant species

Subtropical Forest (1700 -2000 masl)

Among the 27 tree species recorded in subtropical zone, *Pyrus pashia* showed the highest frequency (93.33%) and relative frequency (14.74) followed by *Lyonia ovalifolia* (frequency 73.33% and relative frequency 11.58) and *Myrica esculenta* (frequency 66.67% and relative frequency 10.53). Similarly, *Pyrus pashia* showed highest tree density (1086.67 stem per hectare) followed by *Lyonia ovalifolia* (620 stem /ha) and *Neolitsea pallens* (333.33 stem /ha). Basal area of *Aesculus indica* was highest (24.59 m^2 /ha) followed by *Pyrus pashia* (16.3 m^2 /ha) and *Pinus roxburghii* (13.92 m^2 /ha). Importance Value Index (IVI) of *Pyrus pashia* was found to be highest (58.53), followed by *Lyonia ovalifolia* (40.56) and *Aesculus indica* (26.01). Tree species like *Pyracantha crenulata, Toricellia tiliifolia* and *Viburnum erubescens* showed least IVI (1.28). IVI of most dominant ten trees species in decending order is shown in Figure 6. Quantitative analysis of vegetation is shown in Appendices III and IV.

Understory of this Subtropical forest was covered by 34 species of plants. Among them *Berberis asiatica* showed the highest frequency (86.67%), both *Maesa chisia* and *Osbeckia stellata* showed 66.67% and *Phyllanthus parvifolius* 60%. Density of *Phyllanthus parvifolius* 12893.33 individuals per hectare was found to be the highest and was followed by *Maesa chisia*(1080 ind /ha) and B*erberis asiatica* (1053.33 ind /ha). Cover of *Phyllanthus parvifolius* (6.97%) was found to be the highest, followed by B*erberis asiatica* (5.13%) and *Maesa chisia* (3.93%). IVI of *Phyllanthus parvifolius* was found to be highest (90.7) and was followed by B*erberis asiatica* (28.99) and *Maesa chisia* (23.61). IVI of most dominant ten understory woody plant species in decending order is shown in Figure 7.

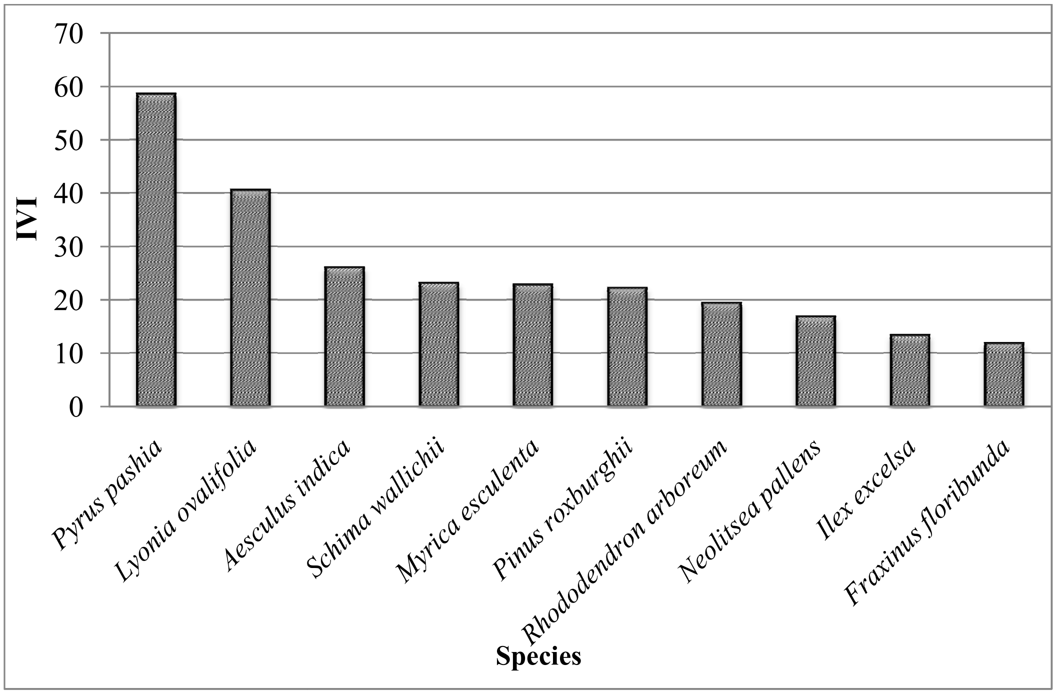

Figure 6: IVI of most dominant ten tree species in Subtropical forest.

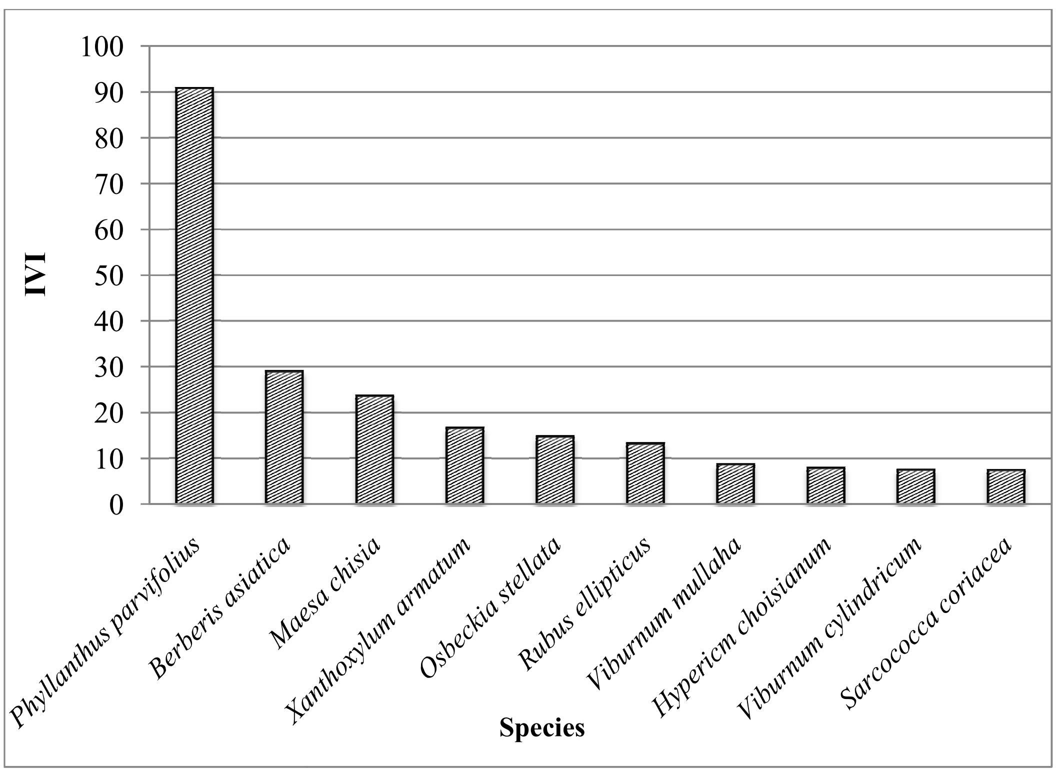

Figure 7: IVI of most dominant ten understory woody species in Subtropical forest.

Temperate Forest (2000 -2350 masl)

Among 32 tree species recorded in Temperate forest, *Neolitsea pallens* showed the highest frequency (82.35%) and relative frequency (9.66), followed by *Rhododendron arboreum* and *Symplocos ramosissima* (both having frequency 70.59% and relative frequency 8.28) and *Quercus semecarpifolia* having frequency 58.82% and relative frequency 6.9. Similarly, *Quercus semecarpifolia* showed highest tree density (1653 stem per hectare) followed by *Symplocos ramosissima* (929.4 stem /ha) and *Neolitsea pallens* (723.5 stem /ha). Basal area of *Quercus semecarpifolia* was highest (115.9 m^2 /ha) followed by *Rhododendron arboreum* (39.29 m^2 /ha) and *Symplocos ramosissima* (18.69 m^2 /ha). Importance Value Index (IVI) of *Quercus semecarpifolia* was found to be highest (85.57), followed by *Symplocos ramosissima* (32.63) and *Neolitsea pallens* (27.74). Species like *Pyracantha crenulata* and *Viburnum mullaha* showed least IVI (0.81). IVI of most dominant ten species of trees is shown in Figure 8. Quantitative analysis of vegetation is shown in Appendices V and VI.

Understory of this temperate forest was covered by 39 species of plants. Among them *Berberis asiatica* and *Myrsine semiserrata* showed the highest frequency (58.82%), *Eurya acuminate* showed 52.94%, *Neolitsea pallens, Symplocos ramosissima* and *Viburnum erubescens* each showed 47.06% frequengy. Density of *Myrsine semiserrata* (1147.06 individuals per hectare) was found to be the highest and was followed by *Wikstroemia canescens* (582.35 ind /ha) and *Symplocos ramosissima* (541.18 ind /ha). Cover of *Myrsine semiserrata* (2.94%) was found to be the highest, followed by B*erberis asiatica* (1.68%) and *Persea odoratissima* (1.41%). IVI of *Myrsine semiserrata* was found to be highest (40.43), followed by *Symplocos ramosissima* (19.99) and B*erberis aristata* (19.94). IVI of most dominant ten woody understory species is shown in Figure 9.

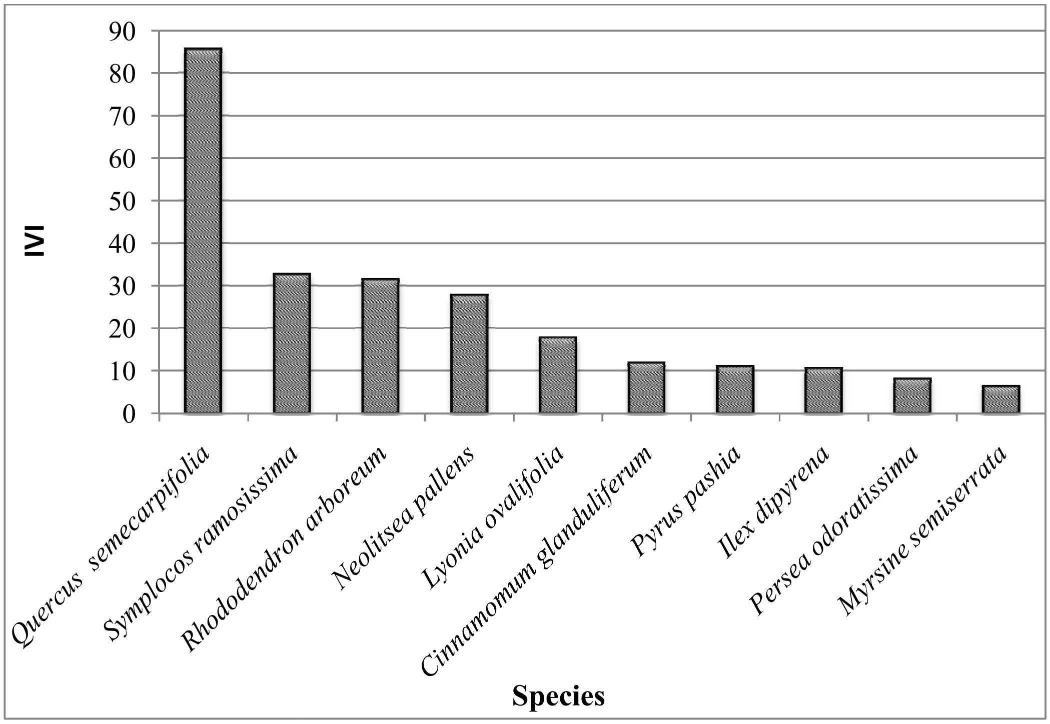

Figure 8: IVI of ten most dominant tree species in Temperate forest.

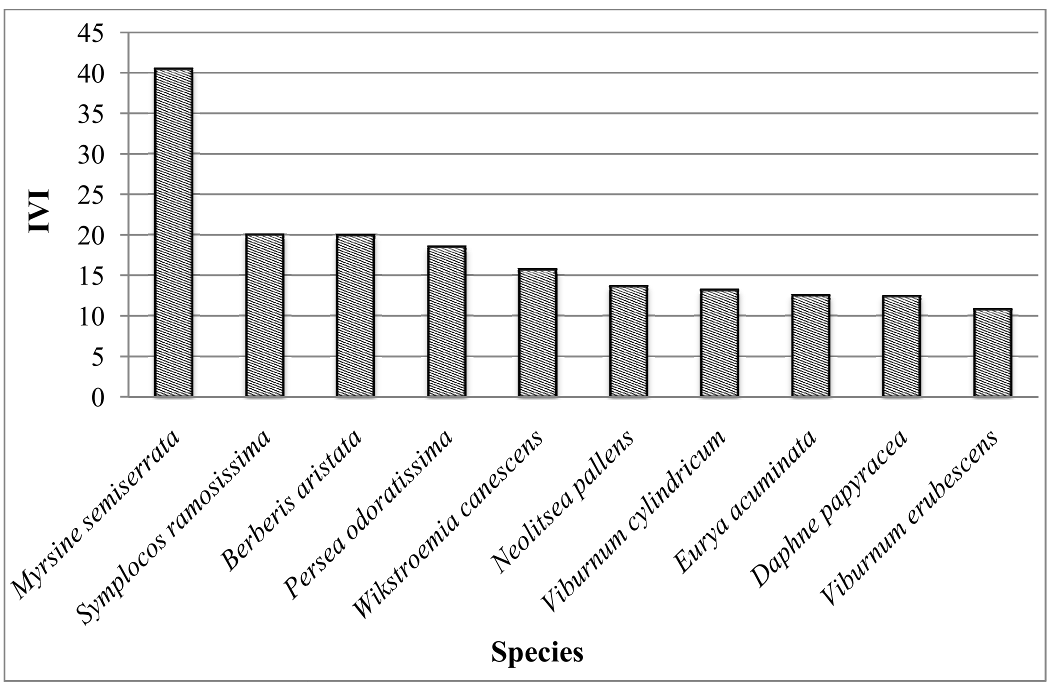

Figure 9: IVI of ten most dominant understory species in Temperate forest.

4.3 Species Diversity Indices

Altogether 74 woody species were collected from study area. Species richness of woody species was higher in subtropical forest (3.33 per 100 m^2) and 2.88 per 100 m^2 in temperate forest. Simpson's index of dominance (C) for trees was higher in subtropical forest (0.143) than in temperate forest (0.141). Shannon-Wiener's index (H') was higher in temperate forest (2.459) than subtropical forest (2.374). Similarly, Simpson's index of dominance (C) for understory shrubs and tree saplings was higher in subtropical forest (0.429) than in temperate forest (0.072). Shannon-Wiener's index (H') was higher in temperate forest (3.062) than subtropical forest (1.676). Sorenson's similarity index for woody species between subtropical and temperate forests was 78.79%.

4.4 Size Class Distribution

Tree species were classified into size classes with DBH interval of ten cm. Then density diameter curve was developed. Almost inverse –J shaped curve was obtained. (Figure 10).

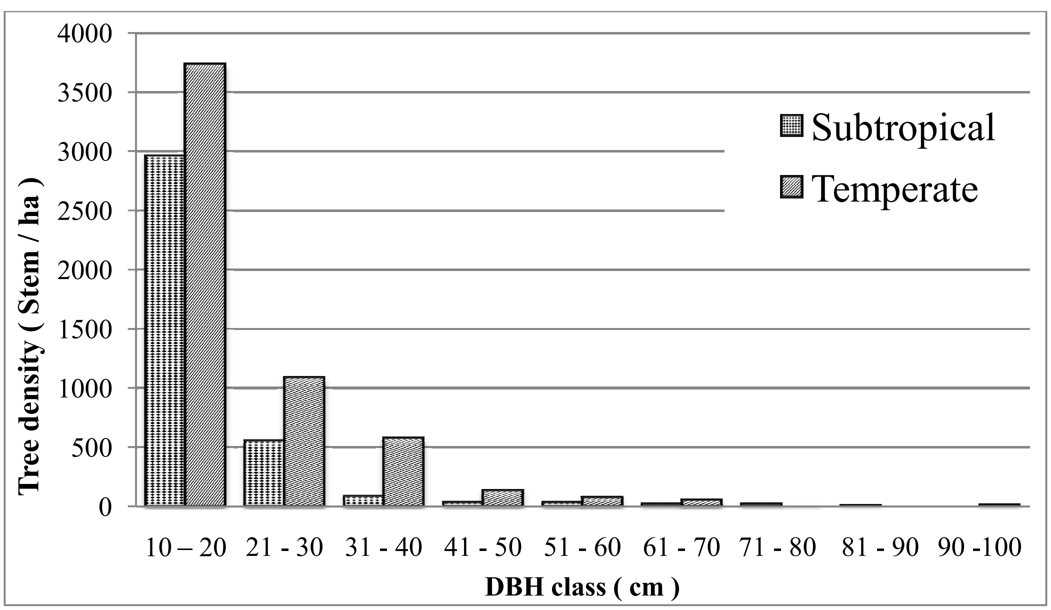

Figure 10: Density –Diameter distribution of tree species.

4.5 Species richness and elevation gradients

The altitude showed significant relationship along with richness in shrub species, tree species and total woody plant species richness (Table 1). In all the cases, the richness showed bell shaped pattern of distribution. The number of both shrub species and tree species linearly increased from 1700 m to 1900 m. At altitude between 1900 - 2000 m asl, woody plant species showed highest species richness (Figure 11). The number of species reduced in both cases after 2000 m asl. The probability of representation of highest number of species in this region should be linked to the ecotone effect.

Table 1: Univariate linear regression analysis of the relationship between vegetation attributes along different altitudes. R^2 is the coefficient of determination; Beta is the standardized regression coefficient. The values were analyzed at 95% confidence interval.

Vegetation attributes	R^2	df	Beta	*F*	*P*
Total no. of tree species	0.948	1, 32	0.974	565.744	0.000
Total no. of shrub species	0.918	1, 32	0.958	344.897	0.000
Total no. of woody species (Shrub & trees)	0.963	1, 32	0.981	812.125	0.000

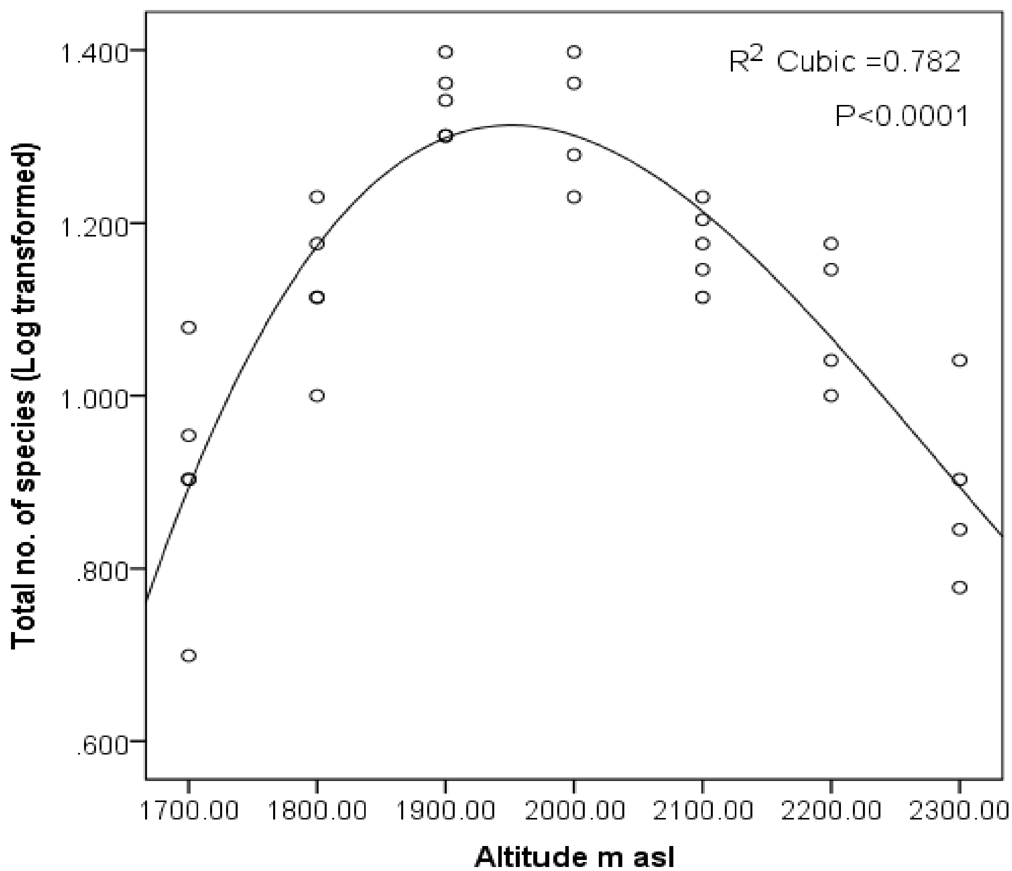

Figure 11: Relationships between total woody species (shrubs and trees) richness along altitude based on linear regression analysis.

4.6 Species composition

4.6.1 Detrended Correspondence Analysis (DCA)

The detailed summary of Detrended Correspondence Analysis (DCA) showed quite strong Eigen value along the axis I (Table 2). The axis length in terms of standard deviation (SD) units for first and second axes were 5.09 SD unit and 2.81 SD units respectively which means that there is a unimodal pattern among species along main gradient. The axis lengths remained greater than 1.5 SD units. Thus direct ordination of longer lengths of gradients *i.e.,* CCA has been permitted.

Table 2: Summary of Detrended Correspondence Analysis

Axis	DCA1	DCA2	DCA3	DCA4
Eigenvalues	0.82	0.40	0.14	0.23
Decorana values	0.83	0.37	0.20	0.09
Axis lengths	5.09	2.81	2.83	1.65

4.6.2 Canonical Correspondence Analysis (CCA)

The direct ordination for longer length of gradient, *i.e.*, Canonical Correspondence Analysis (CCA) was carried for the species and environment data. The DCA ordination (length of the gradient = 5.09 and 2.81, and Eigen value = 0.82 and 0.40 for first axis and second axis respectively) explains the differences in compositional variation along the altitude. Based on the axis length obtained in DCA ordination, CCA was performed and CCA ordination clearly denoted compositional variation along the altitudes. The plant species *Pinus roxburghii* and *Phyllanthus parvifolius* form a cluster in lower elevation. *Quercussemecarpifolia*, *Q. lanata, Benthamidia capitata, Persea odoratissima, Wikstroemia canescens, Symplocos ramosissima, Neolitsea pallens* are mostly found in close association in higher elevation towards the top of the forest. Other most of the species are found in close association in mid-elevation of the study area (Figure 14).

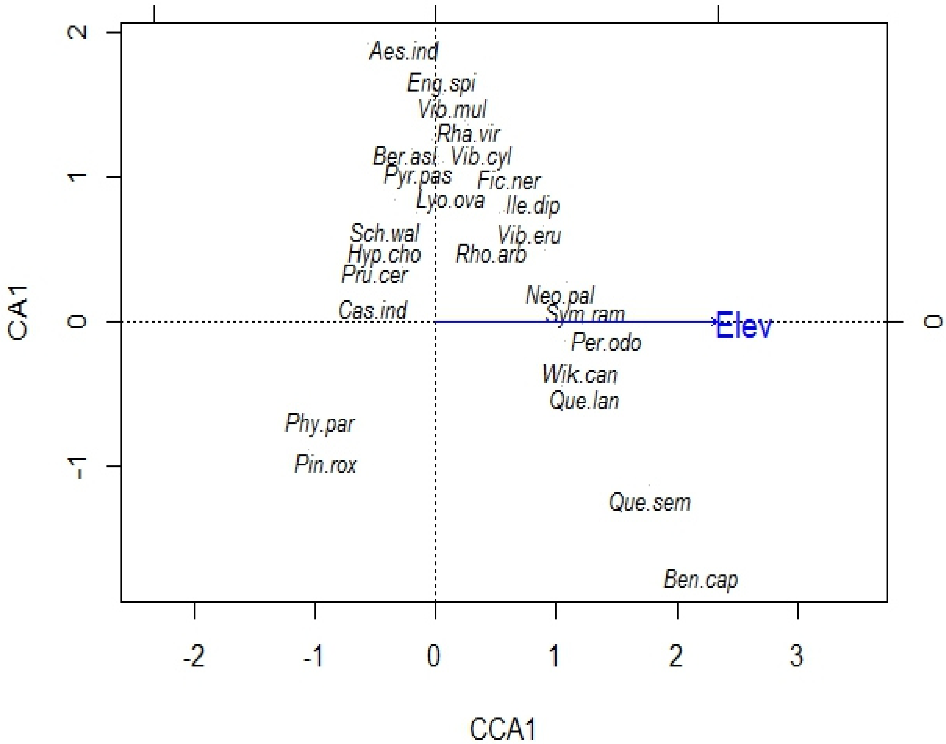

Figure 12: CCA biplot showing species and elevation. Full name of each species is given in Appendix I.

5. DISCUSSION

5.1 Community structure of woody plant species

Vegetation composition was varied in this area. The common vegetations were *Schima-Pine-Lyonia* at Subtropical forest (1700-2000 m) and *Quercus-Symplocos-Neolitsea* at Temperate forest (2000-2350 m). The frequent species were *Pyrus pashia, Lyonia ovalifolia, Schima wallichii, Rhododendron arboreum* and *Myrica esculenta.* The forest floor is not uniform and it was anthropogenically disturbed due to grazing, firewood and foddercollection and felling of tree for timber uses.

The forest of study area is diverse type that ranges from Pine dominated Subtropical community to *Quercus* dominated temperate community. With increasing elevation domination of *Schima, Lyonia, Pyrus, Neolitsea, Symplocos, Rhododendron* and *Quercus* is gradually increased. In many Community Forests collection of fodder and fuel-wood is regular, but chopping trees for timber is not so common.

Stand density differed slightly. Density is influenced by various factors, including elevation, soil type, dominant and associated species and human activities (Shrestha *et al.* 1998). The total density of tree species was higher in Temperate forest sinceit is more protected. This was because the distance to the nearest settlement increases with increasing altitude, consequently decreases resources access to local people in higher elevation. Moreover, in higher altitude, the presence of less priorities trees species like *Quercus, Symplocos, Neolitsea and Lindera* for fodder and timber also resulted in higher density of tree species. Lower density of trees at Subtropical forest comparing to the Temperate forest may be due to human interference as subtropical region is nearer from the human settlement. Subtropical forest thus, faced disturbance pressure where local people collect fodder, firewood and even timber, resulted in low tree density.

The total basal area of tree species is higher in Temperate forest than Subtropical forest. The forest having small basal area per hectare showed the sparsely dispersed tree species in comparison with large basal area (Duwadee *et al.* 2002). The higher basal area was also due to higher tree density. The difference in basal area of tree layer may be due to difference in altitude, species composition, age of trees and degree of disturbance and succession stage of stands.

The IVI for any species in this altitudinal range did not exceed 45% of total IVI. It indicates considerable sharing of importance by number of species. This shows an overall mixed type of forest. The Shannon-Wiener's index (H') for the natural communities is often found to fall in range of 1 to 6. Shannon-Wiener's index of diversity for trees was found higher for Temperate forest than Subtropical forest. Concentration of dominance (C) showed reverse trend as compared to species diversity. This study showed the Concentration of dominance (C) higher in Subtropical forest than in Temperate forest. Lower value of C showed that area was shared by many species. Index of Similarity (IS) calculated for woody species regarding the number of common species present in both regions suggested overlapping of some common taxa.

The number of different age groups of plant species was more uniformly present at Temperate forest. Although the recently regenerating plants were nearly equal in Subtropical forest and Temperate forest, plants of mature age groups were lesser in Subtropical forest. The regenerating plants were more in Temperate forest and also forest was more healthier at higher elevation. The reverse J-shaped size class distribution of trees in a community indicated sustainable regeneration (Vetaas 2000). Almost inverse J-shaped graph was obtained from both forests. The regeneration potential of trees was somewhat continuous. Similar result was found by Shrestha (2005) and Pandey (2009). The different shape of density-diameter showed the extent of effect of disturbances on the density diameter classes (Gautam and Watanabe 2005). In a montane rain forest in Mexico, Ramirez-Marcial *et al.* (2001) found that stem density decreases with disturbance intensity. This study also found that the stem density declined with increasing disturbances such as grazing, cutting, browsing and trampling.

Regarding woody species, species richness is higher in Subtropical forest which was moderately disturbed and at the stage of regeneration. The canopy gap was wider in this region. Canopy was also a significant factor, probably through its influence on the light intensity reaching to the ground (Spur and Barens 1973). Due to human disturbances the density of plants were found less and there may be the chance of migration of seeds of new plants to grow and establish in moderately disturbed forest so that newly germinating and regenerating plants can get the nutrients without struggle. The less species richness in Temperate forest is due to close canopy which was dominated by few trees only.

5.2 Species richness patterns and elevational gradient

General concept about the species richness with the elevation is gradual decrease in species richness as the elevation increases (Brown and lomolino 1999; Körner 2002; Fossa 2004; Baniya *et al.* 2010). There are three main patterns of species richness: a monotonic increase with elevation, a monotonic decrease with elevation and unimodal pattern (Rahbek 1995, 1997). The most dominant pattern of species richness along elevation is the unimodal pattern (Rahbek 1995; Brown 2001; Vetaas and Grytnes 2002; Carpenter 2005; Rowe and Lidgard 2009). This pattern applies well along the Nepalese Himalayan elevational gradient (Bhattarai and Vetaas 2003, Grytnes 2003, Bhatarai *et al*. 2004, Carpenter 2005). This study also showed similar unimodal pattern of woody species richness along the elevational gradient. In this study, understory shrub and tree species richness showed similar trend along an elevational gradient. Bhattarai and Vetaas (2003) have found unimodal pattern of species richness for shrub species with maximum species at an elevation range 600-800masl in subtropical zone of eastern Nepal. Carpenter (2005) also found the hump shaped understory as well as tree density with peaked at 1470 m asl and 1430 m asl along the elevational gradient in eastern Nepal. Species richness found maximum at mid-elevation and decreasing towards lower and higher elevational gradients was found similar as Grytnes (2003), Baniya *et al.* (2009), Sharma (2012), Chhetri and Bhattarai (2013) and Bhattarai *et al.* (2014).

The species richness pattern depends upon the scale of elevation taken. In whole range of Himalayas, species richness starts to increase from low elevation then becomes saturation at mid elevation and decreases further up and forms unimodal pattern (Bhattarai and Vetaas 2003, Grau *et al.* 2007, Baniya *et al.* 2010, Acharya *et al.* 2011, Chhetri and Bhattarai 2013 and Bhattarai *et al.* 2014).

Present study carried out in short range of middle elevational gradient also showed mid elevation peak of species richness. This is because the mid elevation region is the ecotone between subtropical and Temperate forests. Ecotones, comprising meeting areas between adjoining communities, include a combination of species from two or more community types (Risser 1995). Ecotonal areas often comprise the edge of the range for species on both sides where many peripheral populations occur (Kark and van Rensburg 2006; Shmida and Wilson 1985). Shmida and Wilson (1985) proposed that the high number of species in transitional areas could be due to a process they called the mass effect, which is the flow of individuals from favorable to unfavorable areas.

One consequence of ecotone has been described as the edge effect, the tendency for increased population density and species richness at the junction zone between two communities (Odum 1958). The ecotone contains not only species common to the communities on both sides; it may also include a number of highly adaptable species that tend to colonize such transitional areas (Smith 1974). The phenomenon of increased variety of plants as well as animals at the community junction is called the edge effect and is essentially due to a locally broader range of suitable environmental conditions or ecological niches.

5.3 Species composition

The eigenvalue of first DCA axis was found greater than 0.5 which means the complete turnover of species along the environmental variable. The complete turnover of species along the environmental variable was found to be similar as Baniya *et al.* (2009), Sharma (2012), Katuwal (2013). The length of gradient for first axis was found greater than 5 SD units that indicate the area is highly heterogeneous and rich in beta diversity which is also similar as Baniya *et al.* (2009). The species found at one end of the gradient are different from another end of gradient (CCA biplot). The length of gradient was found greater than 1.5 which indicates the unimodal relationship of species with the elevation.

6. CONCLUSION

This study concludes subtropical-temperate ecotone forest of Resunga region is rich in plant diversity. Woody species richness along the elevational gradient showed the general mid-elevation peak of species richness. Tree species richness and understory shrub species richness also followed the similar pattern of intermediate peak in richness with elevation. The species composition of woody species showed the area is highly heterogeneous and rich in beta diversity. IVI of woody species indicates considerable sharing of importance by number of species. This study showed subtropical-temperate ecotone forest of Resunga region is an overall mixed type of forest.

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APPENDICES

Appendix I: Full name of plant species used in CCA Analysis.

Abbreviation		Full name of plant species
Aes ind	=	*Aesculus indica* (Colebr. ex Cambess.) Hook.
Aln nep	=	*Alnus nepalensis* D. Don
Ben cap	=	*Benthamidia capitata* (Wall.) H. Hara
Ber ari	=	*Berberis aristata* DC.
Ber asi	=	*Berberis asiatica* Roxb. ex DC.
Cas ind	=	*Castanopsis indica* (Roxb.) Miq.
Cas tri	=	*Castanopsis tribuloides* (Sm.) A. DC.
Cin gla	=	*Cinnamomum glanduliferum* (Wall.) Meisn.
Dap pap	=	*Daphne papyracea* Wall. ex Steud.
Ela par	=	*Elaeagnus parvifolia* Wall. ex Royle
Eng spi	=	*Engelhardtia spicata* Lesch. ex Blume
Eur acu	=	*Eurya acuminata* DC.
Fic ner	=	*Ficus neriifolia* var. *nemoralis* (Wall. ex Miq.) Corner
Fra flo	=	*Fraxinus floribunda* Wall.
Hyp cho	=	*Hypericm choisianum* Wall. ex N. Robson
Ile dip	=	*Ilex dipyrena* Wall.
Ile exc	=	*Ilex excelsa* (Wall.) Hook. f.
Ind exi	=	*Indigofera exilis* Grierson & D.G.
Leu can	=	*Leucosceptrum canum* Sm.
Lin pul	=	*Lindera pulcherrima* (Nees) Benth. Ex Hook. f.
Lon qui	=	*Lonicera quinquelocularis* Hardw.
Lyo ova	=	*Lyonia ovalifolia* (Wall.) Drude
Mae chi	=	*Maesa chisia* Buch.-Ham. ex D. Don
May ruf	=	*Maytenus rufa* (Wall.) H. Hara
Mic kis	=	*Michelia kisopa* Buch.-Ham. ex DC.
Myr esc	=	*Myrica esculenta* Buch.-Ham. ex D.Don
Myr sem	=	*Myrsine semiserrata* Wall.
Neo pal	=	*Neolitsea pallens* (D. Don) Momiy. & H.Hara ex H. Hara
Osb ste	=	*Osbeckia stellata* Buch.-Ham. ex D. Don
Osy wig	=	*Osyris wightiana* Wall. ex Wight
Per gam	=	*Persea gamblei* (King ex Hook. f.) Kosterm. ex Kosterm . & Chater.
Per odo	=	*Persea odoratissima* (Nees) Kosterm.
Phy par	=	*Phyllanthus parvifolius* Buch.-Ham. ex D. Don
Pin rox	=	*Pinus roxburghii* Sarg.
Pru cer	=	*Prunus cersasoides* D. Don
Pyr cre	=	*Pyracantha crenulata* (D. Don) M. Roem.
Pyr pas	=	*Pyrus pashia* Buch.-Ham. ex D. Don
Que lan	=	*Quercus lanata* Sm.
Que sem	=	*Quercus semecarpifolia* Sm.
Ran tet	=	*Randia tetrasperma* (Roxb.) Benth. & Hook. f. ex Brandis
Rha vir	=	*Rhamnus virgatus* Roxb.

Rho arb	=	*Rhododendron arboreum* Sm. Var. arboreum
Rhu jav	=	*Rhus javanica* L.
Rhu suc	=	*Rhus succedanea* L.
Ros ser	=	*Rosa sericea* Lindl.
Rub ell	=	*Rubus ellipticus* Cycl.
Rub pan	=	*Rubus paniculatus* Sm.
Sar cor	=	*Sarcococca coriacea* (Hook.) Sweet
Sch wal	=	*Schima wallichii* (DC.) Korth.
Smi asp	=	*Smilax aspera* L.
Sym luc	=	*Symplocos lucida* (Thunb. ex Murray) Siebold & Zucc.
Sym pan	=	*Symplocos paniculata* (Thunb.) Miq.
Sym ram	=	*Symplocos ramosissima* Wall. ex G.Don
Tor til	=	*Toricellia tiliifolia* DC.
Tri con	=	*Trichilia connaroides* (Wight & Arn.) Bentv.
Vib cyl	=	*Viburnum cylindricum* Buch.-Ham. ex D. Don
Vib eru	=	*Viburnum erubescens* Wall. ex DC.
Vib mul	=	*Viburnum mullaha* Buch.-Ham. ex D. Don
Wik can	=	*Wikstroemia canescens* Meisn.
Xan arm	=	*Xanthoxylum armatum* DC.

Appendix II: Characteristics of sample plots.

Plot No.	Elevation	Latitude	Longitude	Slope (°)	Aspect	Exposed Ground (%)	Expose d Rock (%)	Disturbance
1	1700	28.0788 N	83.2558 E	25	N	5	1	medium, cutting, trampling
2	1709	28.07993 N	83.25549 E	30	NW	10	3	medium, cutting
3	1715	28.0773 N	83.25751 E	25	NW	8	1	slight, cutting, trampling
4	1714	28.07447 N	83.26167 E	30	NW	2	0	Slightcutting
5	1742	28.07231 N	83.26432 E	35	NW	5	40	Slightcutting
6	1804	28.07602 N	83.25618 E	25	N	5	0	slight, trampling, cutting
7	1803	28.07594 N	83.25701 E	25	N	3	0	medium, trampling, cutting
8	1800	28.07506 N	83.25813 E	30	NE	3	0	medium, cutting
9	1810	28.07318 N	83.26101 E	20	N	3	0	medium, cutting
10	1806	28.07173 N	83.26395 E	30	NW	5	2	medium, cutting trsampling
11	1914	28.07248 N	83.3582 E	15	N	2	0	slight trampling
12	1919	28.07229 N	83.25895 E	15	NE	1	0	slight , trampling cutting
13	1917	28. 07176 N	83.25992 E	25	NE	1	0	slight , cutting
14	1910	28.07122 N	83.26079 E	30	NE	2	0	slight, cutting, trampling
15	1910	28.07084 N	83.26211 E	30	NW	2	2	slight, cutting trampling
16	2005	28.07006 N	83.26051 E	10	NW	3	2	slight, trampling
17	2015	28.06977N	83.26133E	25	NW	2	2	slight, cutting, trampling
18	2025	28.06929N	83.26214E	25	N	1	1	slight , cutting, trampling
19	2037	28.06892N	83.26344E	25	NE	2	0	slight , cutting , trampling
20	2130	28.06845N	83.27048E	25	NE	2	1	slight, trampling, cutting
21	2140	28.06935N	83.27407E	25	NE	1	1	slighht , cutting trampling
22	2143	28.06872N	83.27244E	30	NE	2	1	slight, cutting, trampling
23	2126	28.06769N	83,26749E	30	NE	2	1	slight, cutting , trampling
24	2148	28.06842N	83.26998E	10	NW	2	1	medium, cutting , trampling
25	2207	28.06736N	83.27033E	20	NE	3	0	medium, cutting, trampling
26	2200	28.06688N	83.27106E	25	NE	3	0	medium, cutting, trampling
27	2225	28.06674N	83.27015E	15	N	3	0	medium, cutting , trampling
28	2205	28.06216N	83.27602E	25	NW	3	0	slight, trampling
29	2318	28.06402N	83.26860E	15	NE	3	0	medium, cutting, trampling
30	2319	28.06472N	83.26651E	15	N	1	0	medium, cutting, trampling
31	2321	28.06394N	83.26717E	15	NE	5	0	medium, cuting, trampling
32	2300	28.06218N	83.26822E	20	NE	5	0	medium, trampling, cutting

AppendixIII: Density, RD, Frequency, RF, Basal area (BA), RBA and IVI of trees (DBH ≥ 10cm) in Subtropical forest (1700 -2000 m asl).

SN	Species	Density stem/ha	Frequency (%)	BA m^2/ha	RD	RF	RBA	**IVI**
1	*Aesculus indica*	73.33	13.33	24.59	1.97	2.11	21.9	26.01
2	*Castanopsis indica*	13.33	13.33	0.32	0.36	2.11	0.28	2.75
3	*Cinnamomum glanduliferum*	26.67	20	0.8	0.72	3.16	0.72	4.59
4	*Engelhardtia spicata*	6.67	6.67	0.87	0.18	1.05	0.77	2.01
5	*Fraxinus floribunda*	173.3	26.67	3.3	4.67	4.21	2.95	11.82
6	*Ilex dipyrena*	53.33	13.33	0.75	1.44	2.11	0.67	4.21
7	*Ilex excelsa*	120	33.33	5.43	3.23	5.26	4.84	13.33
8	*Lindera pulcherrima*	6.67	6.67	0.17	0.18	1.05	0.15	1.38
9	*Lyonia ovalifolia*	620	73.33	13.77	16.7	11.58	12.3	40.56
10	*Michelia kisopa*	13.33	13.33	0.1	0.36	2.11	0.09	2.56
11	*Myrica esculenta*	240	66.67	6.53	6.46	10.53	5.83	22.81
12	*Neolitsea pallens*	333.3	26.67	4.13	8.98	4.21	3.68	16.87
13	*Pinus roxburghii*	206.7	26.67	13.92	5.57	4.21	12.4	22.19
14	*Prunus cersasoides*	13.33	6.67	0.21	0.36	1.05	0.18	1.6
15	*Pyracantha crenulata*	6.67	6.67	0.05	0.18	1.05	0.05	1.28
16	*Pyrus pashia*	1087	93.33	16.3	29.26	14.74	14.5	58.53
17	*Rhododendron arboreum*	286.7	40	6	7.72	6.32	5.35	19.39
18	*Rhus javanica*	6.67	6.67	0.25	0.18	1.05	0.23	1.46
19	*Rhus succedanea*	20	13.33	0.64	0.54	2.11	0.57	3.22
20	*Schima wallichii*	213.3	46.67	11.19	5.75	7.37	9.98	23.1
21	*Symplocos lucida*	33.33	13.33	0.46	0.9	2.11	0.41	3.42
22	*Symplocos paniculata*	13.33	6.67	0.13	0.36	1.05	0.11	1.53
23	*Symplocos ramosissima*	46.67	20	0.56	1.26	3.16	0.5	4.92
24	*Toricellia tiliifolia*	6.67	6.67	0.05	0.18	1.05	0.05	1.28
25	*Trichilia connaroides*	73.33	20	1.4	1.97	3.16	1.25	6.38
26	*Viburnum erubescens*	6.67	6.67	0.05	0.18	1.05	0.05	1.28
27	*Viburnum mullaha*	13.33	6.67	0.13	0.36	1.05	0.11	1.53
TOTAL		3713	633.33	112.1	100	100	100	300

AppendixIV: Density, RD, Frequency, RF, Cover, RC and IVI of understory shrubs and tree saplings (DBH <10cm) in Subtropical forest (1700 -2000 m asl).

SN	Spp	Density ind/ha	Freqency (%)	Cover (%)	RD	RF	RC	**IVI**
1	*Berberis aristata*	140	6.67	0.33	0.7	0.72	0.93	2.35
2	*Berberis asiatica*	1053.3	86.67	5.13	5.29	9.35	14.35	29
3	*Daphne papyracea*	26.67	6.67	0.07	0.13	0.72	0.19	1.04
4	*Eurya acuminata*	86.67	13.33	0.33	0.44	1.44	0.93	2.81
5	*Hypericm choisianum*	386.67	33.33	0.83	1.94	3.6	2.33	7.87
6	*Indigofera exilis*	46.67	20	0.2	0.23	2.16	0.56	2.95
7	*Leucosceptrum canum*	80	6.67	0.27	0.4	0.72	0.75	1.87
8	*Lonicera quinquelocularis*	193.33	26.67	1	0.97	2.88	2.8	6.64
9	*Lyonia ovalifolia*	13.33	13.33	0.13	0.07	1.44	0.37	1.88
10	*Maesa chisia*	1080	66.67	3.93	5.42	7.19	11	23.6
11	*Maytenus rufa*	186.67	33.33	0.47	0.94	3.6	1.3	5.84
12	*Michelia kisopa*	20	20	0.13	0.1	2.16	0.37	2.63
13	*Myrsine semiserrata*	93.33	13.33	0.33	0.47	1.44	0.93	2.84
14	*Neolitsea pallens*	26.67	6.67	0.07	0.13	0.72	0.19	1.04
15	*Osbeckia stellata*	626.67	66.67	1.57	3.15	7.19	4.38	14.7
16	*Osyris wightiana*	213.33	26.67	0.4	1.07	2.88	1.12	5.07
17	*Persea odoratissima*	20	6.67	0.1	0.1	0.72	0.28	1.1
18	*Phyllanthus parvifolius*	12893	60	6.97	64.8	6.47	19.48	90.7
19	*Prunus cersasoides*	6.67	6.67	0.07	0.03	0.72	0.19	0.94
20	*Pyracantha crenulata*	186.67	33.33	1	0.94	3.6	2.8	7.33
21	*Pyrus pashia*	260	26.67	0.93	1.31	2.88	2.61	6.79
22	*Randia tetrasperma*	146.67	33.33	0.53	0.74	3.6	1.49	5.82
23	*Rhamnus virgatus*	300	33.33	0.63	1.51	3.6	1.77	6.87
24	*Rhododendron arboreum*	20	6.67	0.47	0.1	0.72	1.3	2.12
25	*Rosa sericea*	13.33	6.67	0.13	0.07	0.72	0.37	1.16
26	*Rubus ellipticus*	233.33	60	2	1.17	6.47	5.59	13.2
27	*Rubus paniculatus*	100	13.33	0.87	0.5	1.44	2.42	4.36
28	*Sarcococca coriacea*	360	33.33	0.73	1.81	3.6	2.05	7.46
29	*Schima wallichii*	6.67	6.67	0.07	0.03	0.72	0.19	0.94
30	*Trichilia connaroides*	33.33	6.67	0.13	0.17	0.72	0.37	1.26
31	*Viburnum cylindricum*	233.33	40	0.73	1.17	4.32	2.05	7.54
32	*Viburnum erubescens*	80	26.67	0.57	0.4	2.88	1.58	4.86
33	*Viburnum mullaha*	326.67	33.33	1.23	1.64	3.6	3.45	8.69
34	*Xanthoxylum armatum*	420	46.67	3.4	2.11	5.04	9.51	16.7
TOTAL		19913	926.67	35.77	100	100	100	300

AppendixV: Density, RD, Frequency, RF, Basal area (BA), RBA and IVI of trees (DBH ≥ 10cm) in Temperate forest (2000 -2350 m asl).

SN	Species	Density stem/ha	Freqency (%)	BA m^2/ha	RD	RF	RBA	**IVI**
1	*Aesculus indica*	23.53	5.88	3.48	0.41	0.69	1.49	2.59
2	*Alnus nepalensis*	11.76	5.88	0.1	0.21	0.69	0.04	0.94
3	*Benthamidia capitata*	5.88	5.88	0.18	0.1	0.69	0.08	0.87
4	*Castanopsis tribuloides*	41.18	23.53	0.56	0.72	2.76	0.24	3.72
5	*Cinnamomum glanduliferum*	176.47	52.94	5.85	3.11	6.21	2.5	11.81
6	*Elaeagnus parvifolia*	23.53	17.65	0.21	0.41	2.07	0.09	2.57
7	*Eurya acuminata*	23.53	11.76	0.21	0.41	1.38	0.09	1.89
8	*Ilex dipyrena*	158.82	52.94	3.5	2.8	6.21	1.5	10.5
9	*Ilex excelsa*	117.65	17.65	2.31	2.07	2.07	0.99	5.13
10	*Leucosceptrum canum*	11.76	11.76	0.11	0.21	1.38	0.05	1.63
11	*Lindera pulcherrima*	82.35	23.53	0.54	1.45	2.76	0.23	4.44
12	*Lonicera quinquelocularis*	5.88	5.88	0.1	0.1	0.69	0.04	0.84
13	*Lyonia ovalifolia*	329.41	47.06	15	5.8	5.52	6.42	17.73
14	*Maytenus rufa*	58.82	5.88	0.8	1.04	0.69	0.34	2.07
15	*Myrica esculenta*	41.18	17.65	0.58	0.72	2.07	0.25	3.04
16	*Myrsine semiserrata*	158.82	23.53	1.75	2.8	2.76	0.75	6.3
17	*Neolitsea pallens*	723.53	82.35	12.52	12.7	9.66	5.36	27.74
18	*Persea gamblei*	35.29	17.65	0.36	0.62	2.07	0.15	2.84
19	*Persea odoratissima*	176.47	29.41	3.48	3.11	3.45	1.49	8.04
20	*Pinus roxburghii*	11.76	5.88	0.95	0.21	0.69	0.41	1.3
21	*Pyracantha crenulata*	5.88	5.88	0.05	0.1	0.69	0.02	0.81
22	*Pyrus pashia*	200	52.94	2.93	3.52	6.21	1.25	10.98
23	*Quercus lanata*	41.18	5.88	0.82	0.72	0.69	0.35	1.76
24	*Quercus semecarpifolia*	1652.9	58.82	115.9	29.1	6.9	49.58	85.57
25	*Rhamnus virgatus*	5.88	5.88	0.08	0.1	0.69	0.03	0.83
26	*Rhododendron arboreum*	358.82	70.59	39.29	6.31	8.28	16.81	31.4
27	*Rhus succedanea*	105.88	29.41	1.46	1.86	3.45	0.62	5.94
28	*Symplocos lucida*	88.24	29.41	1.22	1.55	3.45	0.52	5.52
29	*Symplocos ramosissima*	929.41	70.59	18.69	16.4	8.28	8	32.63
30	*Toricellia tiliifolia*	11.76	11.76	0.2	0.21	1.38	0.08	1.67
31	*Viburnum erubescens*	58.82	41.18	0.49	1.04	4.83	0.21	6.07
32	*Viburnum mullaha*	5.88	5.88	0.05	0.1	0.69	0.02	0.81
TOTAL		5682.4	852.94	233.8	100	100	100	300

AppendixVI: Density, RD, Frequency, RF, Cover, RC and IVI of understory shrubs and tree saplings (DBH <10cm) in Temperate forest (2000 -2350 m asl).

SN	Species	Density ind/ha	Frequency (%)	cover (%)	RD	RF	RC	**IVI**
1	*Berberis aristata*	288.2	58.82	1.68	4.68	6.58	8.68	19.94
2	*Berberis asiatica*	170.6	11.76	0.71	2.77	1.32	3.65	7.74
3	*Castanopsis tribuloides*	11.76	11.76	0.09	0.19	1.32	0.46	1.96
4	*Cinnamomum glanduliferum*	64.71	23.53	0.35	1.05	2.63	1.83	5.51
5	*Daphne papyracea*	241.2	35.29	0.88	3.92	3.95	4.57	12.43
6	*Elaeagnus parvifolia*	41.18	17.65	0.38	0.67	1.97	1.98	4.62
7	*Eurya acuminata*	170.6	52.94	0.74	2.77	5.92	3.81	12.5
8	*Ficus neriifolia*	17.65	11.76	0.12	0.29	1.32	0.61	2.21
9	*Hypericm choisianum*	135.3	17.65	0.29	2.2	1.97	1.52	5.69
10	*Ilex dipyrena*	17.65	17.65	0.09	0.29	1.97	0.46	2.72
11	*Indigofera exilis*	17.65	5.88	0.06	0.29	0.66	0.3	1.25
12	*Lindera pulcherrima*	164.7	23.53	0.56	2.67	2.63	2.89	8.2
13	*Lonicera quinquelocularis*	23.53	11.76	0.15	0.38	1.32	0.76	2.46
14	*Lyonia ovalifolia*	147.1	11.76	0.09	2.39	1.32	0.46	4.16
15	*Maesa chisia*	111.8	5.88	0.18	1.81	0.66	0.91	3.39
16	*Maytenus rufa*	111.8	23.53	0.38	1.81	2.63	1.98	6.43
17	*Michelia kisopa*	11.76	11.76	0.12	0.19	1.32	0.61	2.12
18	*Myrica esculenta*	5.88	5.88	0.03	0.1	0.66	0.15	0.91
19	*Myrsine semiserrata*	1147	58.82	2.94	18.6	6.58	15.2	40.43
20	*Neolitsea pallens*	235.3	47.06	0.88	3.82	5.26	4.57	13.65
21	*Osbeckia stellata*	88.24	5.88	0.09	1.43	0.66	0.46	2.55
22	*Osyris wightiana*	17.65	5.88	0.06	0.29	0.66	0.3	1.25
23	*Persea gamblei*	35.29	23.53	0.21	0.57	2.63	1.07	4.27
24	*Persea odoratissima*	488.2	29.41	1.41	7.93	3.29	7.31	18.52
25	*Pyracantha crenulata*	64.71	17.65	0.53	1.05	1.97	2.74	5.76
26	*Pyrus pashia*	52.94	23.53	0.26	0.86	2.63	1.37	4.86
27	*Quercus semecarpifolia*	5.88	5.88	0.06	0.1	0.66	0.3	1.06
28	*Randia tetrasperma*	58.82	11.76	0.24	0.96	1.32	1.22	3.49
29	*Rhamnus virgatus*	141.2	23.53	0.41	2.29	2.63	2.13	7.06
30	*Rhus succedanea*	41.18	17.65	0.12	0.67	1.97	0.61	3.25
31	*Rubus ellipticus*	58.82	11.76	0.38	0.96	1.32	1.98	4.25
32	*Rubus paniculatus*	70.59	23.53	0.47	1.15	2.63	2.44	6.21
33	*Sarcococca coriacea*	205.9	11.76	0.38	3.34	1.32	1.98	6.64
34	*Smilax aspera*	141.2	29.41	0.26	2.29	3.29	1.37	6.95
35	*Symplocos ramosissima*	541.2	47.06	1.15	8.79	5.26	5.94	19.99
36	*Viburnum cylindricum*	229.4	35.29	1.06	3.72	3.95	5.48	13.15
37	*Viburnum erubescens*	123.5	47.06	0.68	2.01	5.26	3.5	10.77
38	*Viburnum mullaha*	76.47	23.53	0.41	1.24	2.63	2.13	6
39	*Wikstroemia canescens*	582.4	35.29	0.44	9.46	3.95	2.28	15.69
TOTAL		6159	894.12	19.32	100	100	100	300

Appendix VII: Checklist of the plants recorded from study area

SN	Family	*Names*	Altitude (m)	Life Forms
1	Acanthaceae	*Justicia procumbens* var. *simplex* (D. Don) T.Yamaz	700-2500	Herb
2	Acanthaceae	*Strobilanthes glutinosa* Nees	1000 -2800	Herb
3	Amaranthaceae	*Achyranthes aspera* L.	100-2900	Herb
4	Anacardiaceae	*Rhus javanica* L.	1300-2400	Tree
5	Anacardiaceae	*Rhus succedanea* L.	1300-2400	Tree
6	Apiaceae	*Bupleurum hamiltonii* N.P. Balakr.	1300-3900	Herb
7	Apiaceae	*Hydrocotyl himalaica* P. K. Mukh.	1500-2500	Herb
8	Apiaceae	*Oenanthe thomsonii*C.B. Clarke	1600 -2500	Herb
9	Apiaceae	*Pleurospermum apiolens* C.B. Clarke	3600-4500	Herb
10	Apiaceae	*Sanicula elata* Buch.-Ham. ex D.don	1600 -3500	Herb
11	Aquifoliaceae	*Ilex dipyrena* Wall.	2500-3000 *	Tree
12	Aquifoliaceae	*Ilex excelsa* (Wall.) Hook. f.	600-2100	Tree
13	Araceae	*Arisaema erubescens* (Wall.) Schott	1900-2600	Herb
14	Araceae	*Arisaema tortuosum* (Wall.) Schott	1300 -2900	Herb
15	Asteraceae	*Ainsliaea latifolia* (D. Don) Sch. Bip.	1700-3500	Herb
16	Asteraceae	*Anaphalis busua* (Buch.-Ham. ex D. Don) DC.	1500-2900	Herb
17	Asteraceae	*Anaphalis contorta* (D. Don) Hook. f.	1700 -4500	Herb
18	Asteraceae	*Anaphalis margaritacea* (L.) Benth.	1800-3100	Herb
19	Asteraceae	*Anaphalis triplinervis* (Sims) C. B. Clarke	1800-3300	Herb
20	Asteraceae	*Artemisia indica* Willd.	300-2400	Herb
21	Asteraceae	*Aster albescens* (DC.) Hand.	1500 -4200	Herb
22	Asteraceae	*Bidens pilosa* (Blume) Sherff	700-2100	Herb
23	Asteraceae	*Carpessium abrotanoides* L.	1400 -2200	Herb
24	Asteraceae	*Cicerbita macrorhiza* (Edgew.) P. Beauv.	1300 -4500	Herb
25	Asteraceae	*Cirsium verutum* (D. Don) Spreng.	750 -2200	Herb
26	Asteraceae	*Conyza leucantha* (D. Don) Ludlow & P.H. Raven	700 -1200 *	Herb
27	Asteraceae	*Conyza stricta* Willd.	600 -2000	Herb
28	Asteraceae	*Crassocephalum crepidiodes* (Benth.) S. Moore	400-1900	Herb
29	Asteraceae	*Dichrocephala integrifolia* (Lef.) Kuntze	800-3000	Herb
30	Asteraceae	*Galinsoga parviflora* Cav.	850-3000	Herb
31	Asteraceae	*Gnaphalium affine* D. Don	600 -3700	Herb
32	Asteraceae	*Inula cappa* (Buch.-Ham. ex D. Don) DC.	150-2500	Shrub
33	Asteraceae	*Myriactis nepalensis* Less.	1400 -3900	Herb
34	Asteraceae	*Senecio diversifolius* Wall. ex Dc.	2300 -4000	Herb
35	Asteraceae	*Senesio acuminatus* Wall. ex DC.	2100 -3700	Herb
36	Asteraceae	*Siegesbeckia orientalis* L.	400-2700	Herb
37	Asteraceae	*Taraxacum parvulum* Wall. ex Dc.	800 -2800	Herb
38	Asteraceae	*Tragopogon gracilis* D. Don	1500 -3200	Herb
39	Asteraceae	*Xanthium strumarium* L.	100-2500	Herb
40	Balsaminaceae	*Impatiens falcifer* Hook. f.	2500 -3400	Herb
41	Balsaminaceae	*Impatiens puberula* DC.	1500-2700	Herb
42	Begoniaceae	*Begonia picta* Sm.	600-2800	Herb
43	Begoniaceae	*Begonia rubella* Buch.-Ham. ex D. Don	600 -1700 *	Herb
44	Berberidaceae	*Berberis aristata* DC.	1800-3000	Shrub
45	Berberidaceae	*Berberis asiatica* Roxb. ex DC.	1200-2500	Shrub
46	Betulaceae	*Alnus nepalensis* D. Don	500-2600	Tree
47	Boraginaceae	*Cynoglossum zeylanicum* (Vahl) Thunb. ex Lehm.	1200-4100	Herb
48	Buxaceae	*Sarcococca coriacea* (Hook.) Sweet	600-1600	Shrub
49	Campanulaceae	*Campanula pallida* Wall.	1000-4500	Herb
50	Campanulaceae	*Codonopsis purpurea* Wall.	1600 -3000	Herb
51	Campanulaceae	*Lobelia pyramydalis* Wall.	1100-2300	Herb
52	Campanulaceae	*Pratia numularia* (Lam.) A. Barun &Asch.	1000 -2400	Herb
53	Cannabaceae	*Cannabis sativa* L.	200-2700	Herb
54	Caprifoliaceae	*Lonicera quinquelocularis* Hardw.	1500 -2700	Shrub

55	Caryophyllaceae	*Drymaria cordata* (L.) Willd. Ex Roem. & Schult.	2200 -4300	Herb
56	Caryophyllaceae	*Drymaria diandra* Blume	700-2000	Herb
57	Celastraceae	*Maytenus rufa* (Wall.) H. Hara	1300 -2200	Tree
58	Commelinaceae	*Commelina benghalensis* L.	900-1800	Herb
59	Commelinaceae	*Commelina palludosa* Blume	300 -3500	Herb
60	Commelinaceae	*Cyanotis vaga* (Lour.) Schult. & Schult.	800 -2700	Herb
61	Convolvulaceae	*Cuscuta europaea* var. *nepalensis* Yunck.	2300 *	Herbaceous Climber
62	Convolvulaceae	*Ipomea purpurea* (L.) Roth	910-2400	Herb
63	Cornaceae	*Benthamidia capitata* (Wall.) H. Hara	2100 -3400	Tree
64	Cucurbitaceae	*Coccinia grandis* (L.) Vioget.	200-900 *	Herbaceous Climber
65	Cucurbitaceae	*Diplocyclos palmatus* (L.)C. Jeffery	200 -1500	Herbaceous Climber
66	Cyperaceae	*Carex nubigena* D. Don	1500-4000	Herb
67	Cyperaceae	*Cyperus sp.*	-	Herb
68	Cyperaceae	*Kyllinga brevifolia* Rottb.	100 -2300	Herb
69	Dioscoreaceae	*Dioscorea bulbifera* L.	150-2100	Herb
70	Dioscoreaceae	*Dioscorea deltoidea* Wall.	450-3100	Herb
71	Dipsacaceae	*Dipsacus inermis* var. *mitis* (D. Don) Y.J. Nasir	1400 -4100	Herb
72	Droseraceae	*Drocera peltata* var. *lunata* (Buch.-Ham. ex DC.) C.B. Clarke	2500 -3600 *	Herb
73	Elaeagnaceae	*Elaeagnus parvifolia* Wall. ex Royle	1300 -3000	Tree
74	Ericaceae	*Gaultheria fragrantissima* Wall.	1200-2600	Shrub
75	Ericaceae	*Lyonia ovalifolia* (Wall.) Drude	1300 -3300	Tree
76	Ericaceae	*Rhododendron arboreum* Sm. *Var. arboreum*	1500 -3300	Tree
77	Euphorbiaceae	*Phyllanthus parvifolius* Buch.-Ham. ex D. Don	1100 -2000	Shrub
78	Fagaceae	*Castanopsis indica* (Roxb.) Miq.	1200 -2900	Tree
79	Fagaceae	*Castanopsis tribuloides* (Sm.) A. DC.	450 - 2300	Tree
80	Fagaceae	*Quercus lanata* Sm.	460 -2600	Tree
81	Fagaceae	*Quercus semecarpifolia* Sm.	1700 -3800	Tree
82	Gentianaceae	*Swertia ciliata* (D. Don ex G. Don) B. L. Brutt	2800 -4000	Herb
83	Gentianaceae	*Swertia nervosa* (G. Don) C. B. Clarke	700-3000	Herb
84	Geraniaceae	*Geranium nepalense* Sweet	1500-4000	Herb
85	Geraniaceae	*Geranium pratense* L.	2200 -3500	Herb
86	Geraniaceae	*Geranium wallichianum* D. Don ex Sweet	2100 -4200	Herb
87	Gesneriaceae	*Chirita urticifolia* Buch.-Ham. ex D. Don	900-2300	Herb
88	Gesneriaceae	*Didymocarpus aromaticus* Wall. ex D. don	1600 -3000	Herb
89	Gesneriaceae	*Lysionotus serratus* D. Don	1000-2400	Shrub
90	Guttiferae	*Hypericum choisianum* Wall. ex N. Robson	2400-3600	Shrub
91	Hippocastanaceae	*Aesculus indica* (Colebr. ex Cambess.) Hook.	1900 -2400	Tree
92	Juglandaceae	*Engelhardtia spicata* Lesch. ex Blume	400 -1700	Tree
93	Juncaceae	*Juncus wallichianus* Laharpe	1500-2900	Herb
94	Lamiaceae	*Anisomeles indica* (L.) Kuntze	200-2400	Herb
95	Lamiaceae	*Clinopodium umbrosum* (M. Bieb.) K. Koch.	180 -3400	Herb
96	Lamiaceae	*Elsholtzia strobilifera* (Benth.) Benth.	1900 -4800	Herb
97	Lamiaceae	*Isodon lophanthoides* (Buch.-Ham. ex D. Don) H. Hara	1300 -2700	Herb
98	Lamiaceae	*Leucas mollissima* Wall. ex Benth.	500 -2400	Herb
99	Lamiaceae	*Leucosceptrum canum* Sm.	1000 -2800	Shrub
100	Lamiaceae	*Mosla dianthera* (Buch.-Ham. ex Roxb.) Maxim.	700 -2100	Herb
101	Lamiaceae	*Nepeta laevigata* (D. Don) Hand.-Mazz.	2000 -5000	Herb
102	Lamiaceae	*Notochaete hamosa* Benth.	1500-2600	Herb
103	Lamiaceae	*Prunella vulgaris* L.	1200 -3800	Herb
104	Lamiaceae	*Salvia nubicola* Wall. ex Swet	2100 -3600	Herb
105	Lamiaceae	*Scutellaria discolor* Colebr.	700-2400	Herb
106	Lamiaceae	*Stachys melissaefolia* Benth.	2100 -4000	Herb
107	Lamiaceae	*Teucrium quadrifarium* Buch.-Ham. ex D. Don	1200 -2400	Herb

108	Lamiaceae	*Thymus linearis* Benth.	2400 -4500 *	Herb
109	Lauraceae	*Cinnamomum glanduliferum* (Wall.) Meisn.	2100 -2600	Tree
110	Lauraceae	*Lindera pulcherrima* (Nees) Benth. Ex Hook. f.	1400 -2700	Tree
111	Lauraceae	*Neolitsea pallens* (D. Don) Momiy. & H.Hara ex H. Hara	2000 -3000	Tree
112	Lauraceae	*Persea gamblei* (King ex Hook. f.) Kosterm. ex Kosterm . & Chater.	2000 -2600	Tree
113	Lauraceae	*Persea odoratissima* (Nees) Kosterm.	1000 -2000 *	Tree
114	Leguminosae	*Apios carnea* (Wall.) Benth. ex Baker	1700 -2300	Herbaceous Climber
115	Leguminosae	*Cochlianthus gracilis* Benth.	1800-2000	Herb
116	Leguminosae	*Crotalaria sessiliflora* L.	200 -2800	Herb
117	Leguminosae	*Desmodium confertum* DC	300-2000	Shrub
118	Leguminosae	*Desmodium elegans* DC.	1200 -3000	Shrub
119	Leguminosae	*Desmodium microphyllum* (Thunb.) DC.	1500-2300	Shrub
120	Leguminosae	*Desmodium podocarpum* DC.	1600 -2000	Herb
121	Leguminosae	*Flemingia strobilifera* (L.) W. T. Aiton	300 -2300	Herb
122	Leguminosae	*Indigofera dosua* Buch.-Ham. ex D. Don	1000-3000	Herb
123	Leguminosae	*Indigofera exilis* Grierson & D.G.	800 -3000	Shrub
124	Leguminosae	*Piptanthus nepalensis* (Hook.)D. Don	2000-3800	Shrub
125	Leguminosae	*Trigonella emodi* Benth.	1300 -4900	Herb
126	Liliaceae	*Asparagus filicinus* Buch.-Ham. ex D. Don	2100 -2900	Herb
127	Liliaceae	*Asparagus racemosus* Willd.	600 -2100	Woody Climber
128	Liliaceae	*Chlorophytum nepalense* (Lindl.) Baker	1400 -2500	Herb
129	Liliaceae	*Disporum cantoniense* (Wall.) H. Hara	1100 -2900	Herb
130	Liliaceae	*Polygonatum cirrhifolium* (Wall.) Royle	1700-4600	Herb
131	Liliaceae	*Smilax aspera* L.	1200-2600	Herb
132	Liliaceae	*Theropogon pallidus* (Kunth) Maxim.	1800-2700	Herb
133	Magnoliaceae	*Michelia kisopa* Buch.-Ham. ex DC.	1400 -2000	Tree
134	Malvaceae	*Sida cordata* (Burm. f.) Bross. Waalk.	400 -1800	Herb
135	Malvaceae	*Urena lobata* L.	200-1300 *	Herb
136	Melastomataceae	*Melastoma normale* D. Don	900-1800	Shrub
137	Melastomataceae	*Osbeckia stellata* Buch.-Ham. ex D. Don	1300-2600	Shrub
138	Meliaceae	*Trichilia connaroides* (Wight & Arn.) Bentv.	700 -3400	Tree
139	Menispermaceae	*Cissampelos pareira* L.	150 -2200	Climbing Shrub
140	Moraceae	*Ficus neriifolia var. nemoralis* (Wall. ex Miq.) Corner	1400 -2200	Tree
141	Myricaceae	*Myrica esculenta* Buch.-Ham. ex D. Don	1200-2300	Tree
142	Myrsinaceae	*Maesa chisia* Buch.-Ham. ex D. Don	1200 -2600	Shrub
143	Myrsinaceae	*Myrsine semiserrata* Wall.	1200 -2700	Shrub
144	Oleaceae	*Fraxinus floribunda* Wall.	1200 -2000	Tree
145	Onagraceae	*Circaea repens* Wall. ex Asch.& Magnus	2000 -2800	Herb
146	Orchidaceae	*Calanthe plantaginea* Lindl.	1500-2100	Herb
147	Orchidaceae	*Calanthe tricarinata* Lindl.	1500-3200	Herb
148	Orchidaceae	*Coelogyne cristata*Lindl.	1000 -2000	Herb
149	Orchidaceae	*Dendrobium eriiflorum* Griffith	1500 -2100	Herb
150	Orchidaceae	*Habenaria arietina* Hook. f.	2000 -2900	Herb
151	Orchidaceae	*Satyrium nepalense* D. Don	600 -4600	Herb
152	Orchidaceae	*Spiranthes sinensis* (M. Bieb.) H. Hara	100 -4600	Herb
153	Oxalidaceae	*Oxalis corniculata* L.	300 -2900	Herb
154	Papaveraceae	*Corydalis govaniana* Wall.	3000-4800	Herb
155	Phytolaccaceae	*Phytolacca acinosa* Roxb.	2200 -3200	Shrub
156	Pinaceae	*Pinus roxburghii* Sarg.	1100 -2100	Tree
157	Plantaginaceae	*Plantago major* L.	900-4100	Herb

158	Poaceae	*Capillipedium assimile* (Steud.) A. Camus	600 -2100	Herb
159	Poaceae	*Cymbopogon Pendulus* (Nees ex Steud.) W. Watson		Herb
160	Poaceae	*Cynodon dactylon* (L.) Pers.	100-3000	Herb
161	Poaceae	*Eleusine indica* (L.) Gaertn.	600 -2600	Herb
162	Poaceae	*Eragrostis atrovirens* (Desf.) Trin. ex Steud.	200 -1800	Herb
163	Poaceae	*Eulaliopsis binata* (Retz.) C. E. Hubb.	150 -2600	Herb
164	Poaceae	*Heteropogon contortus* (L.) P. Beauv. ex Roem and Schult	400 -2600	Herb
165	Poaceae	*Imperata cylindrica* (L.) P. Beauv.	700 -2400	Herb
166	Poaceae	*Oplismenus compositus (*L.) Beauv.	300-2800	Herb
167	Poaceae	*Poa annua* L.	2300-3500	Herb
168	Polygonaceae	*Aconogonum molle* (D. Don) H. Hara	120-2400	Herb
169	Polygonaceae	*Bistorta amplexicaulis* (D. Don) Greene	2100-4800	Herb
170	Polygonaceae	*Persicaria capitata* (Buch.- Ham.) H. Gross	600-2400	Herb
171	Polygonaceae	*Persicaria chinensis* (L.) H. Gross	1200-2900	Herb
172	Polygonaceae	*Persicaria microcephala* (D. Don) Sasaki	1200 -1800	Herb
173	Polygonaceae	*Persicaria nepalensis* (Meisn.) H. Gross	1200 -4100	Herb
174	Polygonaceae	*Persicaria runcinata* (Buch.-Ham. ex D. Don) H. Gross	1600-3800	Herb
175	Polygonaceae	*Rumex nepalensis* Spreng.	1200-4200	Herb
176	Primulaceae	*Lysimachia debilis* Wall.	1200 -2900	Herb
177	Ranunculaceae	*Anemone rivularis* Buch.-Ham. ex DC.	1600 -4000	Herb
178	Ranunculaceae	*Anemone vitifolia* Buch.-Ham. ex DC.	1300-3300	Herb
179	Ranunculaceae	*Clematis buchananiana* DC.	1800 -3300	Woody Climber
180	Ranunculaceae	*Clematis montana* Buch.-Ham. ex DC.	1600-4000	Woody Climber
181	Ranunculaceae	*Clematis tibetana* DC.	1400 -1600 *	Woody Climber
182	Ranunculaceae	*Ranunculus diffusus* DC.	1500-1700	Herb
183	Ranunculaceae	*Thalictrum foliolosum* DC.	1300-3400	Herb
184	Rhamnaceae	*Rhamnus virgatus* Roxb.	1000 -3000	Shrub
185	Rosaceae	*Cotoneaster integrifolius* (Roxb.) G. Klotz	1800 -3500	Shrub
186	Rosaceae	*Potentilla fulgens* Wall. ex Hook	1600-4800	Herb
187	Rosaceae	*Potentilla kleiniana* Wight	1000-2200	Herb
188	Rosaceae	*Potentilla lineata* Trev.	1600 -4800	Herb
189	Rosaceae	*Prunus cerasoides* D. Don	1300-2400	Tree
190	Rosaceae	*Pyracantha crenulata* (D. Don) M. Roem.	1200 -2500	Shrub
191	Rosaceae	*Pyrus pashia* Buch.-Ham. ex D. Don	750 -2600	Tree
192	Rosaceae	*Rosa sericea* Lindl.	2200-4600	Shrub
193	Rosaceae	*Rubus accuminatus* Sm.	1000-2300	Shrub
194	Rosaceae	*Rubus ellipticus* Sm.	1700-2300	Shrub
195	Rosaceae	*Rubus paniculatus* Sm.	2100-2900	Shrub
196	Rubiaceae	*Galium asperifolium* Wall.	1500 -3000	Herb
197	Rubiaceae	*Galium elegens* Wall. ex Roxb.	1400 -3000	Herb
198	Rubiaceae	*Galium hirtiflorum* Req. ex DC.	1200-2200	Herb
199	Rubiaceae	*Hedyotis scandens* Roxb.	400-1800	Herb
200	Rubiaceae	*Randia tetrasperma* (Roxb.) Benth. & Hook. f. ex Brandis	1300 -2600	Shrub
201	Rubiaceae	*Rubia manjith* Roxb. Ex Fleming	1200-2100	Herb
202	Rutaceae	*Boenninghausenia albiflora* (Hook.) Rchb. ex Meisn.	600-3300	Herb
203	Rutaceae	*Xanthoxylum armatum* DC.	1100 -2500	Shrub
204	Sambucaceae	*Viburnum cylindricum* Buch.-Ham. ex D. Don	1200 -2500	Tree
205	Sambucaceae	*Viburnum erubescens* Wall. ex DC.	1500 -3000	Tree
206	Sambucaceae	*Viburnum mullaha* Buch.-Ham. ex D. Don	1800 -3700	Tree
207	Santalacae	*Osyris wightiana* Wall. ex Wight	1100 -2600	Shrub
208	Saxifragaceae	*Astilbe rivularis* Buch.-Ham. ex D. Don	2000-3600	Herb

209	Saxifragaceae	*Saxifraga parnassifolia* D. Don	1900 -4900	Herb
210	Scrophulariaceae	*Lindernia crustacea* (L.) F. Muell.	250 -1800	Herb
211	Scrophulariaceae	*Adenosma indianum* (Lour.) Merr.	200 *	Herb
212	Scrophulariaceae	*Hemiphragma heterophyllum* Wall.	1800-3500	Herb
213	Scrophulariaceae	*Lindenbergia indica* (L.) Vatke	300 -2600	Herb
214	Solanaceae	*Solanum aculeatissimum* Jacq.	1600 *	Herb
215	Symplocaceae	*Symplocos lucida* (Thunb. ex Murray) Siebold & Zucc.	1500 -3000	Tree
216	Symplocaceae	*Symplocos paniculata* (Thunb.) Miq.	1000 -2500	Tree
217	Symplocaceae	*Symplocos ramosissima* Wall. ex G.Don	1400 -2600	Tree
218	Theaceae	*Eurya acuminata* DC.	1300 -2500	Shrub
219	Theaceae	*Schima wallichii* (DC.) Korth.	900 -2100	Tree
220	Thymelaeaceae	*Daphne papyracea* Wall. ex Steud.	1500-2300	Shrub
221	Thymelaeaceae	*Wikstroemia canescens* Meisn.	1800 -3200	Shrub
222	Toricilliaceae	*Toricellia tiliifolia* DC.	1600 -2500	Tree
223	Urticaceae	*Boehmeria ternifolia* D. Don	900-2300	Herb
224	Urticaceae	*Debregessia salicifolia* (D. Don) Rendle	1500-2400	Herb
225	Urticaceae	*Elatostema sessile* J. R. Forst.	1800-3000	Herb
226	Urticaceae	*Girardinia diversifolia* (Link) Friis	1700-3000	Herb
227	Urticaceae	*Pilea scripta* (Buch.-Ham. ex D. Don) Wedd.	1300-2500	Herb
228	Urticaceae	*Pilea umbrosa* Blume	1200-2500	Herb
229	Urticaceae	*Urtica dioca* L.	3000-4500 *	Herb
230	Valerianaceae	*Valeriana hardwickii* Wall.	1200-4000	Herb
231	Valerianaceae	*Valeriana jatamansii* Jones	1500 -3300	Herb
232	Violaceae	*Viola pilosa* Blume	1200 -3000	Herb
233	Vitaceae	*Tetrastigma serrulatum* (Roxb.) Planch	500-2400	Herb
234	Zingiberaceae	*Cautleya spicata* (Sm.) Baker	1800-2800	Herb
235	Zingiberaceae	*Hedychium spicatum* (Roscoe) Wall.	2100-2400	Herb
236	Zingiberaceae	*Roscoeapurpurea* Sm.	1500-1900	Herb

(* = with different altitudinal distribution than Annotated checklist of the flowering plants of Nepal)