Chapter 1
Introduction

1.1. Background

1.1.1. Forest in Nepal

Forests in Nepal cover approximately 29 % of the total land area (DFRS 1999). They are amongst the most important natural resource to sustain life in Nepal. They provide 75 % of the total energy consumed in the country (fuel wood) and more than 40% of fodder for livestock is extracted from forest (MPFS 1988). Forests also play a dynamic role in protecting the fragile mountain ecosystems and maintaining diverse and complex ecosystems of the country (Thompson 1995).

Nepal's great variation in topography, altitudes ranging from 60 to 8,848 meters above sea level (masl) over a small distance of 190 km from south to north has diversified the bioclimatic features of Nepal. Almost all types of global bioclimatic zones ranging from the tropical to the nival zone are juxtaposed along the slopes of the Nepalese mountains. Nepal has a very diverse flora with 35 forest types (Stainton, 1972).These forests has been endowed with a rich variety of plants and animals. Nepal possesses 2.76 percent of the world's flowering plants (Bhuju et al. 2007).

1.1.2. Altitudinal Distribution of Forest in Nepal

The basic pattern of vegetation distribution along altitudinal gradients is controlled by solar radiation, temperature and humidity. As a result, the altitudinal distribution of vegetation communities in Nepal shows an extreme complexity on account of its bioclimatic diversity (Fig.1.1). The floristic characteristics, structure, phenology, habitat, environment and physiography are employed to classify these vegetation communities in Nepal (Troll, 1959; Kawakita, 1965; Schweinfuth, 1957; Numata, 1966; Stainton, 1972; Dobremez, 1976).

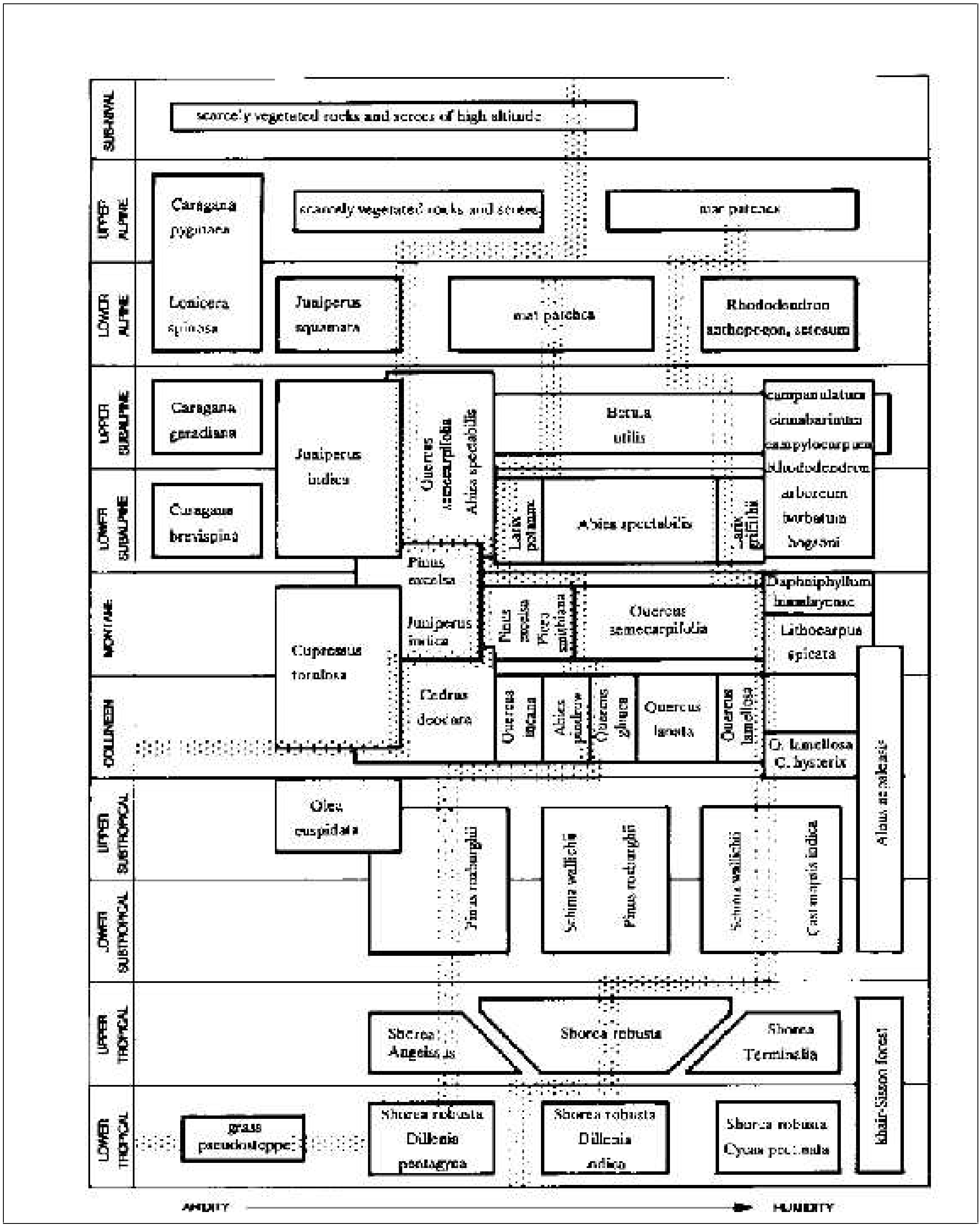


Figure 1.1. Schematic representation of major vegetation communities as a function of altitude in Nepal. The stippled boundaries correspond to the four phyttogeographic region of Nepal: from left to right, Northwest Nepalese, West Nepalese, Central Nepalese. From J-F.Dobremez, 1976:244, Figure 169.

As regard the composition of forest by altitude, *Shorea robusta* and *Terminalia alata* are the most common species at low altitude giving way to *Pinus roxburghii*, *Quercus species*, *Rhododendron species*, *Tsuga dumosa* and *Abies spectabilis* at high altitudes.

1.1.3. Sustainable Forest Management and Ecological Research

Sustainable forest management has been the subject of increased research after 1990.This is due to the realization that forest resources have been utilized in an unsustainable manner.Achieving a long term production of continuous flow of desired forest products and services, without undue reduction of its inherent values and future productivity and undesirable effects on the physical and social environment is directly related to the sustainable forest management (ITTO, 1998). The criteria and indicator (C & I) frameworks have grown in popularity for improving the sustainability of forest management over the last decade. Although the long-term objective of the Nepalese forest policy is sustainable forest management, no national level criteria and indicator(C & I) specifically for this has been developed (Poharel & Larsen 2007). Following seven thematic areas (indicators) are to be considered as essential components in the sustainable management of forest ecosystems.

1. Conservation of biological diversity.
2. Maintenance of productive capacity of forest ecosystems.
3. Maintenance of forest ecosystem health and vitality.
4. Conservation and maintenance of soil and water resources.
5. Maintenance of forest contribution to global carbon cycles.
6. Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies.
7. Legal, institutional and economic framework for forest conservation and sustainable management.

To be sustainable, forest management needs to be based on a sound knowledge of the ecology, structure and composition of the resource species. Stand structure and floristic composition of forest is important in management of multiple forest resource, wildlife, aesthetic values, hydrologic recovery, and range of forage conditions and as bases for projecting changes in vegetation over time. It is also important for regeneration, growth, mortality, understory development and spread of disturbances (Chen and Bradshaw 1999). Floristic composition of forests has been documented for Nepal over several decades (Hara 1966, Shrestha 1982). Most previous studies in Nepal have focused on the socio-economic and environmental impact of decline in forest cover. The ecological changes associated with human-induced disturbance of forests in the hill forests of Nepal have, however, received relatively little attention (Khatry-Chhetry 1997, Acharya 1999).

The Gulmi district forest office is practicing forest management in the study area but unfortunate it is not among the areas covered by previous studies and therefore no information is available on the floristic composition and stand structure on its forests. This study analyzes floristic composition, stand structures and diversity of forests along an altitudinal gradient. It also analyzes human induced disturbances on the structure of forest.

1.2. Statement of the Problem

The forests in Resunga hill contain rich biological diversity, including rich array of plant distributed according to altitude and aspect of slopes. But there are no previous scientific studies of vegetation of Resunga hill focusing on the altitudinal distribution of these forests. These forests have not been studied despite their diversity. Little attention has been given to quantify the structure, floristic composition, use and management of these forests.

Since the entire population depends directly on the use of these forests for their well-being, the various changes in the forests may be appearing in their structure, density and composition due to uncontrolled lopping and felling of trees for fuel wood, fodder, timber and grazing. These biotic pressures which play an important role in forest community dynamics often regulate the recruitment and survival pattern of tree seedlings .Each form of biotic pressure has different effects on the subsequent development of vegetation. With this scenario, the pressure on this forest for supply of fuelwood and fodder can only be expected to get worse. If the forests are not properly managed, serious degradation is likely to occur, a phenomenon already common in Nepal. Therefore, it is necessary to examine the growing concern about forest structure and composition and try to determine what new directions, if any, are needed.

1.3. Aims and Objectives

The broad objective of the study was to generate ecological information about the structure and composition of Resunga forest for informed management. The specific objectives were:

1. To determine the quantitative tree species composition of forest stands along an altitudinal gradient.
2. To determine the stand structure such as: size (DBH) class distribution, total Basal Area (BA), and Biodiversity Index (H') of forest stands along an altitudinal gradient.
3. To analyze human induced disturbances on the forest stands.
4. To assess the use of forest products and explore the potential implications for sustainable forest management.

1.4. Rationale of Study

One of the obstacles that made the planning of future forest management activities is that there is no reliable data about ecological information on forest vegetation composition and structure. There has been lack of reliable data on the ecological status of tree species, in particular under consideration of altitude. Therefore, assessment of the current forest structure and floristic composition were based on various dubious assumptions. Consequently; validity of the assessment has always been questioned.

It is of great significance to assess and analyze the ecological information on the vegetation before and after the improvement of the management activities. If realistic informations on the forest structure and floristic composition with respect to altitude and management are obtained, they can be a very powerful planning tool for the future.

1.5. Limitation of the Study

This study has attempted to analyse the stand structure and floristic composition of forest vegetation of the Resunga hill along an altitudinal gradient. However, it has some limitations as follows:

1. This study is limited to northeastern slope of Resunga hill and findings from this study may not be generalized for all slopes.
2. The species diversity is studied only in respect of woody vegetation in the present study.
3. The study area is situated between the altitude range of 690 m asl to 2339 masl in the middle hill of central Nepal, so it may not represent sensitive for whole Nation.
4. The questionnaire survey covered a sample of the population of study area. Due to inadequacy of time and resource, the researcher could cover only a five percent sample of population in the study area.

Chapter 2

Review of Literature

2.1. Botanical Exploration in Nepal

The botanical exploration in Nepal was initiated in 1802 with the collection of Nepali specimens by Buchanan Hamilton. Then Nathaniel and Wallich followed his works in 1802-21 (HMGN 1976). In 1825, David Don published *Prodromus Florae Nepalensis* with the record of 650 species from Nepal (Don,1976).Hooker explored some parts of eastern Nepal in 1948 and became the first botanist to describe the amazing richness and diversity of the Himalayan forest, and this was followed by Burkill (1910).Banergi (1965) reported 591 dicots from Tamor valley and again published a list of 196 species of flowering plants from east Nepal.Kihara (1955) compiled 5000 specimens of plants from central Nepal.Itoh (1963) collected 1000 medicinal plants from Khaptar area of west Nepal.Rao (1967) reported 200 species of plants from eastern Nepal. Later on many explorations were conducted by different foreigner and also by the Nepalese scientist. Koba et al. (1994) extended the lists of flowering plant species prepared by Hara and Williams (1979); Hara et al. (1978; 1982), enumerating 5,806 species belonging to 203 families. To this number, a list of 50 species had been added by Akiyama et al. (1998) bringing the total angiosperm species count in Nepal to 5,856. The introduction of additional species new to Nepal raised this number to 5,891 (Malla and Shakya 1998).However, Hara (1978) and the World Conservation Monitoring Centre estimated a total of 6,500 species. This figure was corroborated by the Biodiversity Profiles Project (1995) ranking Nepal as having the tenth richest flowering plant diversity in Asia. On a world scale, Nepal ranks 31st (Bhuju et al. 2007).

2.2. Phyto-geographical Study of Nepal

Stearn (1960) divided Nepal into three units: Western Nepal (West of 83 ^{0} E) which is dominated by Western Himalaya flora, Eastern Nepal(East of 86^{0}30'E) dominated by eastern Himalaya flora and Central Nepal(between 83^{0}E and 86^{0}30')which represents a zone of interpenetration for both flora.

Stainton(1972) described 35 types of forest in Nepal on the basis of climate and vegetation composition concluding that the vegetation of Nepal is greatly influenced by different environmental factors like rainfall, aspect, slope, altitude and exposure. He used the following climatic and vegetation divisions in his classification of forest types in Nepal:

1. Terai and outer foothills, including the Siwalik Hills and valleys
2. Midlands and southern slopes of the main Himalayan ranges
    1. Western Midlands
    2. Central Midlands
    3. Eastern Midlands
    4. South of Annapurna and Himalchuli
3. Jumla-Humla region
4. Dry river Valleys
5. Inner valleys
6. Arid Zone

Dobremez (1972, 1976) recognized four domains (western, northwestern, central, and eastern); six levels, and 11 sublevels of bioclimatic zones in Nepal (Table 2.1). Dobremez and his co-authors, including three Nepali scientists, TB Shrestha, PR Shakya, and DP Joshi, prepared a series of ecological maps of Nepal and contributed to the study of ecology and vegetation of Nepal .They identified 189 different vegetation types and 118 ecosystem types distributed in six bioclimatic zones from Lower tropical zone (below 500 m) to Nival Zone (above 5000 m) along the slope of Himalaya.

Table 2.1.Bioclimatic and Equivalent Physiographic Zones of Nepal

Altitude (m)	Bio-climatic Zones	Sub-zones	Physiographic Zones	BPP/NBYP
Above 5000	Nival/Arctic	Nival	High Himal	Highland
4501 to 5000	Alpine	Upper	High Mountains	
4001 to 4500		Lower		
3501 to 4000	Sub-alpine	Upper		
3001 to 3500		Lower		
2501 to 3000	Temperate	Upper	Mid-Hills	Midhills
2001 to 2500		Lower		
1501 to 2000	Sub-tropical	Upper		
1001 to 1500		Lower		
501 to 1000	Tropical	Upper	Siwalik	Terai-Siwaliks
Below 500		Lower	Terai	

Source: Dobremez (1972), LRMP, 1986

2.3. Ecological Study of Forest in Central Nepal

Quantitative analysis of species has been widely applied in many research activities for the exploring of biodiversity potentials and constrains, development of biodiversity databases of natural resources and ecological impact assessment.

Sharma(1984) conducted a research on floristic study of North-West Chandragiri Hill Area (Cental Nepal).The vegetation analysis of Chandragiri Hill depicted that it had 325 species belonging to 255 genera and 94 families. Monocot had 11 families with 31 genera and 39 species, of which Graminae was dominant with 15 species.Dicot had 83 families, including 224 genera and 286 species.Compositae was the dominant family followed by Labiatea, Leguminosae, and Fosaceae etc.It had been found that different species had different flowering and fruiting periods, as in total only 204 species were found flowering between June to November, of which only 33 belonged to monocot families. Herbaceous flora dominate during mid-summer to the beginning of autumn. Vertical zonation varied from subtropical to lower temperate. Floral diversity decreased with altitude where broad-leaved mixed hardwood forest was replaced by dry-oak forest through the oak-laurel forest.

Acharya (1989) carried out a study of Fagaceae in Phulchoki hill on its northwest slope. The study area had a maximum altitude of 2715 m. The general analytical method demonstrated that the dominant species was *Quercus semicarpifolia* and less dominant species were *Castanopsis indica* and *Quercus spicata*.Interspecific association analysis showed that only two pairs, *Castanopsis indica-Castanopsis tribuloides* and *Quercus glauca-Quercus semecarpifolia*, among five possible ones were closely associated but only the former pair had significant correlation. The diameter at breast height (DBH) and height were positively correlated in all species but significant in only five among six Fagaceae members except for *Castanopsis indica*.Altitudinal correlation of species showed insignificant negative correlation in five species among Fagaceae members except for *Quercus semecarpifolia*, which was significantly positive. The observation and results of this area revealed a decrease in plant diversity and individuals with the increase in altitude.

Shrestha (1996) carried out an ecological study of degraded, regenerating and natural forest in Kavrepalanchok district. At the study site, 66 species belonging to 35 families were enumerated. Many plant species were found at the natural site, followed by the regenerating and degraded sites. Generally, total Density, Basal Areas (BA) were maximum at the natural site, followed by the regenerating and degraded sites. At the study site, soil texture varied from loam to sandy loam. Soil pH measurements were 4.3, 4.2 and 4.8 on degraded, regenerating and natural sites respectively. The study revealed that degraded areas were facing plant species' loss.

Upadhya (1997) had conducted a research on comparative study of biodiversity in Community Managed Forest and Government Managed Forest of Shiwalaya

Village Development Committee (VDC) of Parbat district. This study was conducted in *Shorea-Schima* forests. The objective was to compare vegetation in a community managed forest and government forest and the implication of management practices on biodiversity. Stratified random sampling of the vegetation was carried out along three transacts. The vegetation analysis of government forest showed that it had 36 tree species and 38 shrub species compared to 26 tree species and 31 shrub species in the community forest. Density, Basal Area (BA) and natural regeneration were also less in the community forest than in the government forest. There were fewer coppices in community, while the species diversity index was greater in the government protected forest. There was a greater dominance of trees in the community forest, but dominance of shrubs species was less there than in the government protected forest. The richness index for tree species in community forest was also less than in the government protected forest. Overall, the biodiversity of community forest was less than that of government managed forests.

Shrestha (1997) carried out a study on plant community diversity and ecological factors among a disturbance gradient in a *Quercus Semicarpifolia Forest* at Phulchoki hill. The objective was to evaluate the influence of disturbance on community diversity and plant environment relationships in *Quercus semicarpifolia* forest. This study comprised the analysis of soil properties with other environmental characteristics and their relationship with the variation in species' composition. The study showed the species diversity on a spatial scale. The study revealed altitude, disturbance, light intensity, canopy cover and loss on ignition of soil had a strong influence on species composition. Different disturbance classes were categorised in *Quercus semecarpifolia* forest on the basis of growth, form of tree, and degree of lopping intensity. It was found that species richness was highest in the intermediate disturbance class.

Dhungana (1997) carried out a research on vegetation analysis and natural regeneration status of Hill Sal (*Shorea robusta* Gaertn) Forests in Kavrepalanchok distict.For this study two hills of sal forest within Panchkhal Valley were chosen: i) site no. 1 (natural forest site and community forest) and ii) site no.2 (a private plantation forest site). The study showed that *Shorea robusta* was the only dominant species in both of the studied forest sites and was the most gregarious species among 24 species with the highest Importance Value Index (155% at site no.1 and 234% at site no 2).Other common species were *Phyllanthus emblica, Rhus parviflora, Woodfordia fruticosa, Pinus roxburghii, Cornus oblonga* etc.Natural regeneration of forest was good (3,434 seedlings/ha at site no.2 and 1872 seedlings/ha at site no.1). The soil analysis indicated that both plots had acidic soil with pH values 4.5 and 5.6 at site no 1 and site no.2 respectively. The study concluded that natural regeneration of sal in hilly region is prominent. However, it appeared less prominent than the natural regeneration in terai forest.

Shrestha et al. (2000) carried out a research natural and degraded forests in Chitrepani in Siwalik region of Central Nepal. The study was undertaken to determine status of forests and trends of species loss in degraded, natural and regenerating forests. Four sites were selected for the study: Site I, Chitrepani Community Forest (Sal regenerating forest); Site II, Chitrepani Community Forest (mixed regenerating forest); Site III, Karne Forest (natural forest), and Site IV, Chitrepani Leasehold Forest (degraded forest).The vegetation analysis depicted a total of 46 woody species (28 tree and 18 shrub) belonging to 27 different families. Site III had the highest number (39) of species while Site IV, degraded site, had the lowest number (10) of species. Sites I, II and IV each had five shrub species. Site IV, degraded forest, had the highest value for species loss (78.2% species), followed by Site I regenerating forest which lost 71.7% species. The total density of trees was found highest in Site II (1326 plants ha-1) and lowest in Site IV (23.9 plants ha-1). Total basal area of trees was highest in Site III, natural forest (59.6 m2 ha-1) and lowest in Site IV, degraded site (11.4 m2 ha-1). All the three natural and regenerating forest sites had a much higher tree density and total basal area values than the degraded forest site.

Karki (2004) had conducted a research in the national forest and community forest at Churiyamai VDC in Makwanpur district of Central Nepal. The objective was to analyse the effects of deforestation on tree diversity and livelihoods of local community. To analyze the tree diversity, Shannon's index was measured. The diversity index (H') was significantly higher in the national forest (1.072) than in the community forest (0.833). Also, individuals were more evenly distributed in the national forest. The national forest also supported the higher number of tree species (7) than the community forest (5).Both the species richness and evenness statistics were higher in the national forest. The study revealed that deforestation decreased the number of tree species as well as individuals in both of the forests. However, the national forest contained a higher number of tree species than the community forest.

Sigdel (2008) had conducted a research on altitudinally coordinated pattern of plant community structure in the Shivapuri National Park (SNP), Nepal. He analysed different plant community structure in different altitudinal ranges in SNP with regards to altitudinal variation. In each of three altitudinal ranges from 1366m to 2732m, standard quadrat method was applied for vegetation analysis. Altogether, 147 species (36 trees, 37 shrubs and 74 herbs) belonging to 125 genera and 58 families were recorded from the study site. The highest number of species was found at 1900-2300 m and species diversity among tree and shrub species was higher at 1600-1800 m.The study found three distinct forest types on the southern section of National Park.*Pinus roxburghii* was the ecologically most important tree species in lower altitude (1600-1800 m).At mid elevation (1900-2300 m) *Rhododendron arboreum* and *Quercus lantana* were the most dominant species. At the higher altitude (2400-2732 m), *Quercus semicarpifolia* was the most dominant species. The pattern of distribution of plant species was not uniform according to altitude.

2.4. Forest Utilization Pattern in Central Nepal:

Khatry (1994) carried out a research at Nagarkot, in Bhaktapur district. The objective of the study to increase an understanding of the condition of the Nagarkot forest in regard to biomass standing crop and relate this with the needs, practices, and attitudes of the local people who used this forest. Literature review, vegetation sampling, and household socioeconomic survey were conducted to gather the information. It was found that, in general, the villagers had a favourable attitude towards the implementation of natural forest management systems for *Schima-Castanopsis* forest. The study revealed that the biomass production of the forest was inadequate to meet the demands of the users. However, there was a potential for meeting demands if the resource was managed properly. Recommendations were given to increase forest productivity, biodiversity conservation, and people's participation to facilitate the proper management of forest resources.

Pandey (1995) carried out a research on forest utilization pattern in Birgha Archale village development committee in Syangja district. Various data collection techniques were used to gather different quantitative and qualitative data and relevant information. The study revealed that people used a great deal of firewood. Important factors such as caste/ethnicity, the size of family, and livestock numbers influenced the amounts of firewood used by given households. The other forestry products used by villagers are fodder, timber, grazing land, and animal bedding which helped to increase the amount of mannure available for agriculture land. The interrelationship of cropping pattern, animal husbandry, and forest had been an important feature of village economy. The farming system was traditional and the family was the main farming unit.

Adhikari (1998) carried out a research on utilization pattern of forest resources in Khoplang village development committee in Gorkha district. This study revealed that the village people were heavily dependent on the forest resources. Due to the lack of electricity and biogas energy, firewood was the main source of energy. The sources of fuel wood were forest and agricultural land. The pattern of firewood use was influenced by important factors such as caste, family size, livestock numbers, income and distance from the households. Larger families with their livestock numbers and low income levels needed a lot of firewood. Firewood collection method was traditional. The villagers collected firewood by cutting green trees and their main source of firewood was private forest, community forest, and agriculture land.

Shrestha (2005) carried out a research on fuelwood harvest, management and regeneration of two community forests (Namjung forest and Khari forest) in Gorkha district. He studied the impact of forest resource use and management practices on community structure and regeneration of locally managed *Shorea robusta* forest. He carried out a household survey in two villages and studied the community structure and regeneration of important multipurpose tree species (*Shorea robusta* Gaertn.and *Schima wallichii* DC.) in community forests. This research revealed that dependancy on forests had been decreasing due to limited access to resources of fuelwood, decrease in cattle number and the cultivation of more fuelwood and fodder trees in non-forested land.Neverthless, forest remained the major source of fuelwood, supplying 63% of the total. Alternative energy sources (biogas and solar cell) were not significant at the time of study. *Shorea robusta* was the dominant tree in both forests, with high relative density (74%) in Namjung forest (NF) and 50% in Khari forest (KF); its importance value index (IVI) was 171 in NF and 152 in KF. Tree density of sal in NF was the highest (909 tree ha–1) among the reported values in references for the same species. Both forests had comparatively low species diversity (1.09 in NF and 1.30 in KF); local management appeared to contribute to reduced diversity. Regeneration of sal was sustainable and fairly high, with a typical reverse-J-shaped size class diagram (in NF), a good predictor of mono-dominant sal forest. Regeneration of *Schima wallichii* was unsustainable in both forests.

Chapter 3
Study Area

3.1. Location and Physiography

Nepal has been divided into five physiographic regions which are High Himal, High Mountain, Middle Mountain, Siwaliks and Terai.The study area lies in Gulmi district which is located in Middle Mountain and Siwalik region in the central Nepal. This study was carried out in forests of Resunga Hill that belonged to the ownership of the government.

The area under investigation lies between the longitude $83^0$15’22”E to $83^0$18’11” E and latitude $28^0$03’36” to $28^0$07’24” N. The elevation of the study area ranges from 690 to 2339 m asl.

3.2. Climate

The meteorological station of Resunga hill is situated at 1530 m asl, in the district headquater of Gulmi and the pertinent data have been recorded by the department of hydrology and meteorology of Nepal. The Gaussen's ombrothermic diagram for an average year in Resunga area shows a typical pattern with a two months period of water stress or dry period during winter (Fig. 3.1). A 15 year record shows the highest maximum average monthly temperature during August (24.18^{0}C). The minimum average temperature was recorded during January (3.99^{0}C).The mean annual temperature was found to be 17.3^{0}C. The average monthly precipitation was highest during July (471.7mm) and lowest precipitation was recorded during November (11.3mm).The total annual rainfall was found to be 1903.6mm.The average monthly temperature and rainfall of the Resunga area since 1991 to 2005 is shown below (Annex VII).

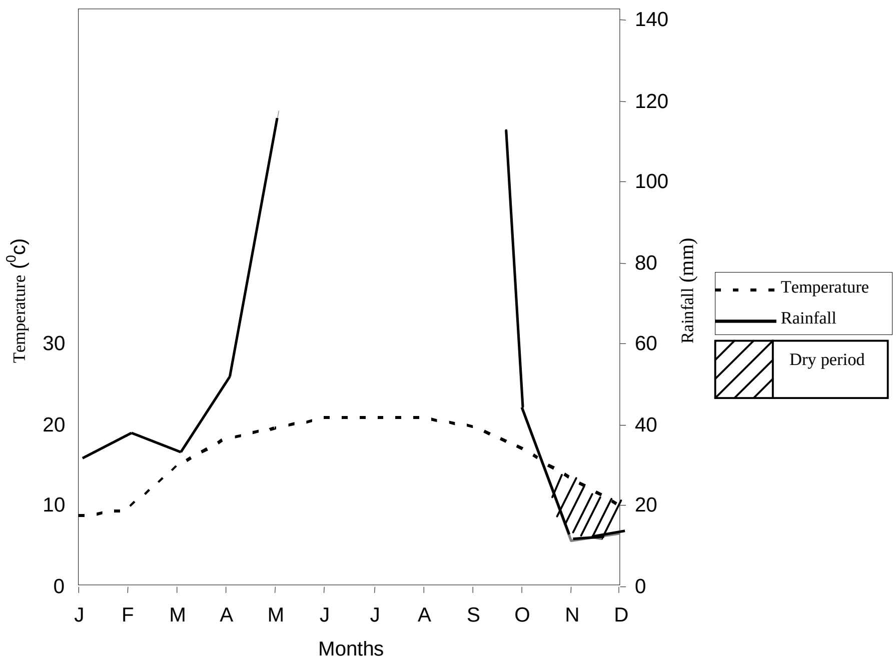


Fig.3.1: The ombrothermic climatic diagram of long-term mean monthly temperature and monthly precipitation (1991-2005)

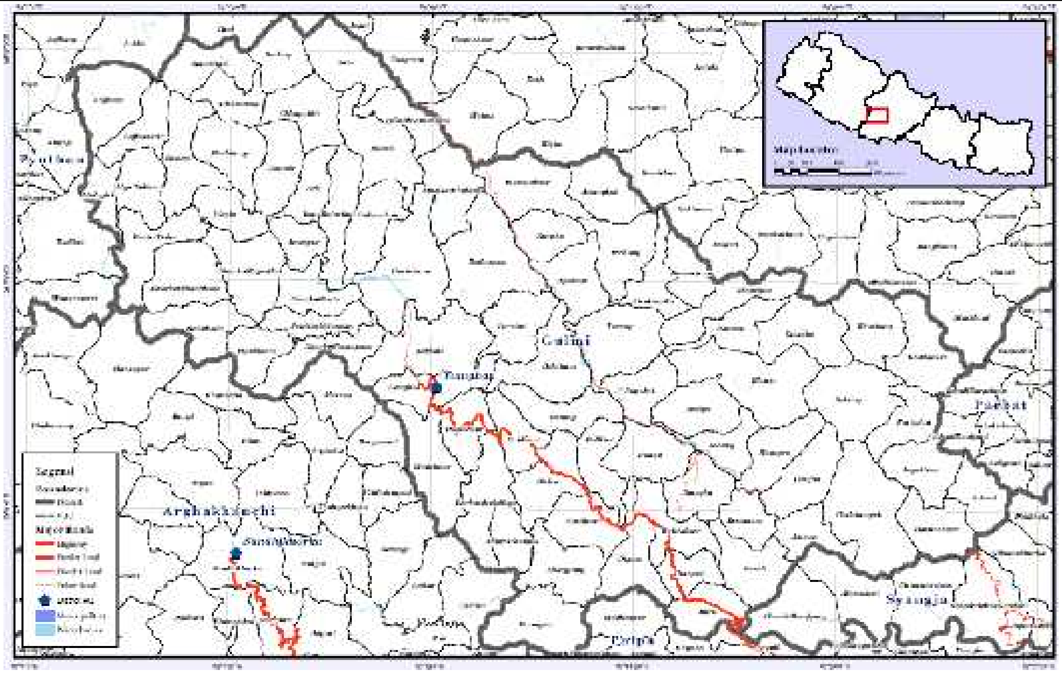
3.3. Vegetation

The dominant vegetation of the Middle Mountain region in the country are pine forest, mixed hardwood and oak forest.The district of Gulmi cross three bioclimatic zones, staggered from Temperate zone to the Tropical, each regrouped in different subzones (Annex IX).

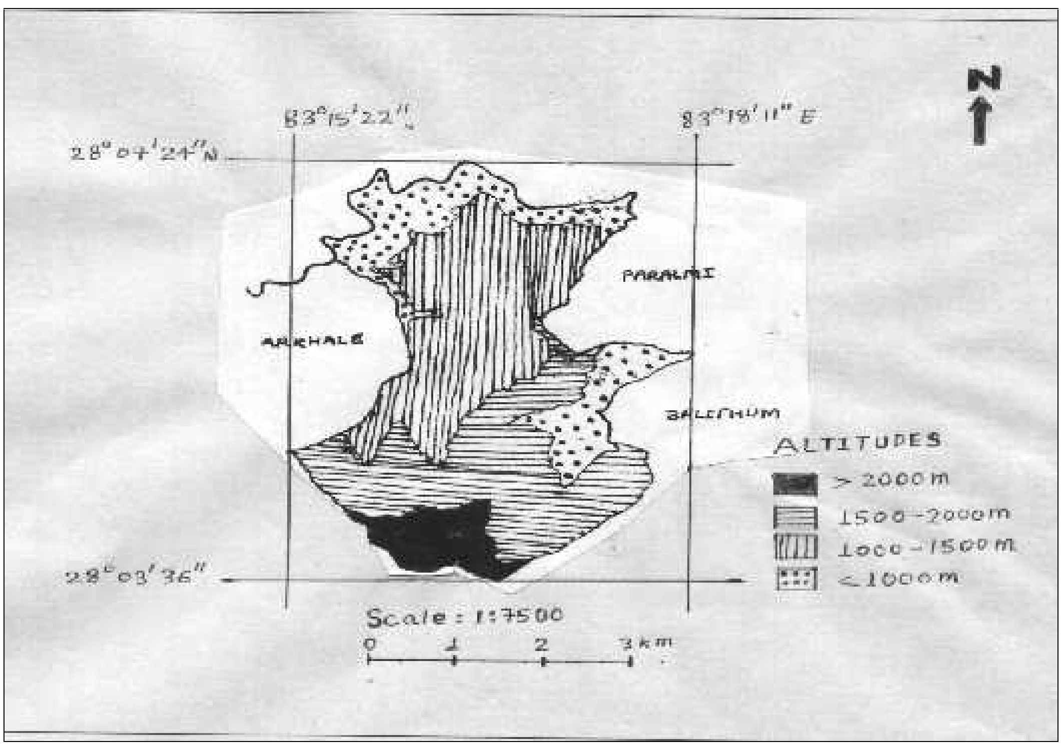
3.4. Population and Settlement

The forests in the Resunga Hill are surrounded by 11 VDCs.Most of the VDCs are adjacent to study area and lie in the foot hill region.According to 2001 census, the total population of all these VDCs is 61,831 with the total households of 12,735.The average family size is 6.The villagers are heavily dependent on agricultural activities. They depend on natural resources of this hill, directly or indirectly for the sustenance of their livelihood.

Figure 3.2.Map of the study area



Location of Gulmi district



Location of study area

Chapter 4
Materials and Methods

4.1. Reconnaissance Survey

A reconnaissance survey was carried out in consultation with the DFO, Gulmi and the site for the study was ascertained. Visit to the site and discussion with the local people was made to know the general status and condition of the forest. The survey of the study area was carried out prior to the in-depth field study in order to gain general information about the research site by consulting with DFO, and local people so as to match the research objectives of the proposed field.

4.2. Data Collection Procedure

Both primary and secondary data were collected. Primary data were collected from the study area while secondary data were collected from published and unpublished documents regarding this research.

4.2.1. Primary Data Collection

Primary data collection was done by following ways –

4.2.1.1. Vegetation Measurement and Specimen Collection

The phytosociological analysis of the forests of study area was carried out during October to Novemember 2005 and March to April 2006.To analyze the vegetation a stratified random sampling method was adopted along an altitudinal gradient in Resunga hill. The altitude ranged from 690 to 2339 m asl.A topographic map and an altimeter was used to identify the different bioclimatic zones in the study area. The study area was divided into four elevation ranges: 690-1000m, 1000-1500m, 1500-2000m and 2000-2339m.Twenty eight square quadrates (20 m × 20 m) for tree, fifty six square quadrats (10 × 10 m) for sapling or shrub stage and fifty six square quadrates (5m × 5 m) for seedling or herb stage were sampled. The size of the quadrat and numbers of quadrats laid were determined through species-area curve method as mentioned in Zobel et al. (1987). All trees of greater than 10 cm (in 20 m x 20 m quadrats) in diameter at breast height (DBH) were measured. In

10m x 10m saplings were also measured for DBH. The data were analysed for structure (Size class distribution, Basal Area, and Biodiversity Index) and for species composition (Number of Species, Species Relative Frequency, and Density, Dominance and Importance Value Index) for each Bioclimatic Zone.

4.3.1.2. Soil Sampling

Twenty eight soil samples of the sample plots were chosen from the different bioclimatic zones of the study area. Soil samples were taken in each plot at a depth between 0 and 30 cm. The collected soil samples were packed in polythene bags and taken to the laboratory for analysis. Soil analyses were performed for soil texture and soil reaction (i.e.active hydrogen ion, H^+) at the Central Department of Environmental Science, Tribhuvan University.

4.3.1.3. Questionnaire Survey

A standard respondent group was designed including key information from various socioeconomic groups to reflect diverse viewpoints and concerns on use of forest resources. Respondents were selected purposely who were directly involved in forest resource collection and utilization. They included forest user committee members and farmers. The survey questionnaire (Annex V) included 3 sections. The first section is about the current status and use of forest resources. The second section comprises the views on forest management.The last section is about household information. Design of questionnaire was carefully planned to create division between each category. The rationale behind the sequence was to obtain information on the use of forest resources.

4.3.1.4. Key Informants Interview

The realistic data by socioeconomic characteristics were also collected from key informants using the semi or unstructured interview method. The informants were interviewed on the current status, use and management conditions of forest products (eg. firewood and fodder) in the study area. The key informants were selected from the forest user groups, Resunga Conservation Committee members, District Forest Office staffs and the people involved in forest resource management.

4.3.2. Secondary Data Collection

Secondary data were collected from various published and unpublished documents related to the study. To generate the secondary data, the maps, official records, research reports, forest management plan, annual reports and other published and unpublished materials from District Forest Office (DFO), Department of Hydrology and Meteorology, internet were consulted and collected.

4.4. Data Processing and Analysis

Both quantitative and qualitative methods were used to analyze the data. For qualitative analysis, the information collected from observation, formal and informal discussion in the group and the individuals, key informant survey and data obtained from the survey were used. The quantitative analysis was done adopting following methods and formula:

4.4.1. Floristic Composition of Forest Stands

Composition is the assemblage of plant species that characterize the vegetation (Martin 1996). The most common measure of composition is richness (the number of different species) and abundance (the number of individuals per species found in specified area). Species richness can be documented by calculating its relative density (RD). Relative Density does not show the distribution of species which is shown by relative frequency (RF). The abundance is calculated as relative dominance (RDo). The definations and formulas used to calculate RD, RF, RDo and the importance value index (IVI) are as follows (Zobel et al 1987):

4.4.1.1. Measurement of Density

Density is the number of individuals of a species out of total number of species per unit area. The number of tree species was counted within each plot and the density was calculated to express it in terms of number per hector. It was calculated by using the following formula.

$$\text{Density} = \frac{\text{No. of individuals of a species in all the sampling units}}{\text{Total no. of sampling units studied} \times \text{area of sampling}} \times 10{,}000$$

To make density comparisons within and among sites easier, often the relative density is also calculated. Relative density is a unitless measure of the density of each species relative to the densities for all species in a given area; values range from 0 to100.

$$\text{Relative Density} = \frac{\text{Density of a species}}{\text{Total density of all species}} \times 100$$

4.4.1.2. Measurement of Dominance

Because one large tree may have a greater influence on the character of a habitat than one small herbaceous plant, dominance is another parameter usually measured. For each species the total coverage or basal area (BA) per unit area is its dominance. Basal Area is one of the chief characteristics which determines dominance. It is the cross section area of tree trunk at 1.37m above the ground which is expressed in m^2 per hector of land area.

$$\text{Basal Area (BA)} = \pi(\text{DBH})^2/4$$

Where, DBH is the diameter at breast height at 1.37 m above the average level at the base of tree.

Relative Dominance is simply the coverage or Basal Area of a particular species relative to that of all species in that sample; again, its range is 0 to 100.

$$\text{Relative Dominance (RDo)} = \frac{\text{Combined basal area for a species}}{\text{Total basal area for all the species}} \times 100$$

4.4.1.3. Measurement of Frequency

Because some plants are very dense and dominant in one area of a habitat but completely missing from other areas, frequency is also a common parameter measured. It is simply the number of plots or transects in which a particular species is found per number of plots sampled. Percentage frequency is often used as a measure of abundance, especially for vegetation studies. Percent frequency is calculated as follows.

$$\text{Frequency (\%)} = \frac{\text{Total number of plots in which a species occurred}}{\text{Total number of plots sampled}} \times 100$$

Relative frequency is the ratio of frequency of a species to that of all species in the plots sampled, and ranges from 0 to100.

$$\text{Relative frequency} = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100$$

4.4.1.4. Measurement of Average Importance Value

The three relative parameters namely relative frequency (RF), relative density (RD) and relative dominance (RDo) can be summed and averaged to give the average importance value, which takes all aspects of the density, coverage and distribution into account, it can also range from 0 to 100.

$$\text{Average Importance} = \frac{RF + RD + RDo}{3} \times 100$$

4.4.2. Structure of forest stands

The structure of forest along an altitudinal gradients were described based on size class distribution, total basal area and species diversity.

4.4.2.1. Measurement of size class distribution

Stand structure can be described as the distribution of species and tree sizes in a forest area (Husch et al.1982).Structure has been also defined as the distribution of trees by diameter classes (Adams and Ek 1974). Individuals were categorized based on diameter classes, i.e. seedlings (DBH = 0, ht < 1.37 m), sapling (DBH < 10 cm, ht> 1.37 m), pole (10-29.5 cm DBH), and tree (≥30 cm DBH) respectively. These gave the frequency of trees in each diameter class. The frequency distribution table was then used to draw pyramid diagram.

4.4.2.2. Measurement of Basal Area per hectare

The basal area for all the trees in each sampling unit was summed and divided by the size of the sampling unit to give basal area per hectare.

4.4.2.3. Measurement of Biodiversity Index

Plant species diversity refers to the number of species and their relative abundance in a defined area.Diversity measurement incorporates both species richness (S, the number of plant species in a community) and species evenness (J, an estimate of species distribution within a community). A community is perfectly "even" if all the species in the community have an equal number of individuals and are all the same size. A community dominated by one or two species is considered to be less diverse than one in which several different species have a similar abundance. As species richness and evenness increase, so diversity increases. Various indices combine these two factors to measure diversity in plant communities. Commonly used diversity index include the Shannon-Wiener index (H').

Shannon-Wienner Diversity Index (H')

The Shannon Index is a measurement used to compare diversity between habitat samples. The comparison can be between two different habitats or a comparison of one habitat over time. The actual formula for the Shannon-Weiner Diversity Index was calculated by the following formula (Brewer and McCann, 1982):

$$H' = -\sum p_i \ln p_i \qquad (1)$$

Where:

H' = Shannon-Wiener diversity index

Pi = Proportion of all individuals in the sample that belongs to species i (ni/N)

ni = total number of individuals in the ith species

N = total number of individual of all species

Values of H' varies from 0 for a community of one species to 7 or more in rich forests.

Evenness (j)

Evenness is a measure of the relative abundance of the different species making up the richness of an area.

Evenness (j) = H'/Hmax = H'/lns (2)

E is constrained between 0 and 1 with 1 being complete evenness.

Species Richness (SR)

For species richness (SR) was calculated following the method of Margalef (Odum, 1971):

SR = (S – 1)/ (log10 N) (3)

Where:

SR = species richness,

S = the number of species at that site and N as in equation (1).

4.4.3. Soil Analysis

4.4.3.1. Texture

Soil texture refers to the relative portions of different particle sizes that make up soil, including sand (large), silt (medium) and clay (fine). By definition, sands are particles with diameters between 2.0 mm and 0.02 mm, silts are between 0.02 mm and 0.002 mm, and clays are smaller than 0.002 mm in diameter. Soil texture classes include: sand, loamy sands, sandy loams, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. Particle size analysis was determined by the hydrometer method with sodium hexametaphosphate as dispersing agent. This method is based upon the differential rate of settling of soil particles in water. The texture group was determined by means of a texture triangle (Anderson and Ingram, 1993).

4.4.3.2. Soil Reaction (pH)

Soil reaction (pH) is the negative logarithm of the active hydrogen ion (H^+) concentration in solution.

pH = - log [H^+]

Where, [H^+] = hydrogen ion concentration. When measuring pH, [H^+] is in units of moles of H^+ per liter of solution.

pH is an indication of the acidity or basicity of the soil and is measured in pH units.pH 7 is defined as neutral. From pH 7 to 0 the soil is increasingly more acidic; from pH 7 to 14 the soil is increasingly more alkaline (basic).Soil reaction (pH) was determined with a digital pH meter in 1:2.5 soil water solution (Anderson and Ingram, 1993).

4.4.4. Use of Forest Resources

This research analyzed the proportion of total supply of forest products from various categories forest management as mentioned in forest act 1991.The various purposes of use and people's perception on various types of changes caused by human activities and potential threats to forest resources of the study area were analysed.Similarly, this research analysed the people's views on the current status of forest management The various threats to the sustainability of Forest Products use were also evaluated by examining the key informants views on use of forest products, the adequacy of present protection procedures, periodicity of forest resource assessment including the effectiveness of role played by DFO in raising public awareness in forest management.

Chapter 5

Results

The plant communities in the northeastern slope of Resunga hill were distributed along an altitudinal gradient from the Upper Tropical Zone (UTZ) to Lower Temperate Zone (LTZ). In overall, 43 species of trees and shrubs spread across 23 different families were recorded in the forests (Annex II).The measurement of structure and composition of forest stands were carried out in different altitudinal ranges separately. Data obtained from the sampling units were analysed and tabulated separately for different altitudinal ranges of the tree species.

5.1. Floristic Composition of Forest Stands

Lower Temperate Zone (2000-2339m)

Altogether 13 species were recorded in this zone (Table 5.1).*Quercus semecapifolia* and *Eurya acuminata* had the highest densities with 695 pl/ha and 454 pl/ha respectively. The relative densities of *Quercus semecapifolia* and *Eurya acuminata* were 42.30 and 27.63 respectively.

The basal area was highest for *Quercus semecapifolia* (18.50 m^2/ha) followed by *Rhododendron arboreum* (11.46 m^2/ha).The relative basal areas of *Quercus semecarpifolia* and *Rhododendron arboreum* were 46.10 and 28.56 respectively.

The frequency (100) and relative frequency (17.14) was highest for *Q. semecarpifolia* while *Cinnamomum glaundiferum (*16.67*), Myrsine semiserrata* and two unidentified species (Local name: Telchapre and Gayalo) were the least frequent species (16.67) with the same value of relative frequency having 2.86.

The average importance value of *Quercus semecarpifolia* (35.18) was greater in this Zone followed by *Eurya acuminata(*16.64*)* and *Rhododendron arboreum* (14.34) respectively, while *Myrsine semiserrata* had the least average importance value of 1.09.

Table 5.1. Average Importance Values (AVG IVs) for all species within Lower temperate zone (LTZ).

Species	D (no./ha)	Freq. (%)	BA (sq.m/ha)	RD (%)	Rel Freq (%)	Rel.BA (%)	AVG IVs (%)
Quercus semecarpifolia	695	100	18.50	42.30	17.14	46.10	35.18
Eurya acuminata	454	66.7	4.36	27.63	11.43	10.87	16.64
Rhododendron arboreum	50	66.67	11.46	3.94	11.43	28.56	14.34
Litsea doshia	96	50	2.53	5.84	8.57	6.31	6.91
Lyonia ovalifolia	33	50	1.96	2.01	8.57	4.88	5.15
Symplocus ramosissima	71	50	0.58	4.32	8.57	1.43	4.41
Pyrus pashia	71	50	0.14	4.32	8.57	0.34	4.41
Viburnum erubescens	71	50	0.11	4.32	8.57	0.27	4.38
Persea odoratissima	53	33.34	0.25	3.23	5.71	0.63	3.19
Cinamomum glanduliferum	29	16.67	0.16	1.77	2.86	0.41	1.54
*Telchapre	12	16.67	0.003	0.73	2.86	0.0072	1.19
*Gayalo	4	16.67	0.004	0.24	2.86	0.0099	1.19
Myrsine semiserrata	4	16.67	0.07	0.24	2.86	0.18	1.09

*: Local name

Upper Sub-tropical Zone (1500-2000m)

Among 43 species of woody vegetation in Resunga hill, a total of 19 species were recorded in this zone (Table 5.2). *Lyonia ovalifolia* had the highest density with 250 pl/ha. The relative density of *Lyonia ovafolia* was 21.31.

The basal area was highest for *Schima wallichii* (11.15 m^2/ha) followed by *Lyonia ovalifolia* (9.51 m^2/ha).The relative basal areas of *Schima wallichii* and *Lyonia ovalifolia* were 34.54 and 29.46 respectively. Although *Erythrina arborescens* was found abundant in number, it lacked basal area as it was found only in seedling stage.

The two species *Lyonia ovalifolia* and the *Schima wallichii* were the most frequent with the values of frequency and relative frequency being 100 and 12.50 for both of the species.The values of frequency and relative frequency for *Rhus javanica* were 66.67 and 8.33 respectively. The rest of the species were least frequent with the values of frequency and relative frequency having 33.34 and 4.17 respectively.

The average importance value of *Lyonia ovalifolia* (21.09) was greater in this Zone followed by *Schima wallichii* (18.52), and *Pinus roxburghii* (12.72). *Acer oblongum* had the least importance value of 1.62.

The following table 5.2 presents the tree density, basal area, and frequency of occurance for each species within Upper Sub-tropical Zone. Relative density, relative BA, and relative frequency are used to calculate Average Importance Value for all species within delineated area.

Table 5.2 Average Importance Value Index (AVG IVs) for all species within Upper Sub-tropical Zone.

Species	D (no./ha)	Freq. (%)	BA (sq.m/ha)	RD (%)	Rel Freq (%)	Rel.BA (%)	AVG IVs (%)
Lyonia ovalifolia	250	100	9.51	21.31	12.50	29.46	21.09
Schima wallichii	100	100	11.15	8.53	12.50	34.54	18.52
Pinus roxburghii	158	33.34	6.63	13.47	4.17	20.52	12.72
Rhododendron arboreum	75	33.34	3.47	6.39	4.17	10.76	7.11
Viburnum mullaha	175	33.34	0.54	14.92	4.17	1.67	6.92
Litsea doshina	100	33.34	0.29	8.53	4.17	0.91	4.53
Rhus javanica	58	66.67	0.02	4.94	8.33	0.08	4.45
Erythrina arborescens	100	33.34	0	8.53	4.17	0	4.23
Pyrus pashia	42	33.34	0.24	3.58	4.17	0.73	2.83
Eurya acuminata	25	33.34	0.02	2.13	4.17	0.06	2.12
Persea odoratissima	17	33.34	0.03	1.45	4.17	0.092	1.90
Engelhardia spicata	17	33.34	0.02	1.45	4.17	0.06	1.89
Myrica esculenta	8	33.34	0.26	0.68	4.17	0.81	1.88
*Thakare	8	33.34	0.02	0.68	4.17	0.15	1.67
Viburnum erubescens	8	33.34	0.02	0.68	4.17	0.06	1.64
*Phurse	8	33.34	0.05	0.68	4.17	0.05	1.63
Quercus lantana	8	33.34	0.01	0.68	4.17	0.03	1.63
Castanopsis tribuloides	8	33.34	0.003	0.68	4.17	0.008	1.63
Acer oblongum	8	33.34	0.01	0.68	4.17	0.02	1.62

*:Local name

Lower Sub-tropical Zone (1000-1500m)

Altogether 16 species were recorded in this zone (Table 5.3). *Viburnum erubescens* and the *Pinus roxburghii* had the highest densities with 1324 pl/ha and 599 pl/ha respectively. The relative densities of *Viburnum erubescens* and the *Pinus roxburghii* were 35.78 and 16.19 respectively.

The basal area was highest for *Pinus roxburghii* (10.15 m^2/ha) followed by *Lyonia ovalifolia* (6.77 m^2/ha) and *Castanopsis indica* (3.70 m2/ha).The relative basal areas of *Pinus roxburghii* and *Lyonia ovalifolia* were 42.42 and 28.30 respectively.

Pinus roxburghii, *Lyonia ovalifolia*, *Engelhardia spicata*, *Schima wallichii* and *Myrica esculenta* were the most frequent with the values of frequency and relative frequency having 100 and 8.7 for all of the species. The rest of the species were least frequent with the values of frequency and relative frequency having 50 and 4.35 respectively.

The average importance value of *Pinus roxburghii* (22.44) was greater in this zone. *Lyonia ovalifolia* (16.04), *Viburnum erubescens* (14.82) and *Castanopsis indica* (12.2) were the next dominant species in the forest, while *Eurya acuminata* (1.56), *Quercus gauca* (1.56) and *Trichilia cannaroides* (1.57) had the least importance value.

The following table (5.3) presents the tree density, basal area, and frequency of occurance for each species within Lower Sub-tropical Zone. Relative density, relative BA, and relative frequency are used to calculate average Importance Value for all species within delineated area.

Table 5.3. Average Importance Value Index (AVG IVs) for all species within Lower Sub-tropical Zone (LSZ).

Species	D (no./ha)	Freq. (%)	BA (sq.m/ha)	RD (%)	Rel Freq (%)	Rel.BA (%)	AVG IVs (%)
Pinus roxburghii	599	100	10.15	16.19	8.70	42.42	22.44
Lyonia ovalifolia	412	100	6.77	11.14	8.70	28.30	16.04
Viburnum erubescens	1324	50	0	35.78	4.35	0	14.82
Castanopsis indica	462	100	3.70	12.49	8.70	15.45	12.21
Engelhardia spicata	311	100	0.40	8.41	8.70	1.68	6.26
Schima wallichii	149	100	1.29	4.03	8.70	5.37	6.03
Myrica esculenta	74	100	0.86	2	8.70	3.60	4.76
Alnus nepalensis	99	50	0.72	2.68	4.35	2.99	3.34
Castanopsis tribuloides	87	50	0	2.35	4.35	0	2.23
Rhus javanica	62	50	0.02	1.68	4.35	0.07	2.03
Wendlandia puberula	37	50	0	1	4.35	0	1.78
Rhus succedanea	24	50	0.01	0.65	4.35	0.04	1.68
Macaranga indica	24	50	0.01	0.65	4.35	0.04	1.68
Trichilia cannaroides	12	50	0.01	0.32	4.35	0.04	1.57
Eury acuminata	12	50	0	0.32	4.35	0	1.56
Quercus glauca	12	50	0	0.32	4.35	0	1.56

Upper Tropical Zone (690-1000m)

A total of 12 species were recorded in this zone (Table 5.5). *Shorea robusta* had the highest density with 1937 pl/ha. The relative density of *Shorea robusta* was 64.14. *Shorea robusta* was followed by *Terminalia alata* with the values of density and relative density having 462 pl/ha and 15.30 respectively.

The basal area was highest for *Shorea robusta* (8.46 m^2/ha) followed by *Terminalia alata* (2.16 m^2/ha) and *Pinus roxburghii* (0.91m^2/ha).The relative basal areas of *Shorea robusta*, *Terminalia alata* and *Pinus roxburghii* were 66.56, 17.01 and 7.14 respectively. Although an unknown tree species (Local name: Jakad) was found abundant in number, it lacked basal area as it was found only in seedling stage.

The three species *Shorea robusta, Engelhardia spicata* and *Terminalia alata* were the most frequent with the values of frequency and relative frequency being 100 and 13.33 for three of the species. The rest of the species were the least frequent with the values of frequency and relative frequency having 50 and 6.67 respectively.

Shorea robusta had the highest importance value index of (48.01) in this zone. *Terminalia alata* (15.21) was the next dominant species in the forest, while *Lyonia ovalifolia* had the least importance value of 2.41.

The following table (5.4) presents the tree density, basal area, and frequency of occurance for each species within Upper Tropical Zone. Relative density, relative BA, and relative frequency are used to calculate Average Importance Value for all species within delineated area.

Table 5.5. Average Importance Value Index (AVG IVs) for all species within Upper Tropical Zone.

Species	D (no./ha)	Freq. (%)	BA (sq.m/ha)	RD (%)	Rel Freq (%)	Rel.BA (%)	AVG IVs (%)
Shorea robusta	1937	100	8.46	64.14	13.33	66.56	48.01
Terminalia alata	462	100	2.16	15.30	13.33	17.01	15.21
**Jakad*	162	50	0	5.36	6.67	0	5.90
Engelhardia spicata	75	100	0.24	2.48	13.33	1.87	5.90
Pinus roxburghii	62	50	0.91	2.05	6.67	7.14	5.29
Wendlandia puberula DC	74	50	0.26	2.45	6.67	2.01	3.71
Terminalia chebula	62	50	0.20	2.05	6.67	1.55	3.42
Aesandra butyraceae	50	50	0.20	1.66	6.67	1.55	3.29
Desmodium oojeinense	62	50	0.04	2.05	6.67	0.33	3.02
Syzygium cumini	37	50	0.12	1.23	6.67	0.94	2.94
Rhus succedanea	25	50	0.11	0.82	6.67	0.90	2.80
Lyonia ovalifolia	12	50	0.02	0.40	6.67	0.16	2.41

***:** Local name

5.2. Structure of Forest Stands

The structural organization of tree and shrub species along the altitudinal gradient was described based on size class distribution, total basal area and species diversity.

5.2.1. Size Class Distribution

Lower Temperate Zone (2000-2339m)

The size class distribution of forest stands in this zone showed that the stems frequencies decreased with increase in diameter at breast height (figure 5.1).The figure indicated that stands were developing and the regeneration in the forest was present. Generally there was better growth as indicated by the movement of trees in various diameters. However, the density of the size class 30-39.9cm and 40-49.9 cm was very low indicating the intense stress on forest structure. Total density of trees, poles, saplings and seedlings of tree species was 108 trees/ ha, 721 poles/ha, 696 saplings/ha and 118 seedlings/ha respectively.

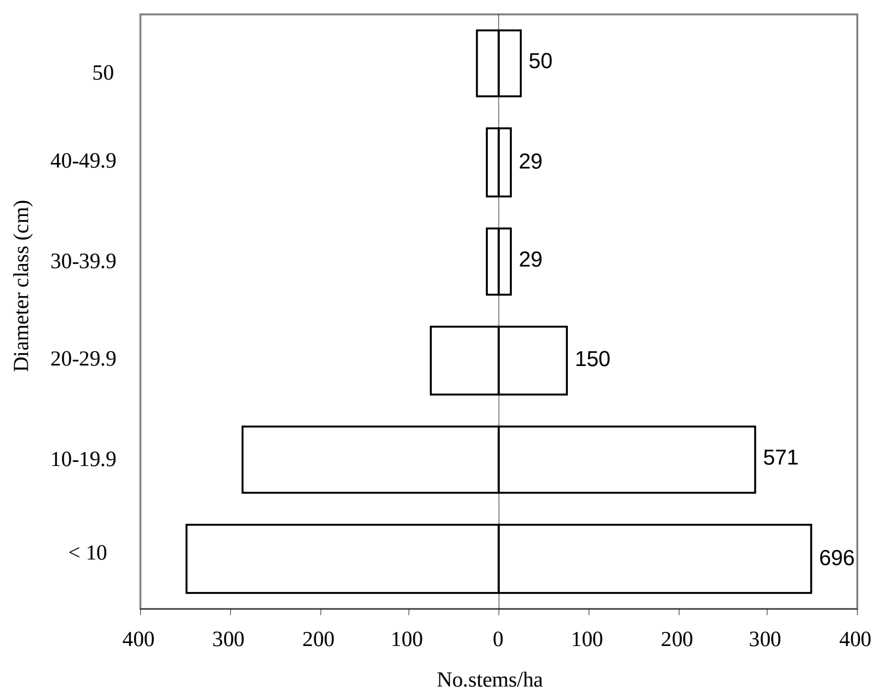


Fig.5.1: Pyramid showing a size class distribution of woody vegetation in the Lower Temperate Zone (LTZ).

Upper Sub-tropical Zone (1500-2000m)

The size class distribution of forest stands in this zone showed that the stems frequencies decreased with increase in diameter at breast height (figure 5.2).The figure indicated that stands were developing and the regeneration in the forest was present. Generally there was better growth as indicated by the movement of trees in various diameters. However, the number of individuals between 40-49.9 cm dbh classes was extremely low. This indicated the stress in stand structure. Total density of trees, poles, saplings and seedlings of tree species was 125 trees/ ha, 367 poles/ha, 367 saplings/ha and 314 seedlings/ha respectively.

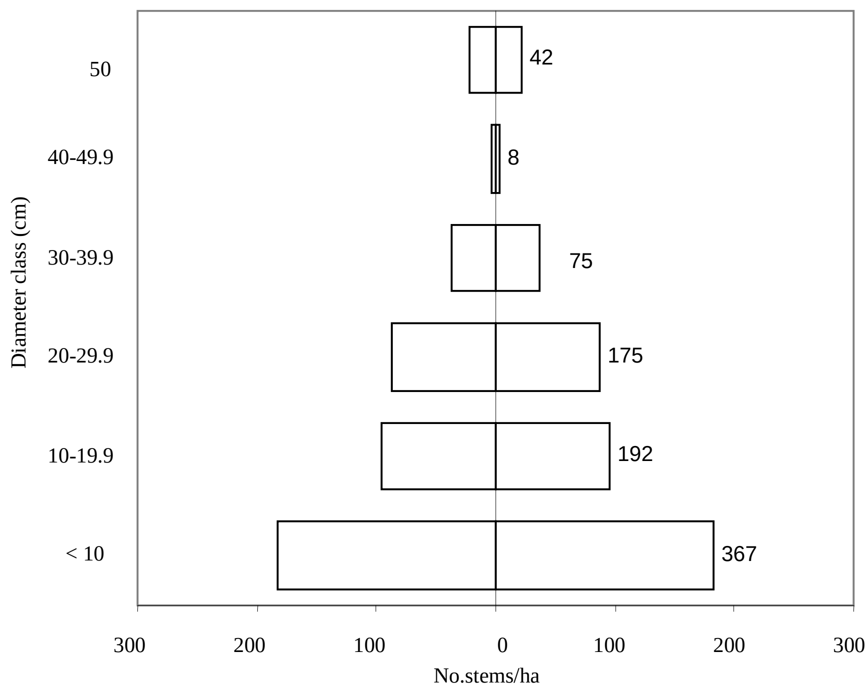


Fig.5.2: Pyramid showing a size class distribution of woody vegetation in the Upper Subtropical Zone (USZ)

Lower Sub-tropical Zone (1000-1500m)

The size class distribution of forest stands in this zone showed the density of the 10–19.9 cm diameter class was higher than those of the preceding and successive size classes. The figure indicated that stands were developing and the regeneration in the forest was present. However, the lower density of smaller size trees indicated a stress on forest regeneration. Total density of trees, poles, saplings and seedlings of tree species was 89 trees/ ha, 651 poles/ha, 300 saplings/ha and 2660 seedlings/ha respectively.

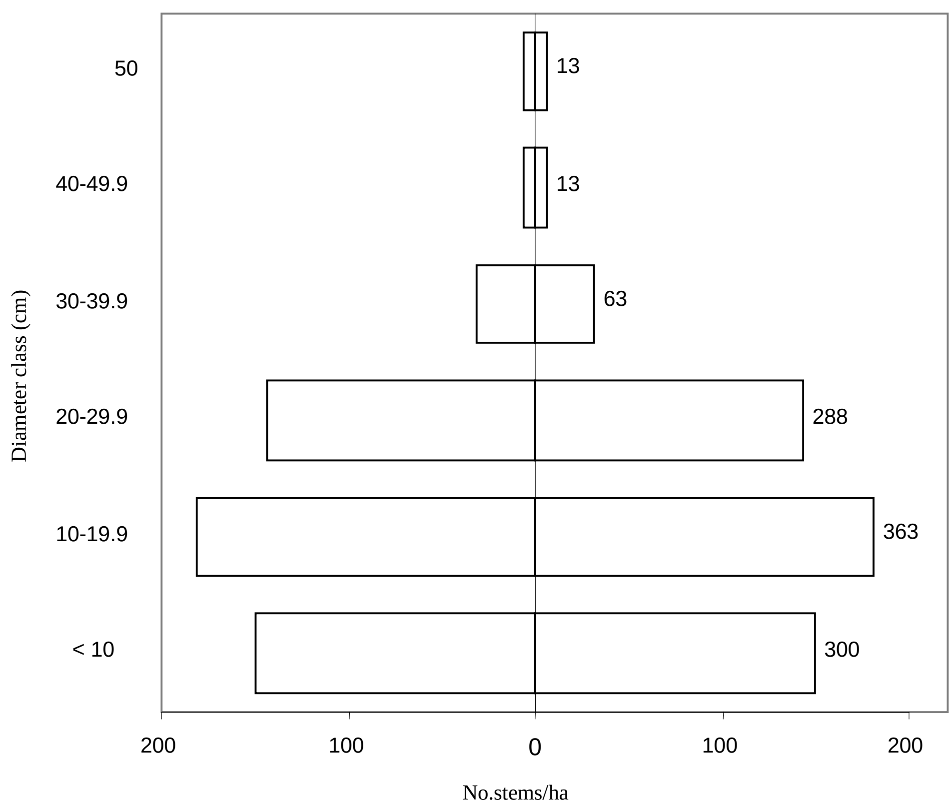


Fig.5.3: Pyramid showing a size class distribution of woody vegetation in the Lower Subtropical Zone (LSZ)

Upper Tropical Zone (690-1000 m)

The size class distribution of forest stands in this zone showed that the stems frequencies decreased with increase in diameter at breast height upto diameter class 20-29.9 (figure 5.4).No trees were found with diameter size greater than 20 to 29.8 in this zone (figure 5.4).The pyramid indicated the overexploitation of higher size class (DBH) individuals during management or utilization in the past. It indicated the greater stress in the forest structure. Although the regeneration in the forest was present, the dearth of large sized trees indicated the impaired sustainability of forest stands in this zone. Total density of poles, saplings and seedlings of tree species was 362 poles/ha, 550 saplings/ha and 2108 seedlings/ha respectively.

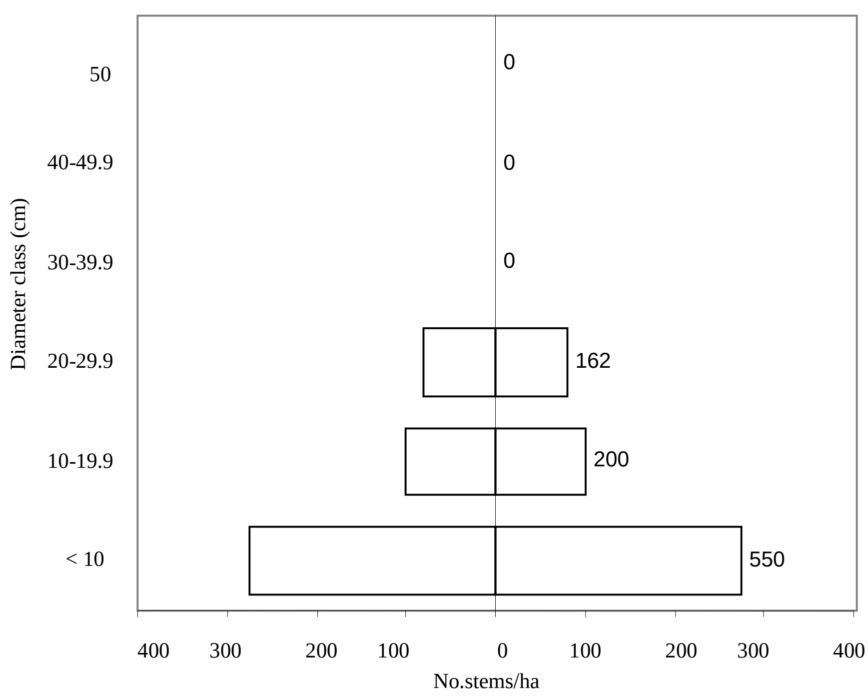


Fig.5.4.Pyramid showing a size class distribution of woody vegetation in the Upper Tropical Zone (UTZ).

5.2.2. Total Basal Area

Basal area per hectare is an indicator of the level of degradation or status of standing stock. The sum of breast-height basal area (BA) of all tree stems in a sample plot varied from 12.71 m^2/ha to 40.15 m^2/ha. On plotting the stand total of stem basal area against altitude, a more or less smooth curve was obtained as shown in figure 5.5.The total basal area(BA) increased with altitude from 12.71 m^2/ha in the Upper Tropical Zone to the maximum around 40.15 m^2/ha in the Lower Temperate Zone.

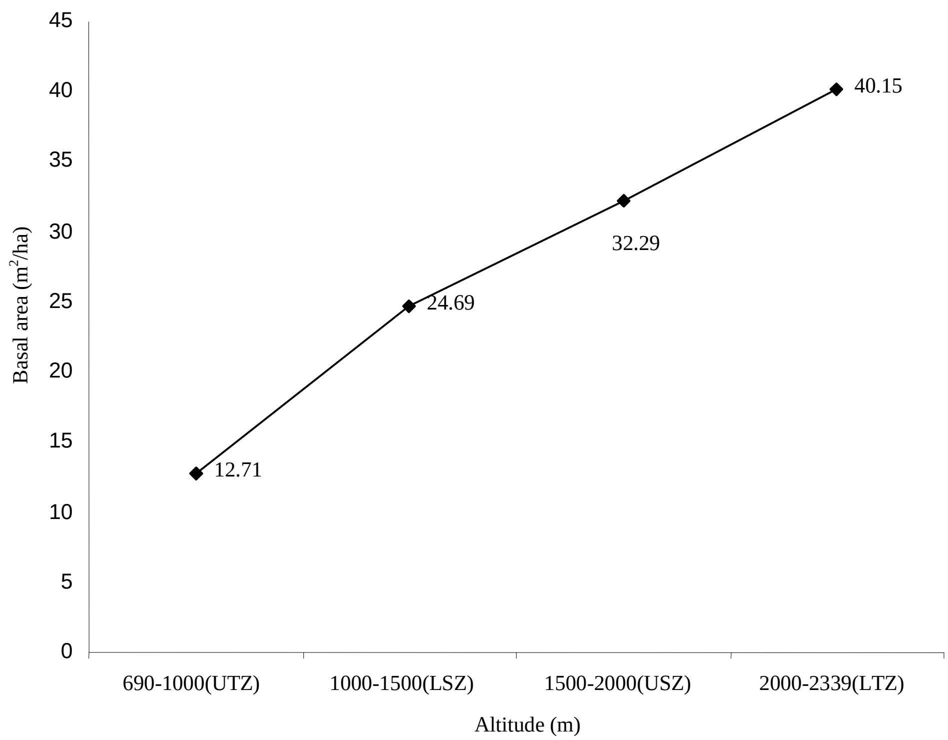


Fig.5.5.Change of summed basal area with altitude.UTZ: Upper tropical zone.LSZ: Lower Sub-tropical Zone, USZ: Upper Sub-tropical Zone.LTZ: Lower Temperate zone.

Lower Temperate Zone (2000-2339m)

The total basal area (BA) for tree, pole, and saplings of tree species was 23.09m^2/ha, 15.08 m^2/ha, 1.98 m^2/ha respectively (figure 5.6).

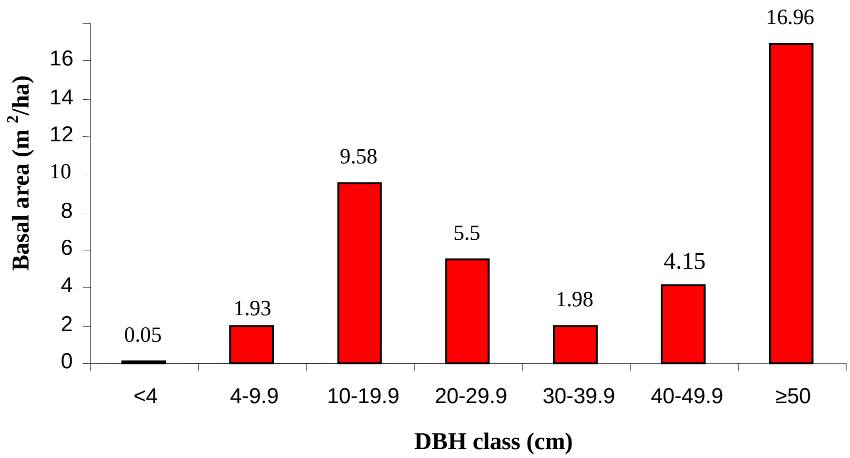


Fig.5.6: Basal area (m^2/ha) distribution in the Lower Temperate Zone (LTZ).

Among the 13 tree sized species recorded in this zone, *Quercus semecapifolia* had the highest basal area and found to be 7.43 m^2/ha for tree and 10.44 m^2/ha for pole.*Quercus semecarpifolia* was followed by *Rhododendron arboreum* for tree by 11.39 m^2/ha whereas for pole it was followed by *Eurya acuminata* by 1.82 m^2/ha.The lowest basal area of trees was followed Lyonia ovalifolia by 1.06 m^2/ha.Basal area of pole-sized tree was found lowest for *Rhododendron arboreum* and found to be 0.06 m^2/ha.The eight species namely *Persea odoratissima*, *Viburnum erubescens, Pyrus pashia, Symplocus ramossima,Myrsine semiserrata*, *Cinamomum glanduliferum* including two unidentified species (Local name:Telchapre and Gayalo) were observed only in seedling stage (DBH=0, ht < 1.37m).Therefore, they lacked basal area for all of tree, pole and sapling diameter classes. No basal area (BA=0) was observed in certain size class that indicated Probability of removed species during forest management or utilization.

Table 5.6. Basal area of tree species in the Lower Temperate Zone (LTZ)

Scientific name	Basal area in the LTZ (2000-2339 m) m^2/ha							
	DBH Size Class(cm)							Total
	< 4	4-9.9	10-19.9	20-29.9	30-39.9	40-49.9	>50	
Quercus semecarpifolia J.E.Smith.	⊙	0.64	6.85	3.57	1.23	⊙	6.18	18.50
Eurya acuminata DC	⊙	0.88	1.27	0.55	⊙	0.69	0.95	4.36
Litsea doshina Buch.-Ham.ex Dado	⊙	0.02	0.75	0.18	⊙	1.57	0.00	2.53
Lyonia ovalifolia (Wall) Drude	⊙	⊙	0.11	0.78	0.30	0.75	0.00	1.95
Rhododendron arboreum Smith	⊙	0.01	0.05	⊙	0.43	1.12	9.82	11.4623
Persea odoratissima (Nees) Kosterm.	⊙	0.02	0.22	0.00	0.00	0.00	0.00	0.25
Viburnum erubescens Wall	⊙	0.10	0.00	0.00	0.00	0.00	0.00	0.10
Pyrus pashia Buch.-Ham.ex D.Don	0.01	0.12	0.00	0.00	0.00	0.00	0.00	0.13
Symplocus ramosissima Wall ex.G.Den	⊙	0.09	0.22	0.25	0.00	0.00	0.00	0.57
Myrsine semiserrata Wall.	⊙	⊙	0.07	0.00	0.00	0.00	0.00	0.07
Cinamomum glanduliferum (Wall.)Meisn.	0.02	⊙	⊙	0.14	0.00	0.00	0.00	0.16
**Telchapre*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
**Gayanlo*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.04	1.93	9.57	5.49	1.98	4.14	16.96	40.15

Note: -

*: Local name

⊙: Probability of removed DBH size class and species during forest management or utilization.

Upper Sub-tropical Zone (1500-2000m)

The total basal area for tree, pole, and saplings of tree species was 20.1 m^2/ha, 11 m^2/ha, 1.19 m^2/ha respectively (fig.5.7).

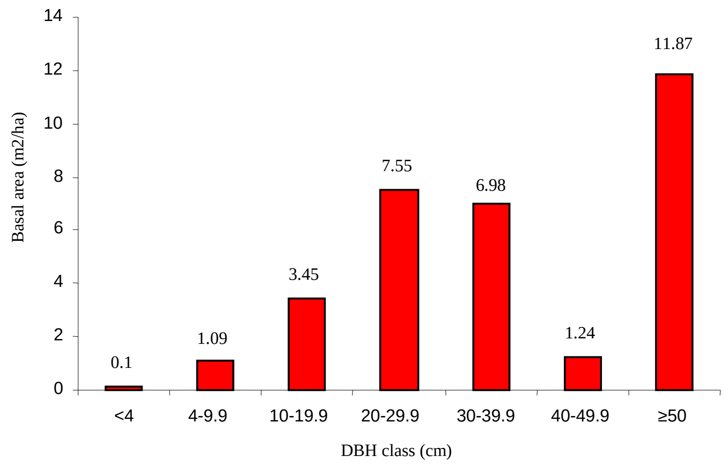


Fig.5.7: Basal area (m^2/ha) distribution in the Upper Sub-tropical Zone (USZ)

Among the 19 tree sized species recorded in this zone, *Schima wallichii* had the highest basal area and found to be 9.59 m^2/ha for tree whereas for pole *Lyonia ovalifolia* had the highest basal area and found to be 4.11 m^2/ha.*Schima wallichii* was followed by *Lyonia ovalifolia* for tree by 4.30 m^2/ha whereas for pole *Lyonia ovalifolia* was followed by *Pinus roxburghii* by 2.56 m^2/ha.The lowest basal area of trees was followed *Rhododendron arboreum* by 2.23 m^2/ha.Basal area of pole-sized tree was found lowest for *Litsea species* and found to be 0.17 m^2/ha. The tree-sized *Pyrush pashia* and *Myrica esculenta* lacked basal area. The 9 species namely *Persea odoratissima*, *Viburnum erubescens, Rhus javanica, Engelhardia spicata, Viburnum mullaha, Lagerstremia parvifolia, Quercus lantana* including two unidentified species (local name: Phurse and Thakare) lacked basal area for both tree and pole-sized diameter class. *Erythrina arborescens*, *Castanopsis tribuloides* and *Acer oblongum* lacked basal area as they were observed only in seedling stage (DBH=0, ht < 1.37m). No basal area (BA=0) was observed in certain size class that indicated Probability of removed species during forest management or utilization.

Table.5.7.Basal area of tree species in the Upper Sub-tropical Zone (USZ).

Scientific name	**Basal area in the USZ (1500-2000 m)m^2/ha**							
	DBH Size Class							**Total**
	< 4	**4-9.9**	**10-19.9**	**20-29.9**	**30-39.9**	**40-49.9**	**>50**	
Lyonia ovalifolia (Wall) Drude	0.01	0.08	1.82	3.28	0.62	⊙	3.67	9.51
Rhododendron arboreum Smith	⊙	0.09	0.15	0.99	0.58	⊙	1.63	3.47
Persea odoratissima (Nees) Kosterm.	⊙	0.02	0.00	0.00	0.00	0.00	0.00	0.02
Viburnum erubescens Wall.	⊙	0.01	0.00	0.00	0.00	0.00	0.00	0.01
Pyrus pashia Buch.-Ham.ex D.Don	⊙	0.03	0.19	0.00	0.00	0.00	0.00	0.23
Myrica esculenta Buch.-Ham.ex D.Don	⊙	⊙	⊙	0.26	0.00	0.00	0.00	0.26
Schima wallichii (DC.)Korth.	0.00	⊙	0.50	1.04	1.79	1.23	6.56	11.15
Erythrina arborescens Roxb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rhus javanica L.	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.02
Pinus roxburghii Sargent	⊙	0.09	0.59	1.97	3.97	0.00	0.00	6.62
Engelhardia spicata Lsch.ex Bl.	⊙	0.02	0.00	0.00	0.00	0.00	0.00	0.02
Viburnum mullaha Buch.-Ham.ex D.Don	⊙	0.53	0.00	0.00	0.00	0.00	0.00	0.53
Litsea doshina	0.02	0.10	0.16	0.00	0.00	0.00	0.00	0.29
Lagerstremia parvifolia Roxb.	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
*Phurse	⊙	0.0164	0.00	0.00	0.00	0.00	0.00	0.01
Acer oblongum Wall.ex DC.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quercus lantana Sm.	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
*Thakare	⊙	0.04	0.00	0.00	0.00	0.00	0.00	0.04
Castanopsis tribuloides (Sm.) A.DC.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.10	1.08	3.44	7.55	6.98	1.23	11.87	32.29

Note:-

*: Local name

⊙: Probability of removed DBH size class and species during forest management or utilization.

Lower Sub-tropical Zone (1000-1500m)

The total basal area for tree, pole, and saplings of tree species was 5.41 m^2/ha, 18.14 m^2/ha, and 1.14 m^2/ha respectively (fig.5.8).

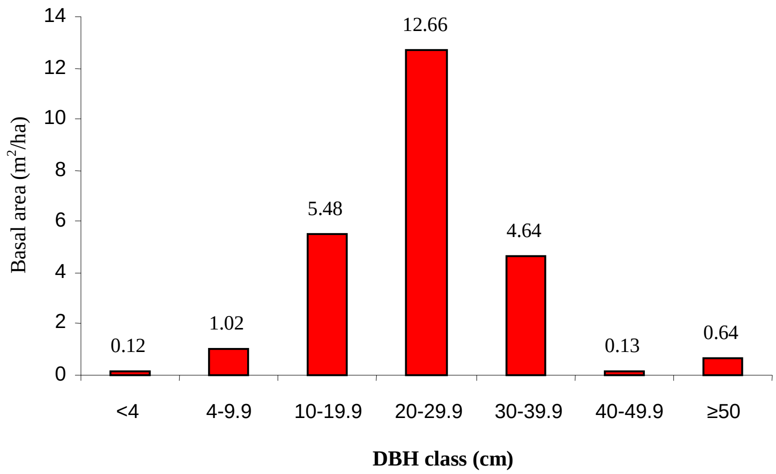


Fig.5.8: Basal area (m^2/ha) distribution in the Lower Sub-tropical Zone (LSZ).

Among the 16 tree sized species recorded in this zone, *Lyonia ovalifolia* had the highest basal area and found to be 3.44 m^2/ha for tree whereas for pole *Pinus roxburghii* had the highest basal area and found to be 9.79 m^2/ha.*Lyonia ovalifolia* was followed by *Castanopsis indica* for tree by 1.10 m^2/ha whereas for pole *Pinus roxburghii* was followed by *Lyonia ovalifolia* and *Castanopsis indica* by 2.80 m^2/ha and 2.46 ^{2}/ha respectively. The lowest basal area of trees was found lowest for *Schima walichii* by 0.13 m^2/ha.Basal area of pole-sized tree was found lowest for *Litsea species* and found to be 0.17 m2/ha. The 2 species namely *Pinus roxburghii* and *Alnus nepalensis* lacked basal area for tree-sized diameter class. Similarly, nine species namely *Viburnum species*,*Rhus javanica*,*Castanopsis tribuloides*,*Eurya acuminata*,*Trichillia canaroides*,*Quercus glauca*,*Rhus succedanea*,*Macaranga indica* and *Wendlandia puberula* were observed only in seedling stage (DBH=0, ht < 1.37m).Therefore, they lacked basal area for all of tree, pole and sapling diameter classes. No basal area (BA=0) was observed in certain size class that indicated Probability of removed species during forest management or utilization.

Table 5.8.Basal area of tree species in the Lower Sub-tropical Zone (LSZ)

Scientific name	**Basal area in the LSZ (1000-1500 m)m²/ha**							
	DBH Size Class(cm)							**Total**
	< 4	**4-9.9**	**10-19.9**	**20-29.9**	**30-39.9**	**40-49.9**	**>50**	
Castanopsis indica (Roxb.) Miq.	0.02	0.10	2.46	⊙	1.10	0.00	0.00	3.69
Lyonia ovalifolia (Wall) Drude	0.03	0.49	0.45	2.33	3.43	0.00	0.00	6.76
Pinus roxburghii	⊙	0.35	1.77	8.01	0.00	0.00	0.00	10.14
Viburnum erubescens Wall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myrica esculenta Buch.-Ham.ex D.Don	⊙	0.02	0.25	0.47	0.10	⊙	0.64	1.50
Schima wallichii (DC.)Korth.	⊙	0.03	0.53	0.71	⊙	0.13	⊙	1.41
Rhus javanica L.	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Alnus nepalensis D.Don	⊙	⊙	⊙	0.71	0.00	0.00	0.00	0.71
Engelhardia spicata Lsch.ex Bl.	⊙	⊙	⊙	0.40	0.00	0.00	0.00	0.40
Castanopsis tribuloides (Sm.)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eury acuminata DC.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trichilia cannaroides (Wight & Arn.)Bentvelzen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quercus glauca Thunb.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rhus succedanea L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macaranga indica Wight	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wendlandia puberula DC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.11	1.01	5.48	12.65	4.64	0.13	0.64	24.69

Note: -

*: Local name

⊙: Probability of removed DBH size class and species during forest management or utilization.

Upper Tropical Zone (690-1000m)

The total basal area for pole and saplings and of tree species was 10.88 m^2/ha and 1.83 m^2/ha respectively. The basal area for tree-sized species could not be found in this zone (fig.5.9).

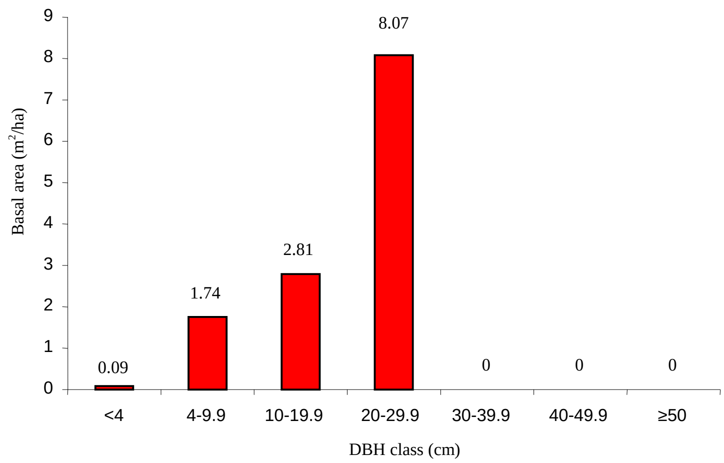


Fig.5.9: Basal area (m^2/ha) distribution in the Upper Tropical Zone (UTZ)

Among the 12 tree sized species recorded in this zone, the basal area for tree-sized diameter could not be found for all of the species. *Shorea robusta* had the highest basal area and found to be 7.70 m^2/ha for pole. It was followed by *Terminalia alata* by 1.78 m2/ha. The lowest basal area of pole was lowest for *Rhus succedanea* by 0.09 m2/ha. The four species namely *Aesandra butyraceae*, *Terminalia chebula*, *Lyonia ovalifolia*, and *Desmodium oojeinense* lacked basal area for pole-sized diameter class too. An unidentified species (Local name: Jakad was observed only in seedling stage (DBH=0, ht < 1.37m).Therefore, it lacked basal area for all of tree, pole and sapling diameter classes. No basal area (BA=0) was observed in certain size class that indicated Probability of removed DBH size class and species during forest management or utilization.

Table 5.9: Basal area of tree species in the Upper Tropical Zone (UTZ)

Scientific name	Basal area in the UTZ (690-1000m) m^2/ha							
	< 4	4-9.9	10-19.9	20-29.9	30-39.9	40-49.9	>50	Total
Shorea robusta Gaertn	⊙	0.75	2.02	5.67	0.00	0.00	0.00	8.45
Aesandra butyraceae (Roxb.)Baehni	⊙	0.19	0.00	0.00	0.00	0.00	0.00	0.19
Terminalia chebula Retz.	⊙	0.19	0.00	0.00	0.00	0.00	0.00	0.19
Lyonia ovalifolia (Wall) Drude	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Engelhardia spicata Lsch.ex Bl.	⊙	⊙	0.23	0.00	0.00	0.00	0.00	0.23
Pinus roxburghii Sargent	⊙	0.12	0.16	0.61	0.00	0.00	0.00	0.90
Syzygium cumini (L.)skeels	⊙	⊙	0.11	0.00	0.00	0.00	0.00	0.11
Terminalia alata Heyne ex.Roth	0.02	0.36	⊙	1.78	0.00	0.00	0.00	2.16
Wendlandia species	⊙	0.08	0.16	0.00	0.00	0.00	0.00	0.25
Rhus succedanea L	⊙	0.01	0.09	0.00	0.00	0.00	0.00	0.11
*Jakad**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Desmodium oojeinense (Roxb.)Ohashi	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Total	0.09	1.73	2.80	8.06	0.00	0.00	0.00	12.71

Note: -

*: Local name

⊙: Probability of removed DBH size class and species during forest management or utilization.

5.2.3. Biodiversity Indices

Diversity was studied in respect of trees and shrubs in the present study. The Shannon Weinner Diversity Index (H') was highest in the Upper Sub-tropical Zone (2.4). It was followed by Lower Sub-tropical Zone (2) and Lower Temperate Zone (1.72) .Upper Tropical Zone had the least diversity(1.33).Similarly, the Evenness (j) was greatest in the Upper Sub-tropical Zone (0.81).It was followed by Lower Sub-tropical Zone (0.72) and Lower Temperate Zone (0.67) . Upper Tropical Zone (0.54) had the least value of evenness. The Species Richness (SR) followed the same trend as evenness. The values of SD, SR and j of the species in each bioclimatic zone are given in the table 5.10 below.

Table 5.10: Shannon Weiner diversity index (H'), species richness (SR) and species evenness (j) at indicated sites in Resunga Forest.

Bioclimatic Zones	Number of species	(H')	(SR)	(j)
Lower Temperate (2000-2339m)	13	1.72	38.59	0.67
Upper Sub-tropical (1500-2000m)	19	2.40	58.32	0.81
Lower Sub-tropical (1000-1500m)	16	2.00	53.52	0.72
Upper Tropical (690-1000m)	12	1.33	38.28	0.54

5.2.4. Physicochemical Properties of Forest Soils

The soil physicochemical properties along an altitudinal gradient showed a considerable variation. Loam soil was predominant in the Upper Tropical Zone and Sandy loam in the Lower Sub-tropical zone. Both the Upper Sub-tropical zone and the Lower Temperate zone had silt loam type of soil texture.

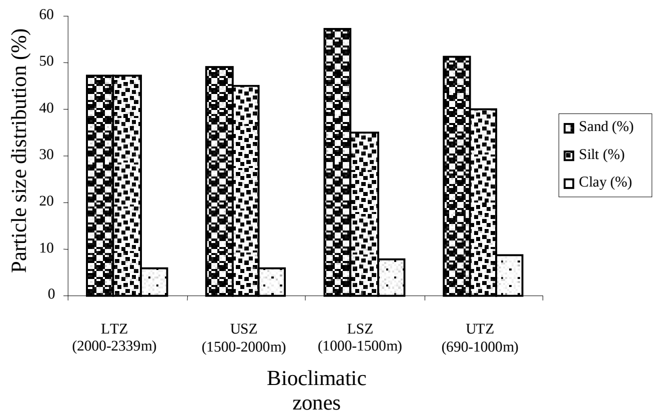


Figure 5.10: Soil texture in the forest.

The soil was very strongly acidic (4.7) in the Upper sub-tropical zone and strongly acidic in both of the Upper tropical zone (5.5) and the Lower sub-tropical Zone (5.3). But in the Lower temperate zone it was slightly basic (7.3). Although the exact reason of variation in soil pH was not clear, the acidic soils found in three bioclimatic zones may partly be due to the presence of pine litter that is known to acidify the soils. The physio-chemical data are given in Annex VII.

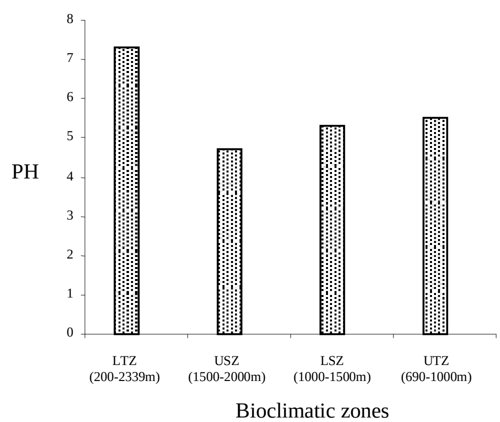


Figure 5.11: Soil PH in the forest.

5.3. Use of Forest Resources

Forest resources were being used for non-commercial and domestic purpose by the local people. The dependency of local people on forest in Resunga hill for fuelwood and fodder had increased in 50% of households, remained the same in 20 % and decreased in 30 % as compared to 10 years prior to this study. Increased use of forest resources was related to increase in family size, restriction in use from community forest, decreased supply of fuelwood and fodder from farm land. The decrease in dependency, where it occurred, is due to reduced numbers of cattle, increased used of LPG gas for cooking and installment of biogas facility. The preferred species for fuel wood were *Quercus semecarpifolia*, *Schima wallichii*, *Castanopsis indica*, *Rhododendron arboreum*, *Pinus roxburghii*.The preferred species for fodder were *Schima walichii* and *Castanopsis indica*. People depended on various categories of forest for the supply of fuelwood and fodder resources (Table 5.11).

Table 5.11: Comparison of supply of forest products from various categories of forest management.

S.N.	Type of dependency on forest management	Respondents (%)
1.	Private/farmland, Community and Government managed forest	35
2.	Community and Government managed	25
3.	Private forest/farmland	20
4.	Private/farmland and Community forest	15
5.	Community forest	5

People were using diverse sources of energy for cooking. Almost 90 % household used fuelwood for cooking. Among fuelwood users, 70 % used LPG gas, 10 % used kerosene and 10 % used biogas as a supplementary energy resource for cooking purpose. Although the alternative sources of energy such as biogas were not widespread, the widespread use of LPG gas had reduced the dependency of people on fuelwood and it had a positive impact on conserving forest. Every household kept domestic animals such a cow, buffalo, and goat. Per capita ownership of domestic animals (3.7) was higher than the national rate (Central Bureau of Statistics, 2002).Buffaloes were kept stallfed, while cows and goats were brought to nearby government managed forest. There was a restriction to graze the livestock on community forest. This showed that people were conserving the community forest but the government managed Resunga forest (RF) was degrading.

Dependance of Local People on Natural Resources from Resunga Hill

Although local people were using the various categories of forest management, overwhelmingly large % of respondents of the study villages regarded the Resunga forest as the source of their livelihood needs such as fuelwood, fodder, water source and aesthetic values (Table 5.12). Significantly, a large proportion of the respondents stressed the importance of this forest in their religious customs. The Resunga peak is worshipped as God rsyasrnga' in the entire region and is a hermitage site since time immemorial.

Table 5.12: Dependance of local people on the natural resources of Resunga Hill.

S.N.	Purposes	Respondents(%)	
		Yes	No
1.	Fuelwood source	65	35
2.	Grass/Fodder source	60	40
3.	Timber products	15	85
4.	Medicinal plants	0	0
5.	Religious value	60	40
6.	Water	45	55
7.	Grazing	40	60
8	Recreation and tourism	50	50

Threats to Sustainability of Forest Products Use

Informal discussion with local people revealed that the forests in Resunga hill were like open access resources and local people enter the forest to collect various products. Illegal harvesting and tree felling activities were very common to these forests. The forests in Resunga hill are facing these stresses because local requirements for timber, fuelwood and fodder are greater than the current production from nearby community and farmland areas. Although the government has some regulatory power to restrict the collection of forest products, its enforcement was very weak. Illegal use, over and improper mode of harvest, overextraction of water resource, landslide and soil erosion due to road construction through forest area, low degree of people's participation, inadequate protection procedure, nonperiodic resource assessment and weak institutional role to increase public awareness were the major problems for the sustainability of forest products use.

Chapter 6

Discussion

The present study deals with structure, composition and use of forests in the Resunga hill along an altitudinal gradient. The structure, composition and function are the three important attributes of forest ecosystems. These attributes change in response to climate, topography, soil and disturbances. The above mentioned factors along with forest successsion are also responsible for both local (within stand) and landscape level variations in forest attributes, thereby producing spatial heterogeneity (Timilsina et al., 2007).In the present study, the forest stand composition and structure of various altitudinal ranges were quite distinct in terms of Importance Value Index, diameter size distribution of tree species, and diversity index. This indicates the vegetation in Central Nepal exhibits diversity in compositional patterns. The differences in the structure and composition of the forests arise out of differences in their disturbance regimes and ecological niche of dominant species (Koirala 2004).

The structure of forest communities at stand and landscape level is controlled by forest management (Spies, 1993, McComb et al., 1993) and disturbances (Foster 1980, White and Jentsch, 2001) and different levels and types of disturbance have a differential impact on forest communities (Halpern and Spies 1995).In a montane rain forest in Mexico, Ramirez-Marcial et al. (2001) found that stem density decreases with disturbance intensity. Similarly, in a study of broadleaved forest in Gedu, Norbu (2000) found out that the trees density increased significantly away from the settlement areas and also lopping of trees for fodder decreased with increasing distances from the villages, this would mean significant influences on the forest structure and composition. Different shapes of pyramid showing size (DBH) class distribution of tree species is due to the extent of effect of forest management and disturbances on the density of size (DBH) classes. This study also found that the stem density declined with increasing disturbance and the individuals of higher girth classes had been overexploited for firewood and other purposes during forest management and utilization. The finding of this study supports the general consensus that forests close to settlements are invariably more intensively exploited than more remote forests (e.g., Acharya 1999, Norbu 2000, Sagar et al. 2003, Koirala 2004).This had reduced the density, basal area and diversity.

Total basal area per hectare is an indicator of the level of degradation or status of standing stock (Sekar, 2001). In this study, the total basal area showed a positive relation with altitude. Basal area (BA) changes in response to species composition, genetic, site difference and human influence. The higher basal area with increasing height may be due to conservation of older trees. The top of Resunga hill is a sacred place and there is a long history of conservation of forest. This is supported by the higher proportion of trees greater than 30 cm in the Lower Temperate Zone. In contrast, the forest stands closer to village settlements were subjected to overexploitation. This was supported by the absence of tree sized species in the Upper Tropical Zone.

The species richness of a forest can be influenced by many interacting factors including plant productivity, competition, geographical area, historical or evolutionary development, regional species dynamics, regional species pool, environmental variables and human activity (Woodward, 1988; Palmer, 1991; Eriksson, 1996; Zobel, 1997; Criddle et al., 2003). In the present study, the indices of diversity (Margalef and Shannon Weiner) showed higher values in forest stands at 1500-2000m range than other altitudinal zones**.** Species richness is maximum at an intermediate level of disturbance (Abugov 1982).The higher values of diversity indicate greater stability of community structure (Kohli et al. 1996).These indices are lowest in the forest stands at 690-1000m range among the studied forests because of the direct influence of disturbance. The impact of human activities such as firewood collection, tree felling and cattle browsing accounts for the reduced diversity of vegetation in the Upper Tropical Zone.

Most of the soils in the middle hills are weakly acidic to acidic and the great majority of Nepalese soils fall into the loamy texture (Shrestha, 1992).This study also confirmed it. The difference in pH of soil along an altitudinal gradient is affected by the variation in in local environmental factors such as aspect, rainfall, and vegetation composition. Most of the litter from broadleaf trees is relatively neutral but the pine needles are known to acidify soils. In the present study, the litter accumulation from *Pinus roxburghii* may have partly contributed to acidify the soils.

The forest in the middle mountain zone of Nepal is under increasing pressure from a rapidly growing population engaged in subsistence agriculture. The rural people are dependent upon forests for fuel, fodder, compost, and timber. In the present study, foothill region of Resunga hill consisted of thickly populated villages. People in the study area depended on forest resources for their subsistence livelihood, primarily as a source of fuelwood, fodder, grazing and water source. Although some part of the Resunga hill on foot hill region and Southern slope was managed by community forest user's group, people did not have free access for the products in the community forest and their requirements for forest products were greater than the current production from nearby community and farmland areas. That's why, local people commonly used to collect the resources from government managed forest for their basic needs. The human stress factors like population growth, unsustainable use of resources and livestock grazing had increased the stress in useful plant diversity of study area. If anthropogenic pressures continue to operate, this may reduce the plant diversity and create a problem for the long term sustainability of forest products use from government managed forest. Weak institutional role to address these stress factors may exacerbate the problem in future.

Chapter 7
Conclusion and Recommendation

7.1. Conclusion

Before sustainable management strategies can be instituted to any forest it is essential to know and understand the structure and composition of forest. This helps to manage it successfully. The forest stands of study area were quite distinct in terms of structure and floristic composition along an altitudinal gradient. The main differences in the structure and composition of the forests studied may be attributed to change of climatic factors, water resources, edaphic variables and anthropogenic pressure along the elevation gradient. There were altogether 13, 19, 16 and 12 species of tree and shrubs with 1643,1173,3700 and 3020 pl/ha contributing to a basal area of 40.15, 32.29, 24.69,and 12.71 m^2/ha in the Lower Temperate Zone, Upper Subtropical Zone, Lower Subtropical Zone and Upper Tropical Zone respectively.

Shorea robusta was the ecologically most important tree species in the Upper Tropical Zone (690-1000m).In the 1000-1500 m altitude *Pinus roxburghii* was the most frequent and dominant species. At the 1500-2000m altitude *Lyonia ovalifolia* was the most dominant species. At the 2000-2330 m *Quercus semecapifolia* was the most dominant species. This result shows the four distinct forest types in the study area. The major associated tree species were *Terminalia alata, Engelhardia spicata, pinus roxburghii* etc at the 690-1000m; *Lyonia ovalifolia, Viburnum erubescens, Castanopsis indica* etc at the 1000-1500 m; *Schima walichii, Pinus roxburghii, Rhododendron arboreum* at the 1500-2000m and *Eurya acuminata*, *Rhododendron arboreum, Litsea doshia* etc at the 2000-2330m altitude.

The structure of forests along the altitudinal gradients were described based on species diversity, total basal area and size(DBH) class distribution of tree species.

Species richness was highest in the middle range i.e. Upper Sub-topical Zone. The middle elevation range from 1500-2000m showed the highest species diversity among tree and shrub species of the four elevation ranges. The total basal area per hector showed positive relation with altitude. It was maximum in the Lower Temperate zone. Structure described by size (DBH) class distribution showed the greater stress in forest sands. Due to overexploitation and illicit felling, structure of forest stands had been changed. The reduction in average importance value of *Schima wallichii* and *Castanopsis indica* from its natural range i.e. Lower Sub-tropical Zone, absence of tree-sized species from Upper Tropical Zone and much lesser number of higher girth (DBH) class individuals (≥30cm) in the Lower Temperate Zone Upper Sub-tropical Zone and Lower Sub-tropical Zone showed the greater stress in forest stands of these zones. Similarly, the lesser number of small sized trees in the Lower Sub-tropical Zone indicated the stress on forest regeneration.This may be attributed to recurrent disturbances (firewood, fodder and grazing). This dearth of mature and small sized trees indicated impaired sustainability of the surveyed forests.

The forests in the Resunga hill were providing multiple benefits such as fuelwood, fodder, water source, recreation and religious importance. The preferred species for fuel wood from this forest were *Quercus semecarpifolia*, *Schima wallichii*, *Castanopsis indica*, *Rhododendron arboreum* and *Pinus roxburghii*.Similarly, the preferred species for fodder from were *Schima walichii* and *Castanopsis indica.* In comparision to situation 10 years ago, dependency on government managed forests for fuelwood, fodder and grazing had increased in 50% of households due to increase in family size, restriction in use from community forest and decreased supply from farmland. The trend showed that with increasing population, dependence on government managed forests for fuelwood, fodder and grazing will increase in future unless efficient ways of fuelwood and fodder use, alternative energy sources (biogas, solar cell) and more trees in farmland are developed.Therefore, well designed management practices are essential for reducing the stress in plant community structure and ensuring the sustainability of forests in the Resunga hill.

7.2. Recommendation

Both the stand structure and floristic composition of forests in Resunga hill were found sensitive to environmental impacts (pressure) in all the bioclimatic zones.Therefore, there is an urgent need to adapt possible measures like increased legal protection, well designed management practices and intensive afforestation at selective altitudes to minimize or avoid stress in plant diversity and conserve the forests for sustainable utilization in the study area. The following recommendations are made for the further improvements of structure, composition, use, management and research of plant communities.

1. There is a need for increased legal protection of large size class (DBH) tree species like *Shorea robusta*, *Castanopsis indica*, *Schima wallichii*, *Rhododendron arboreum* and *Quercus semecarpifolia* and other associated species from overexploitation for the long term sustainability of the floral diversity of study area.

2. Forest regeneration needs to be facilitated for low density species. Well planned enrichment planting of native species on degraded forests at selected altitudes especially foot- and mid-hill areas would support natural establishment of native forest species.

3. To satisfy community needs of fuelwood and fodder, CFUGs and farmers adjoining the GMF should be encouraged to diversify and plant a mixture of multipurpose trees in both of their CFs and farmlands.

4. An alternative fuel energy source for cooking needs to be provided for the inhabitants of the hill area in order to prevent felling, and people in the study area should be instructed to use improved combustion stove, alternative energy

resources like cooking gas, biogas and solar cell, biobriquette etc.as to save the hill forest.

5. The broad-based pyramid diagram showing size class (DBH) distribution of tree species can be used to monitor and assess the sustainability and check destruction of forests. The continuous monitoring of the changes in floristic composition and structure of forest stands due to management or utilization should be carried out to ensure sustainable management through suitable strategies.

6. Public awareness regarding forest regulation, management and suitable techniques for sustainable utilization of forests should be promoted.

8. Future research emphasis should be given to to study the altitudinally coordinated community structure of lower plants in the study area.

9. Governments efforts need to be made to reduce the stress on plant community structure and address the threats especially due to overexploitation for fuelwood, fodder and other purposes for conservation and sustainable utilization of vegetation.

Annex II: List of tree species in various bioclimatic zones

Forest species in the Lower Temperate Zone (2000-2339 m)

S.N.	Scientific name	Local name	Family Name
1	*Quercus semicarpifolia* J.E.Smith.	Kharsu	Fagaceae
2	*Eurya acuminata* DC.	Hade	Theaceae
3	*Litsea doshia* Kosterm	Sere	Lauraceae
4	*Lyonia ovalifolia* (Wall) Drude	Angeri	Ericaceae
5	*Rhododendron arboreum* Smith	Laligurans	Ericaceae
6	*Persea odoratissima* (Nees) Kosterm.	Kaulo	Lauraceae
7	*Viburnum erubescens* Wall.	Ganaune	Sambucaceae
8	*Pyrus pashia* Buch.-Ham.ex D.Don	Myal	Rosaceae
9	*Symplocus ramosissima* Wall ex.G.Den	Dabdabe	Symplocaceae
10	*Myrsine semiserrata* Wall.	Kalikath	Myrsinaceae
11	*Cinamomum glanduliferum* (Wall.)Meisn.	Malyagiri	Lauraceae
12	Unknown	Telchapre	-
13	Unknown	Gayalo	-

Forest species in the Upper Sub-tropical Zone (1500-2000 m)

S.N	Scientific name	Local name	Family Name
1	*Lyonia ovalifolia* (Wall) Drude	Angeri	Ericaceae
2	*Rhododendron arboreum* Smith	Gurans	Ericaceae
3	*Persea odoratissima* (Nees) Kosterm.	Kaulo	Lauraceae
4	*Viburnum erubescens* Wall.	Ganaune	Sambucaceae
5	*Pyrus pashia* Buch.-Ham.ex D.Don	Myal	Rosaceae
6	*Myrica esculenta* Buch.-Ham.ex D.Don	Kaphal	Myricaceae
7	*Schima wallichii* (DC.)Korth.	Chilaune	Theaceae
8	*Erythrina arborescens* Roxb	Githi	Leguminosae
9	*Rhus javanica* L.	Bhakkimlo	Anacardiaceae
10	*Pinus roxburghii* Sargent	Sallo	Pinaceae
11	*Engelhardia spicata* Lsch.ex Bl.	Mauwa	Juglandaceae
12	*Viburnum mullaha* Buch.-Ham.ex D.Don	Maillo	Sambucaceae
13	*Litsea doshia* Kosterm	Sere	Lauraceae
14	*Eurya acuminata* DC.	Hade	Theaceae
15	Unknown	Phurse	-
16	*Acer oblongum* Wall.ex DC.	Phirphire	Aceraceae
17	*Quercus lantana* Sm.	Banjh	Fagaceae

18	Unknown	Thakare	-
19	*Castanopsis tribuloides* (Sm.) A.DC.	Musure Katus	Fagaceae

Forest species in the Lower Sub-tropical Zone (1000 - 1500 m)

S.N	Scientific name	Local name	Family Name
1	*Castanopsis indica* (Roxb.) Miq.	Dharne	Fagaceae
2	*Lyonia ovalifolia* (Wall) Drude	Angeri	Ericaceae
3	*Pinus roxburghii* Sargent	Sallo	Pinaceae
4	*Viburnum erubescens* Wall.	Ganyaune	Sambucaceae
5	*Myrica esculenta* Buch.-Ham.ex D.Don	Kaphal	Myricaceae
6	*Schima wallichii* (DC.)Korth.	Chilaune	Theaceae
7	*Rhus javanica* L.	Bhakkimlo	Anacardiaceae
8	*Alnus nepalensis* D.Don	Uttis	Betulaceae
9	*Engelhardia spicata* Lsch.ex Bl.	Mauwa	Juglandaceae
10	*Castanopsis tribuloides* (Sm.)	Musure Katus	Fagaceae
11	*Eury acuminata* DC.	Jhyano	Theaceae
12	*Trichilia cannaroides* (Wight & Arn.) Bentvelzen	Aankhatare	Meliaceae
13	*Quercus glauca* Thunb.	Phalant	Fagaceae
14	*Rhus succedanea* L	Bhalayo	Anacardiaceae
15	*Macaranga indica* Wight	Maledo	Euphorbiaceae
16	*Wendlandia puberula* DC	Tilkwo	Rubiaceae

Forest species in the Upper Tropical Zone (690 - 1000 m)

S.N	Scientific name	Local name	Family Name
1	*Shorea robusta* Gaertn	Sal	Dipterocarpaceae
2	*Aesandra butyraceae* (Roxb.)Baehni	Chiuri	Sapotaceae
3	*Terminalia chebula* Retz.	Harro	Combretaceae
4	*Lyonia ovalifolia* (Wall) Drude	Angeri	Ericaceae
5	*Engelhardia spicata* Lsch.ex Bl.	Mauwa	Juglandaceae
6	*Pinus roxburghii* Sargent	Sallo	Pinaceae
7	*Syzygium cumini* (L.)skeels	Jamun	Myrtaceae
8	*Terminalia alata* Heyne ex.Roth	Saj	Combretaceae
9	*Wendlandia puberula* DC	Tilkwo	Rubiaceae
10	*Rhus succedanea* L	Bhalayo	Anacardiaceae
11	Unknown	Jakad	-
12	*Desmodium oojeinense* (Roxb.)Ohashi	Sadhan	Leguminosae

Annex: III: Size class distribution of tree species

dbh	No./ha			
	Lower Temperate (2000- 2339m)	Upper Sub-tropical (1500-2000m)	Lower Sub-tropical (1000- 1500m)	Upper Tropical (690-1000m)
4-9.9	696	367	300	550
10-19.9	571	192	363	200
20-29.9	150	175	288	162
30-39.9	29	75	63	0
40-49.9	29	8	13	0
>50	50	42	13	0
Total	1525	859	1040	912

Annex IV: Stands structure in various Bioclimatic Zones

Stand Variables	Lower Temperate (2000-2339m)	Upper Sub-tropical (1500-2000m)	Lower Sub-tropical (1000-1500m)	Upper Tropical (690- 1000m)
Total Basal Area(m^2/ha)	40.1453	32.2902	24.685	12.7052
Stems/ha	1525	859	1040	912
Seedling/ha	118	314	2660	2108

Annex: V: Diversity work sheet

Species	Area Sampled:___________Square meter or hactor			Shannon- Wienner Index (H')	
	Number found in Sample	(A) Number per square meter or hector	(B) Relative Abundance Number of each species(A) ÷Total(N) = p_i	(C) Natural Log of Relative Abundance(B) =ln p_i	B × C =pi ln p_i
Total number of species	Total number of individuals	Total pec square meter or hector	Total = 1.00		Total (∑piln pi
					Multiply by -1 to make positive H'

Annex VI: Questionaire: Use of Forest Resource

(My name is Krishna Prasad Pandey, and I am a research student of the Tribhuvan University. I am conducting a household survey about forest use and management in Resunga Hill. The objective of this survey is to know the current status, use and management of forest, and households' situation regarding forest.I am interviewing many different households in Gulmi district, including Tamghas and Ratamata VDC.Your household was selected just by chance. The interview will be completely confidential and I will never use the individual data but will use data as a group. The interview will take 10-15 minutes. Would you please talk with me?)

(1) Date of Interview: ____/____/2006 (2) Questionnaire No.__________

(3) Place of interview:

A. District: Gulmi B.V.D.C.:______________________________

C.Ward No.: __________ D.Name of place/Village: ___________________

Section 1: Forest status and its use

Now, I would like to ask questions about current forest status that your household is using. Please answer questions considering the present conditions.

Q.1.1.What forest types are your household using now?

("Do you use forest type?")

S.N.	Forest type	Check(√)
1	Private forest	
2	Government managed forest	
3	Community forest	
4	Leasehold forest	
5.	Protected forest	
6.	Other (specify)	

Q.1.2.Forest type: (Community forest/Government Managed forest)

1. What is the purpose of forest type?

("Do you use forest type for purpose?")

	Purposes	Checks(√)
1	Fuelwood source	
2	Fodder source	
3	Timber products	
4	Medicinal plants	
5	Religious value	
6	Water supply (piped from streams/springs)	
7	Grazing	
8	Recreation and tourism	
9	Other(Specify)	

2. Now, I would like to know the name of the most important species currently used for purpose?

	Purposes	Name of species
1	Fuelwood	
2	Fodder	
3	Timber	
4	Medicine	
5	Other(Specify)	

3. Are you satisfied with the available quantity of the forest products from the forest type?

S.N.	Purposes	Yes	No	I don't know
1	Fuelwood			
2	Fodder			
3	Timber			
4	Medicine			
5	Other(Specify)			

4. Do you pay for the forest products from the forest type 1?

S.N.	Purposes	Checks(√)	
		Yes	No
1	Fuelwood		
2	Fodder		
3	Timber		
4	Medicine		
5	Other(Specify)		

5. How do you judge the changes in forest type in the last 10 years?

S.N	Changes	Inc (√)	Dec(√)	Indiff.((√)
1	Encroachment of settlement			
2	Tourist development			
3	Occurrence of landslide and erosion			
4	Use of forest products			
5	Extraction of water			
6	Stream dry off			
7	Forest cover			
8	Regeneration of forest			
9	Other (specify)			

6. Are there any potential dangers to the condition of forest type?

1. Yes

2. No

3. I do not know

7. If yes, what are the potential dangers for this forest type?

S.N.	Changes	Checks(√)	I don't know(√)
1.	Encroachment of agriculture		
2.	Road construction		
3.	Building construction		
4.	Poaching (Illegal exploitation)		
5.	Excessive use of forest products		
6.	Inappropriate harvesting practices		
7.	Over extraction of water		
8.	Occurrence of landslide and erosion		
9.	Forest fire a. Unplanned fire b. Wild fire		
10	Draught		
11.	Pests and diseases		
12.	Storms or natural catastrophes		
13.	Other (Specify)		

Section 2: Views on Forest Management

2.1. How would you judge the people's participation in forest management?

1. Yes, totally satisfied 2. Fair/Normal

3. No-Why? (Specify)____________________ 4. I do not know

2.2. How do you judge the current management practice to monitor forest stands changes?

1. Regular 2. Irregular

3. I don't know

2.3. How do you judge the present protection procedures of forest stands?

1. Enough 2. Fair

3. Insufficient 4. I don't know

2.4. How do you judge the current management practices to carry out assessment of the quantity of the main forest products?

1. Periodic 2. Nonperiodic

3. I do not know.

2.5. How would you judge the DFO's role in raising public awareness?

1. Excellent 2. Fair/Normal

3. Poor 4. Very poor

5. I don't know

2.6. If you have any request, comment, suggestion for the DFO forest management. Please tell me.

____

____

____

( ) Nothing to say.

Section 3: Household information

3.1. How many years has your family stayed in this house?

1.____________ (month, year)   2. I don't know

3.2. (1) Have you involved in forest related industry?

1. Yes   2. No

(2) If yes, What kind of industry is it?

3.3. What is your ethnicity?

3.4. What is a main job and income sources of your household?

3.5. How many livestocks do you have?

No.

3.6. What fuel does your family use for cooking?

1. Wood/Dried cow dung/straw 2. Kerosene 3. LPG 4. Electricity 5. Other

3.7. May I have your name? (A respondent's name)

Name: Sex:Male/Female

3.8. How many members live in your house?

No.

3.9. May I have the name of the HH head?

Name: Sex:Male/Female

(Thank you very much for your time and kind cooperation.)

Annex:VII: Monthly data of temperature and rainfall of Tamghas Station (average value of 1991-2005)

SN	Month	Temperature(^{0}C)			Rainfall (mm)
		Max	Min	Mean	
1	January	14.61	4.28	8.81	30.78
2	February	17.19	6.29	9.48	37.13
3	March	21.93	9.92	14.86	32.4
4	April	25.65	13.56	18.3	50.84
5	May	26.34	15.76	19.6	116.72
6	June	26.74	17.97	20.86	372.28
7	July	25.86	18.91	20.89	471.77
8	August	25.91	18.66	20.8	467.55
9	September	25.35	17.18	19.85	255.23
10	October	23.31	13.24	17.05	44.33
11	November	19.48	9.13	13.35	11.39
12	December	15.97	5.76	10.14	13.25
					1903.66

Source: Department of Hydrology and Meteorology, Government of Nepal

Annex: VIII: Soil physico-chemical characteristics in different bioclimatic zones of the Resunga hill

S.N.	Soil Parameters	Observed values			
		LTZ (2000-2339m)	USZ (1500-2000m)	LSZ (1000-1500m)	UTZ (690-1000m)
1.	pH	7.3	4.7	5.3	5.5
2.	Texture	Silt loam	Silt loam	Sandy loam	Loam
	a. % Sand	47.1	49.1	57.1	51.1
	b. % Silt	47.1	45.1	35.1	40.1
	c. % Clay	5.8	5.8	7.8	8.8

Annex: IX: Bioclimatic zones in Gulmi district

Bioclimatic Zones	Average annual temperature	Vegetation and Soil
I.Temperate Zone (3000-2000 masl) 1.Montane zone 2.Collenean Zone	10^{0} C to 15^{0} C	*Quercus semecarpifolia forest* (over Orchreous brown soil) *Ericaceae, Lauraceae, Symplocos,Aesculus indica, Juglans regia* (over brown soil)
II.Sub-tropical Zone (2000-1000 masl) 1.Upper-subtropical Zone 2.Lower Subtropical Zone	15^{0} C to 20^{0} C	*Rhododendron arboreum, Lyonia ovalifolia,Alnus nepalensis, Schima wallichi,Castanopsis indica,Pinus roxburghii* (over tropical brown soil)
III.Tropical Zone (Less than 1000 masl) 1.Upper Tropical Zone 2.Lower Tropical Zone	>20^{0} C	*Shorea robusta* (over Ferruginous soil)

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