COMMUNITY COMPOSITION AND REGENERATION OF *PINUS WALLICHIANA* A.B. JACKSON ALONG AN ALTITUDINAL GRADIENT IN SUB-ALPINE REGION, CENTRAL NEPAL

A DISSERTATION SUBMITTED FOR THE PARTIAL FULFILLMENT OF M.Sc. DEGREE IN BOTANY

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RECOMMENDATION

This is to certify that the dissertation work entitled **Community Composition and Regeneration of *Pinus wallichiana* A.B. Jackson along an Altitudinal Gradient in Sub-alpine Region, Central Nepal** submitted by Mr. Balkrishna Ghimire for the partial fulfillment of M.Sc. Degree in Botany, has been carried out under my supervision. The entire work is based on the results of his own work and has not been submitted for any other degree to the best of my knowledge.

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LETTER OF APPROVAL

This dissertation work submitted by Mr. Balkrishna Ghimire entitled **Community Composition and Regeneration of *Pinus wallichiana* A.B. Jackson along an Altitudinal Gradient in Sub-alpine Region, Central Nepal** has been accepted as a partial fulfillment of M.Sc. in Botany.

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ABSTRACT

A quantitative vegetation study was undertaken along altitudinal gradient in the forest of an U-shaped valley of Manang. The trans-Himalayan U-valley lies between 28°37′ - 28°39′N latitude and 83°59′ - 84°07′E longitude, north part of Annapurna Conservation Area. Community composition (tree and shrub) and regeneration of *Pinus wallichiana* were studied in randomly placed 10m × 10m quadrat (for tree) and 5m × 5m (for shrub/sapling). The forest was divided into two sites, site I (north aspect) and site II (south aspect), and altitude ranged from 3300m to 4000m a.s.l. on both sites. Both sites were divided into three altitudinal gradients (3300-3500m, 3500-3800m and 3800-4000m). All the tree species were divided into different size classes based on dbh of 10cm intervals. Soil samples were collected from each quadrat.

All together 24 plant species (5 tree and 19 shrub) were found in the study area. Vegetation composition of the two sites was very contrasting. The tree density in both sites decreased from low to high altitude. Similarly the basal area of tree gradually decreased with the increase in elevation. Tree density and basal area was higher in site I. There was no regular decrease or increase in density of shrub in both sites. On the basis of IVI *Pinus wallichiana* was the most important species on the lower belt of both sites, whereas in higher altitude of site II only *Juniperus indica* was found in scruby nature. Regarding the shrub species, *Berberis aristata* and *Lonicera* species were most important species. Tree species richness was higher in lower altitude of site I where as the shrub species richness was approximately same in both site. Tree species diversity was higher in site I.

Soil was slightly acidic in nature. The distinct variation in soil parameters were not observed in two sites as well as along altitude.

Size class distribution showed sustainable regeneration of *P. wallichiana* on both site and along altitudinal gradient. There was lack of large sized tree in high altitude on both sites. Canopy cover of tree species is the most important factor for the establishment of seedlings in the forest. Large number of seedlings were found in lower altitude and less sloppy area and lesser number of seedlings were found in higher altitude and more sloppy area.

There was great variation in vegetation composition, distribution and regeneration of *P. wallichiana* in two sites and also in different altitudes, however the present study could not detect a single factor which brought that great variation. Plants respond to the combine effects of many different environmental factors like moisture, light, temperature and nutrients. Human interference also play a role in that context. The present study concluded that in high altitude Himalayan forest altitude and site factor play a great role in composition, and distribution of vegetation and regeneration of tree species.

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ABBREVIATIONS AND ACRONYMS

a.s.l.	Above Sea Level
ACA	Annapurna Conservation Area
ANOVA	Analysis of Variance
BA	Basal Area
BPP	Biodiversity Profile Project
Cbh	Circumference at Breast Height
CBS	Central Bureau of Statistics
CDB	Central Department of Botany
cm	Centimeter
°C	Degree Centigrade
Dbh	Diameter at Breast Height
df	Degree of Freedom
DHM	Department of Hydrology and Meteorology
DNPWC	Department of National Parks and Wildlife Conservation
DPR	Department of Plant Resources
gm	Gram
Ha	Hectare
HMGN	His Majesty's Government of Nepal
ICIMOD	International Center for Integrated Mountain Development
IVI	Important Value Index
kg	Kilogram
KMTNC	King Mahendra Trust for Nature Conservation
LRMP	Land Resource Mapping Project
m	Meter
MFSC	Ministry of Forests and Soil Conservation
ml	Milliliter
mm	Milimeter
MOPE	Ministry of Population and Environment
Mt.	Mountain
NARC	Nepal Agricultural Research Council
NPK	Nitrogen, Phosphorus and Potassium
OM	Organic Matter
PCARR	Philippine Council for Agriculture and Resources Research
Pl/ha	Plant Per Hectare
RA	Relative Abundance
RD	Relative Density
RDF	Relative Frequency
SPSS	Statistical Package for Social Science
TU	Tribhuvan University
TUCH	Tribhuvan University Central Herbarium

1. INTRODUCTION

1.1 Background

Situated in the Southern Himalayan flank, Nepal is roughly rectangular in shape with a total area of 147181km². It lies between India and the People's Republic of China at 26°22' to 30°27N latitude and 80°4' to 88°12'E longitudes with an altitudinal range from 60m in the south to 8848m in the north. It covers 0.09% of the total land surface area of the world (Jha, 1992); however, it has a share of 2.6% of the flowering plants (Chaudhary, 1998; MOPE, 2000). It has been regarded as the natural showroom of biodiversity. Nepal's biodiversity is a reflection of its unique geographic position and altitudinal and climatic variations. Nepal's location in the central portion of the Himalayas places it in the transitional zone between the eastern and western Himalayas. It incorporates the Palaearctic and the Indo-Malayayan bio-geographical regions and the Major floristic prominences of Asia (the Sino-Japanese, Indian, Western and Central Asiatic, Southeast Asiatic and African Indian desert) creating a unique and rich in terrestrial biodiversity.

The vegetation of Nepal is diverse and is comparatively rich in plant species. High diversity at species level can be attributed to Nepal's significant topographical and climate variations and vertical dissimilarities. About 118 types of ecosystem (natural biomes) have been identified in different physiographic zones of Nepal with about 52 and 38 ecosystems in the middle mountains and the highlands (Maskey, 1995; BPP, 1995). In view of the species diversity in wild habitat Nepal occupies 25th position and 11th position on the global and continental basis respectively (MFSC, 2000). DPR (2001) enumerated the total number of flowering plants to be 6,501 (5,636 species, 206 sub species, 599 varieties and 50 forma).

High altitude vegetation occurring above an elevation of 3000 m a.s.l. is confined to the north of Nepal at the base of the highest mountain of the Himalayas. This vegetation occurring between an elevation of 3000 m a.s.l. to 4100 m a.s.l. has been classified as sub-alpine forest and consists of coniferous forest (Dobremz, 1972). It is characterized by silver fir *(Abies spectabilis)* at the lower level and Birch-Rhododendron *(Betula utilis, Rhododendron companulatum)* at the upper level. In some drier valleys, blue pine *(Pinus wallichiana)* is found as associated species (Dobremez, 1976).

1.2 Himalayan Biogeography

The Himalaya is well known for eternal snow, for the mysterious abode of the abominable snowman, and for adventures offered by its majestic heights. The Himalayan mountain chain links and locks two great land masses of Asia, the Tibetan plateau and the Indian sub-continent (Shrestha, 1989). The Himalayan region, the greatest physical feature of the earth, covers approximately 23% of Nepal along its northern border with Tibet (LRMP, 1986). Nepal Himalaya constitutes the central sector of the mountain chain, which extends from APi-Namp range in the west to Singhalila in the east (Shrestha, 1989). Hagen (1969) has suggested 10 physiographic divisions in a north-south profile of the Himalaya.

1. Tibetan plateau
2. Tibetan marginal range
3. Valleys of inner Himalaya
4. Great Himalaya
5. Fore-Himalaya
6. Midlands
7. Mahabharat lekh
8. Dun valleys
9. Siwalik Range and
10. Terai

Nepal Himalaya is rained by three major river systems, the Karnali, the Gandaki, and the Kosi system. All these river systems have their watershed extended in the trans-Himalayan region.

1.3. Forest and Vegetation Pattern in Nepal

1.3.1 Forest

Forest constitutes an important natural resource in terms of coverage and its use by the local people. Forest plays an important role in the maintenance of ecological and economic balance (Lekhak and Lekhak, 2003). About 29 percent of total area of Nepal is covered with forest with additional 10.6 percent categorized as shrubs. The forest area has declined from 45 percent in 1966 to 29 percent by the end of the 20th century. The quality of forest has also declined as the shrub land area has doubled from 4.8 percent in mid 1980s to 10.6 percent in mid 1990s. The annual deforestation is estimated at 1.7 percent with 2.3 percent in the Hill, and 1.3 percent in the Terai (MFSC, 1999). The forest products are used to meet energy requirement, food, fodder, timber and medicines. Furthermore, forests provide about 42 percent of fodder supply to livestock, and it is predicted that there will a deficit in the available total digestible nutrients (TDNs) by the year 2010 (MOPE, 2004). About 78 percent of the total energy demand is met from forest, and this resource is still used as the "free gift" of nature.

Forest of Nepal has been grouped into four group and 35 types (Stainton, 1972).

1) Tropical and subtropical,
2) Temperate and alpine broad leaved,
3) Temperate and alpine conifer, and
4) Minor temperate and alpine association

1.3.2 Vegetation pattern

As a whole climate, soil, altitude and aspect are the most important factor which reflect the vegetation distribution (Chaudhary, 1999). Vegetation is the term used to describe the total plant cover of a region. It is generally made up of one or more plant communities or aggregation of plants usually forming a mosaic in complex (Fosberg, 1961). The variations of climate, soil and altitude are responsible for the amazing range of natural vegetation in the country.

The vegetation of Nepal has been divided by many workers into various phyto-geographical divisions. For example Stern (1960) and Banerji (1963) have proposed three divisions of Nepal, corresponding to the three big river systems: Karnali, Gandaki, and Kosi. Swan and Laviton (1962) identified seven floristic zones based on moist habitats. Stainton (1972) described six vegetation types of Nepal on the basis of ecology and vegetation composition. The vegetation of different sectors of Nepal has also been studied by various workers such as Dobremez and Shakya (1975), Shrestha (1976), Dobremez (1980), Sharma (1984) etc. The vegetation of Nepal has been described on the basis of levels of altitude and climate under the following three zones (Chaudhary, 1999).

i. Tropical and sub-tropical zones
ii. Temperate zone, and
iii) Sub-alpine and alpine zones

i) Tropical and sub-tropical zones

These zones extend from east to west and include Terai, Siwalik hills, Dun valleys, and the southern slope of Mahabharat range. Tropical zone, represented by warm and humid region of Terai, falls below 1000m a.s.l. Forest is dominated by *Shorea robusta,* and associated species are *Adina cordifolia, Terminalia chebula, T. bellirica, Syzygium cumini,* etc. Sub-tropical region range between Siwalik hills and the southern slope of Mahabharat range. It lies at an elevation range of 1000-2100 m a.s.l. The zone is represented by *Schima-Castonopsis* in eastern and central region while it is replaced by *Pinus roxburghii* in western region.

ii) Temperate zone

This zone includes mainly the Mahabharat range, which lies almost parallel and north to Siwalik Hills from east to west. The zone falls at an elevation range of 2000-3100 m a.s.l. In eastern and central parts of Nepal, it consists of laurel, mixed broad leaved deciduous evergreen Oak and Rhoodendron forests, while in western Nepal, it consists of distinct evergreen coniferous forests.

iii) Sub-alpine and alpine zones

These zones include Inner and Outer Himalayas, and Tibetan marginal land in the northern part of country at an altitude above 3100m a.s.l. The climate is extremely cold, dry and windy. Sub-alpine zone falls at an altitude of 3100-4100m a.s.l., characterised by coniferous forest of fir *(Abies spectabilis)* at lower elevations and Birch-Rhodendron *(Betula utilis-Rhododendron companulatum)* forest at upper elevations near the timber line. The alpine zone is represented by moist alpine scrub and dry alpine scrub at an altitude above the timber line.

1.4 Natural Regeneration

The term natural regeneration implies that the process of re-growing or reproducing of plants by their juvenile. It is important not only for the reproductive role but also for ensuring the replacement of any member of a community that dies off after completing life cycle (Fatubarin, 1987). Therefore, natural regeneration is most important process to maintain the stable age structure in the species of plant in a community.

Population structure of a species in a forest can convey its regeneration behaviour particularly the reproductive strategy (Singh and Singh, 1992). Population structure, characterized by the presence of sufficient population of seedlings, saplings and young trees, indicate a successful regeneration of forest species (Saxena and Singh, 1984). Regeneration of canopy dominant species is commonly assessed by the distribution of size-classes measured as diameter at breast height (DBH) (West *et al.*, 1981).

The natural regeneration of any plant species is directly or indirectly affected by various climatic as well as edaphic factors, such as light, water, rainfall, flood, soil pH, soil nitrogen, organic matter, aspect, slope, etc. Undisturbed old growth forests with sustainable regeneration are found to have reversed J-shaped size class distribution (West *et al.*, 1981). A bell shaped size class distribution has been attributed to disturbed forest, where regeneration is hampered (Saxena *et al.*, 1984).

1.5 Rationale

Forests are the most important natural resources of Nepal, however due to unsustainable use of forests these are being degraded gradually. Deforestation and forest fire are the main problems for the degradation of forest. Increasing human population of Nepal ultimately lead to increase in the demand of forest resources. Therefore, an investigation of how the utilization of forest influences biodiversity can be of importance in planning a sustainable forestry in Nepal.

This study was conducted in arid sub-alpine region of trans-Himalayan zone of Manang district, and with altitudinal range from 3300m to 4000m. Species composition and natural regeneration was studied along an altitudinal gradients, and compared with various factors. Natural regeneration and vegetation is affected by various climatic as well as edaphic factors.

Many qualitative and quantitative vegetation studies of Nepal's middle hill forest have been done. Studies pertaining to high altitude forests are very meagre. Most of the works are mainly confined to botanical expeditions and plant identifications (Kihara, 1955, Yoda, 1968, 1976; Kanai *et al.*, 1975, 1976). Few studies as natural regeneration of tropical species *Shores robusta* have been carried out (Rautiainnen, 1996; Dhungana, 1997; Giri *et al.*, 1999).

Very few studies on natural regeneration and vegetation in trans-Himalayan zone have been carried out (Acharya, 2004 and Khadka, 2004) but no studies along with altitudinal gradient are found. Therefore, this study stands an additional contribution in case of trans-Himalayan forest ecology in Nepal, and it would be helpful to know the effect of altitude and other environmental factors in vegetation composition and regeneration of forest at the high altitude.

1.6 Objectives

The main objective of the present study was quantitative analysis regeneration process of trans-Himalayan sub-alpine forest. Followings are the specific objectives of the research.

1. To study the effect of altitude on vegetation composition in sub-alpine forest (3300-4000m).
2. To compare the vegetation of two aspect (north and south)
3. To study the natural regeneration of dominant species.
4. To correlate the vegetation and regeneration process with edaphic factors.
5. To recommend measures for better management of forest based on the findings.

1.7 Limitation

The study area was far remote and climate was very cold throughout the year. So, due to limitation of time the herbaceous species could not be included and regeneration of only *Pinus wallichiana* was studied.

2. LITERATURE REVIEW

2.1 Vegetation and Altitude

2.1.1 Outside Nepal

Christopher *et al.* (1981) studied the composition, structure and regeneration of Tierra Firme Forest in the Amazon Basin (forest of the San Carlos) of Venezuela. They reported 83 tree species, high number of trees of 10cm or more in dbh, but a comparatively small number of trees of 40cm or more in dbh. Most of the common tree species were well represented in all size classes indicating that the forest studied is floristically stable.

Upreti *et al.* (1985) studied the composition, diversity and regeneration of oak forest at elevation 1200m-2400m in Kumaun Himalaya and reported that beta diversity was lower in tree layer than the shrub indicating the rapid rate of compositional change in shrub layer.

Bankoti *et al.* (1986) studied the vegetation along an altitudinal gradient (600m to 2250) in Kumaun Himalaya, India. They differentiated eight forest types on the basis of IVI, they were *Shorea robusta, Shorea robusta*-mixed broadleaf, *Shorea robusta-Pinus roxburghii, Pinus roxburghii*-mixed broadleaf, *Pinus roxburghii, Pinus roxburghii-Quercus leucotrichophora, Quercus leucotrichophora* and *Quercus floribunda-Quercus leulotrichophora.* There was a positive correlation between the total basal area cover and tree species diversity.

Adhikari *et al.* (1991) conducted study on high altitude forest: composition, diversity and profile structure in a part of Kumaun Himalaya, India. In the study they found that total tree density and basal area vary from 320 trees/ha to 600 trees/ha and $44m^2$/ha to $98m^2$/ha respectively and identified six forest types on the basis of IVI.

Bankoti *et al.* (1992) analysed the forest vegetation of Kumaun Himalaya, India with elevation 2000m to 2500m, and identified eight forests on the basis of altitude and aspect. The total basal area ranged from 17.9-122.5m^2/ha which was higher than the values recorded for other temperate forest in Central Himalaya.

Diaci (1995) conducted research on the structure of the mountain forests of the Savinga Alps. In his research stand structure of natural mountain forest was analysed along two altitudinal gradients (1500m–1600m and 1500m–1800m) and four forest types were recognized; Fir/beech (*Abies alba/Fagus sylvatica);* high alpine beech forest with larch *(Larix decidua);* high alpine beech forest on extreme sites; and spruce (*Picea abies)* and larch replacement forests.

Taylor *et al.* (1996) carried out study on structure and dynamics of sub-alpine forest in Wang Lang Natural Reseme, Sichaun, China. In their study they used population structure (size, age, spatial patterns) and radial growth patterns, to analyse regeneration pattern of various trees. They found that structural and compositional patterns in Wang Lang forests are a reflection of disturbance history, canopy, and species life history attributes such as dispersal ability, shade tolerance, growth rates and longevity and competition of trees and shrubs with understudy bamboos.

Grishin *et al.* (1996) studied sub-alpine vegetation of Mt. Vysokaya, Central Sikkote-Alin, Russia. From this study they concluded that a catastrophic lowering of the tree line and devastation of the sub-alpine vegetation belt occurred several centuries ago, probably as a result of fires.

Adhikari *et al.* (1996) analysed density-diameter (D-D) distribution curve under exposed and unexposed areas at and around Nainital, Central Himalaya (U.P.). They found that the curves for the whole forest were convex, while those for the Cypress forest were curvilinear and those for the Cedar forest were bell shaped.

Chandra *et al.* (1996) studied quantitative pattern of riparian woody vegetation along elevation gradient ranging from 300-2400m, in Kumaun

Himalaya. Seven main forest types were recognized, in order of increasing altitude they were, mixed broadleaf; Sal and mixed broad leaf; chirpine *(Pinus roxburghii);* chirpine mixed broad leaf; mixed banj and tilong oak *(Quercus leucotrichophora, Q. floribunda);* Cypress *(Cupressus torulosa);* and rianj *(Q. lonuginosa)* dominated mixed oak forest. The total basal cover range from 2370cm^2 to 6561 cm^2 per 100m^2.

Liu Qijina (1997) studied structure and dynamics of the sub-alpine coniferous forest on Changbai Mountain, China. He found that the number of woody species becomes less towards higher altitudes while the herb layer was richer due to the lower crown density.

Tang *et al.* (1997) studied Zonal transition of evergreen, deciduous and coniferous forests along the altitudinal gradient on a humid sub-tropical mountain, Mt. Enei, Sichuan China, and three forest zones were identified physiognomically along the altitudinal gradient (i) the evergreen broadleaved forest zone (660-1500m), (ii) the mixed forest zone (1500-2500m) and (iii) the coniferous forest zone (2500m-3099m). They also observed large compositional changes along the altitudinal gradient.

Chang-fu *et al.* (1998) carried a study on evergreen broad leaved forest with elevation range 540m to 1300m of Mount Lopie, Taiwan. They identified four major forest types along the altitudinal gradient based on the species dominance. They also reported that tree density, species diversity, and evenness of the four forest types differed significantly but total basal area and tree volume were not significantly different.

Brockway (1998) conducted study on plant diversity at local and landscape scales in the Cascade Mountains, Washington. The study showed that species richness and diversity were generally lower in communities characterised by environment extremes (i.e. excessive or scare moisture and severely cold high elevation) than in mesic environments at low to middle elevations. Evenness of plant species was greatest at higher elevations. Species turnover rates were also higher near the environmental extremes.

Ansley *et al.* (1998) studied forest composition, structure and change in an old growth mixed conifer forest in the Northern Sierra Navada. They documented current forest conditions and 39 years of change in community composition and structure. During 39 years they found that stand density increased 39% form 157 to 219 stem/ha and stand basal area increase 15% from 57.9 to 66.7m²/ha.

Aiba and Kityam (1999) carried a work on forest structure, composition and tree species diversity in an altitude substrate matrix of rain forest tree communities from 700m to 3100m of Mount Kinabalu (Boneo). They found that the forest statures, mean leaf area and tree diversity decreased with altitude.

Dlugosch and Moral (1999) studied the vegetation heterogeneity along altitudinal gradients and suggested that the heterogeneity in plant cover increases with elevation. They also suggested that percentage similarity decreased with elevation.

Sundarapandian and Swamy (2000) studied the forest ecosystem structure and composition along altitudinal gradient (250m-1150m) in the Western Ghats, South India. They divided the forest into three types' moist deciduous forest, evergreen forest and forest at high altitude. They found that stem density and basal area of the evergreen forest (748 trees/ha, 81.38m²/ha) were twice those of the moist deciduous forest (312-450 trees/ha, 28.05-33 m²/ha) while the forest at higher altitude showed higher density and lower basal area (1173 trees/ha, 72.72m²/ha).

Pande (2001) studied quantitative vegetation analysis as per aspect and altitude and regeneration behaviour of trees species in Garhwal Himalayan forest. He observed that density (tree ha^{-1}) and TBA (m^2/ha^{-1}) values ranged in between 885-111 and 56.42-126 respectively, and Shannon Wiener diversity index range between 1.80-2.33 for trees and 2.23-2.57 for shrubs.

Zhanging *et al* (2002) conducted a study on diversity of communities and their variety along altitude gradient (700m to 2600m) on northern slope of Changbai Mountain. The results showed that in different successional layers of trees or shrub and herb layers richness and diversity decreased linearly with the increase of altitude.

Ferraz *et al.* (2003) studied physiognomy and structure of vegetation along an altitudinal gradient in the semi arid region of north eastern Brazil. A quantitative survey along an altitudinal gradient (1100, 900, 700 and 500m) was undertaken. From this they found that the highest altitudinal site had the greatest density and the largest total basal area and three lower sites had similar basal areas, although their individual densities varied greatly.

Grytnes (2003) studied species richness patterns of vascular plants along seven altitudinal transect in Norway. Altitudinal richness patterns were investigated along altitudinal gradients located in northern Norway (two transects) and along a west-east gradient in southern Norway (five transects). In five transects species richness peaked at mid-altitude, whereas in the two northern transects species richness decreased with altitude.

Theurillat *et al.* (2003) carried out study of vascular plant and bryophyte diversity along elevation gradients in the Alps. They found that vascular plant species richness decreased consistently with increasing elevation and the distribution of vascular plants along elevation gradients is primarily governed by temperature-related processes alongside a gradual change in the physical environment.

Khatri *et al.* (2004) studied altitudinal variation in structural composition of vegetation in Satpura National Park, India. From the study they identified three major communities, at three elevations. The density was decrease with increasing altitude; also diversity index was higher on lower elevation.

Konovalova (2004) studied regeneration and age dynamics of mixed forest in low mountain landscapes of the eastern Sayan Mountains, Russia. He found significant decrease in some parameters like species composition, average tree height and DBH, quality class and mean density in forest of different altitudinal belts.

2.1.2 Inside Nepal

Stainton (1972) carried out extensive study of vegetation of Nepal and published book 'Forest of Nepal'. From his study he concluded that the vegetation of Nepal is greatly influenced by different environmental factors.

Ohsawa *et al.* (1973) conducted the study on vegetation of cool temperate zone in eastern Nepal. They found decreasing tendency of tree height and basal area with increasing altitude. They didn't observe any intimate relation of species diversity, with elevation gradient indicating there by the species diversity is controlled not only by habitat condition but also by the inter-relationship of the component species.

Chhetri (1981) carried out vegetation and floristic study of some adjoining forests of Chandragiri in relation to altitude, slope, aspect and soil factor. He identified four forest types within the range of over thousand meters (1380m to 2510m), which are *Schima-Castanopsis* forest pine forest, *Quercus longinosa-Lyonia ovalifolia* forest and *Rhododendron arboreum- Quercus semecarpifolia* forest and reported that the diversities of species were much more at the lower altitude than that at the higher altitude.

Shrestha (1982) studied the ecology and vegetation of North West Nepal and he found that altitude is the most important factor that determines the vegetation type. Variation in altitude is indicated by change in vegetation distribution and floristic composition.

Shrestha (1989) divided the forest of Nepal into different 6 regions on the basis of climate, altitude and latitude- Terai, Bhabar and Dun Valley bottom region; Siwalik region, Mahabharat region, sub Himalayan region, Dry river valleys and other exceptional areas (desert areas).

Amatya (1993) identified six forest types of Shivapuri Watershed Area on the basis of classification criteria developed by Forest Resources Survey, Department of Forest/HMG, Nepal.

Gurung (1995) conducted study on the vegetation pattern in the Tahr grazing area of Annapurna south and reported that the plant density increased with elevation, whereas species richness generally decreased.

Lokha (1995) carried out a work in the oak forest of Langtang National Park, Nepal, using ordination technique and he reported that altitudinal gradient and soil had greatest impact on the vegetation.

Aryal (1997) studied species composition, species diversity and dominance in Royal Bardiya National Park. Frequency, relative frequency, density, relative density, basal area, relative dominance and important value index were analysed and she found four types of forest *Shorea robusta* forest, moist mixed riverine forest, *Acacia catechu-Dalbergia sissoo* forest and Savannah or wooded grassland on the basis of IVI.

Vetaas (1997) carried out study on the effect of canopy disturbance on species richness in Central Himalayan oak forest. The result indicated that a small-scale lopping regime would enhance the habitat diversity and species richness of vascular plants. However, large scale canopy disturbance will reduce diversity and changes the species composition that becomes dominated by weedy ruderals.

MFSC (1998) analysed the vegetation of Western Development Region, regarding the altitudinal gradients and identified six bio-climatic zones with different forest types and its associated species. They reported that upper mixed hardwood forest (46%) was the most dominant type followed by lower mixed hardwood forest (22%). The number of stems over 10 cm dbh was 570 stems/ha.

Yadav and Sah (1998) studied the quantitative vegetation (trees and shrubs) of North-East slope and South-West slope of Nagarjun hill and concluded that there was variation in species composition and vegetation structure along the altitudinal gradients. Species diversity was maximum at lower altitudes on NE slope (1610m) than that of SW slope (1840) in contrast to total tree density.

Pandit (1999) carried out study on altitudinal impacts on vegetation distribution in Chhimkeswori hill (3000m-2200m) Makwanpur, Nepal. He found six forest types at different altitudinal range. The plant diversity, basal area and tree density decreased with the increase in elevation.

Sharma (2000) studied the biodiversity in relation to altitudinal gradient of Shivapuri (near Baghdwar to Sundarijal) and observed that diversity of trees decreased with the rise in altitudes due to topographic features, soil and climate. Soil nutrient, OM, pH and moisture content of soil were found to have inverse relation with altitude.

Tamot *et al.* (2000) analysed the quantitative characters of vegetation in relation to soil parameters and altitudinal gradients and they reported that the variations in the quantitative characters of plant species were observed along the altitudinal gradient.

Nepal (2001) analysed vegetation (trees and shrubs) along an altitudinal gradient (1700m-2700m) in Annapurna conservation area. From the study he found that the ecological parameters such as density, basal area, important value index, alfa and beta diversity and index of diversity were decreased with increase of altitude.

Shrestha (2001) studied species diversity along disturbance and altitudinal gradient (1250m-3050m) in Landrunk village of Annapurna region, Nepal. He reported four types of forest viz. *Daphnphyllum-Alnus, Quercus- Daphnphyllum, Rhododendron-Quercus* and *Rhododendron* forest.

Gurung *et al.* (2002) carried out a study in Mardi watershed in Nepal to estimate the stem volume and biomass and analysed the factors responsible for their variation in different forest types. They found that distance, altitude and slope explained up to 93% of the total variation in Oak forest biomass.

Khadka (2004) analysed the vegetation (trees and shrubs) in the forest of Pisang, Manang. He found that *Pinus wallichiana* was the most dominant species in that forest followed by *Abies spectabilis*. He also concluded that topographical and climatic features are important factors in determining the vegetation on the Himalayas.

Sigdel (2004) carried out the study on vegetation and soil analysis in southern aspect of Shivapuri National Park; he identified three forest types on the basis of dominancy of trees at different altitudinal gradient. They were lower altitude (1600m-1800m) *Pinus roxburghii* forest, middle altitude (1900m-2300m) *Rhododendron arboreum* and *Quercus lanata* forest and high altitude (2400m-2732m) *Quercus semicarpifolia* forest.

Shrestha *et al.* (2005) studied vegetation pattern of trans-Himalayan zone in the North-West Nepal, and they classified six vegetation types on the basis of vegetation composition, they were Xerophile formation, Alpine scrubs, Alpine meadows, Scree vegetation, Nival formation and Agriculture boarder land vegetation.

2.2 Regeneration

2.2.1 Outside Nepal

Soad and Bhatia (1991) studied regeneration status of tree species in Shimla and they found that occurrence of greater number of proportions of individuals in lower girth classes and fewer numbers of trees with high girth classes of *Pinus wallichiana* in Himanchal Pradesh indicated the frequent regeneration.

Tobita *et al.* (1993) studied effects of site condition on natural regeneration in Japan. They found that *Pinus thumbergii* and *Pinus densiflora* favoured drier conditions and demand for light was greater notably that others. They used multiple regression models to analyse effect of site factors on distribution pattern of regenerating trees. The site factors were relative light intensity, moisture content of the soil and distance from mother trees.

Chung *et al.* (1996) studied vegetation structure, regeneration niche and dynamics of saplings in *Abies koreana* forest of the Mt. Chiri. According to them the regeneration and survivorship of seedling and saplings were best in 25% of crown closure, in order of 50% gap, but lower in over 75% of crown closure.

Sano, J. (1997) carried a study on age and size distribution in a long-term forest dynamics. The result showed that the distribution of diameter showed a reversed J-shape and that of height had small peak showing vertical strata.

Dobrowolska (1998) studied the influence of various ecological factors on natural regeneration of *Abies albain* highlands and mountains of Poland. Results of his study showed that number and development of fir regeneration were also affected by species composition of a stand. Positive influence of pine and birch canopy on initiation and development of fir regeneration was conformed.

Synnestuent and Thompson (1999) studied factors affecting regeneration of *P. wallichaina* and *Juniperus excelsa* in Pakistan. They found that seedlings of *P. wallichiana* were numerous within dense forest, despite the reduced amount of light. This was due to the better soil moisture conditions possibly because of shade and a layer of litter and less grazing.

Kondo, T. and Shiro Tsuyuzaki (1999) studied natural regeneration patterns of the introduced larch, *Larix kaempferi* (pinaceae) on the Volcano Mount Koma, Northern Japan. They found that vegetation primarily depends on the chance of seed immigration, and that the larches may be an earlier successional species than any other native tree species.

Figueroa *et al.* (2000) studied regeneration pattern in relation to canopy species composition and site factor in mixed oak forests in the Sierra de Manan Han Biosphere Reserve, Mexico. They found that every oak seedling species was more frequent, although not dependent on the canopy type where the same oak species dominated.

Guizhong and Yafei (2002) studied relationship between natural regeneration and environmental factors and the result showed that the main factor affecting the natural regeneration was elevation, followed by the coverage of litter and brushwood.

Zhu and Li Zhan (2002) studied the influence of gap on the regeneration of seedlings in southern subtropical rainforest in Hexi, Narjing, China. The result showed that environment has an important effect on seed germination, seedling growth and development in gap and plant species distribution would influence forest regeneration and succession finally.

Chi-Chang *et al.* (2003) studied regeneration pattern of yellow Cyperus as down logs in mixed coniferous broad leaf forest of Yuanyang Lake Nature Preserve, Taiwan. They found that regeneration of trees as down logs was sufficient to maintain the forest community, including its floristic composition canopy structure and species diversity.

Wang *et al.* (2004) carried out a study on age structure of *Picea schrenkiana* forest along an altitudinal gradient in the central Tianshan Mountains, north western China, result showed that limiting environmental factors e.g. temperature and precipitation play important roles in determining the age structure of *P. schrenkiana* population in the high or low limit transect.

Jun *et al.* (2004) studied population structure and regeneration types of dominant species in an evergreen broadleaved forest in Tiantang Eastern

China. They concluded that the population size structure of a species reflects the biological and ecological characteristics of that species.

2.2.2 Inside Nepal

Manandhar (1996) studied high altitude forest in terms of regeneration behaviour and found that the reverse J-shaped structure of *Abies spectabilis.* The size class distribution of the forest showed that mortality rate increased as the seedlings entered higher size class. Very low number of seedlings distribution was found even in relatively undisturbed forest but good in elevated surfaces.

Vetaas (2000) studied the effects of environmental factors on natural regeneration of *Quercus semicarpifolia* in Central Nepal. He found that the regeneration is most reliable in the nearly undisturbed forest. Most recruits were found under the high canopy and high potential radiation. Canopy disturbance has negative effect on the number of seedlings. Seedlings prefer pH around 6. However, there was no clear relationship between number of saplings and soil parameters.

Mong (2003) studied *Pinus wallichiana* colonization in a glacier fore land in Manang. He found that the most important causal factors determining the establishment of *P. wallichiana* are distance to and dispensability of seedlings population as well as anthropogenic influence.

Acharya (2004) studied the post fire natural regeneration of dominant tree species in Pisang, Manang. According to him external factors like human interference and grazing played a major role for post fire regeneration of dominant species, *Pinus wallichiana* and *Abies spectabilis.*

Shrestha *et al.* (2004) studied on regeneration of *Quercus semicarpifolia* in Shivapuri Hill, Nepal. They found that forest had abundant number of seedlings but saplings were very rare, size class of *Quercus* resembled bell shape diagram, and there was lack of continuous regeneration of *Quercus* under its own canopy.

3. STUDY AREA

3.1 Annapurna Conservation Area

Annapurna Conservation Area (ACA) includes the Annapurna range and its adjoining area in western Nepal. It is bounded to the north by dry alpine desert of Mustang and Tibet (China), to the west by Kali- Gandaki river, to the east by Marsyandi valley and to the south by valley and foot hills lying north to Pokhara. Annapurna Conservation Area Comprises Manang and Mustang districts and parts of Kaski, Myagdi and Lamjung districts. It is the largest conservation area in Nepal and covers an area of 7629 sq. km. Annapurna region contains some of the world's highest snow peaks that range over 8,000m and the world's deepest valley of the Kali-Gandaki river between the Dhaulagiri and Annapurna range. Annapurna area is one of the major tourism areas of Nepal. More than 60,000 foreign visitors trek this area each year (KMTNC, 2000).

Within a short span of 120km the altitude rises from less than 1000m to over 8000m in ACA (KMTNC, 1997). Such abrupt altitudinal variation and a diverse climatic and geographical condition support a wide range of broad leaved forests, conifers and alpine meadows. The southern slopes of Annapurna experience some of the highest rainfall in Nepal (approx. 5000mm), while Jomsom, the rain screen areas in the north receive less than 300mm. The area is endowed with diverse climatic conditions that support rich flora (1,226 spp. including over 100 spp. of orchids) and fauna (mammals 101 spp. and birds 747 spp.) (Chaudhary, 1998).

Annapurna Conservation Area is managed by the King Mahendra Trust for Nature Conservation. It is self sustained by entry fee from the visitors and additional supports from the World Wide Fund for Nature-USA, the German Alpine Club and other organizations and individuals.

3.2 Manang District

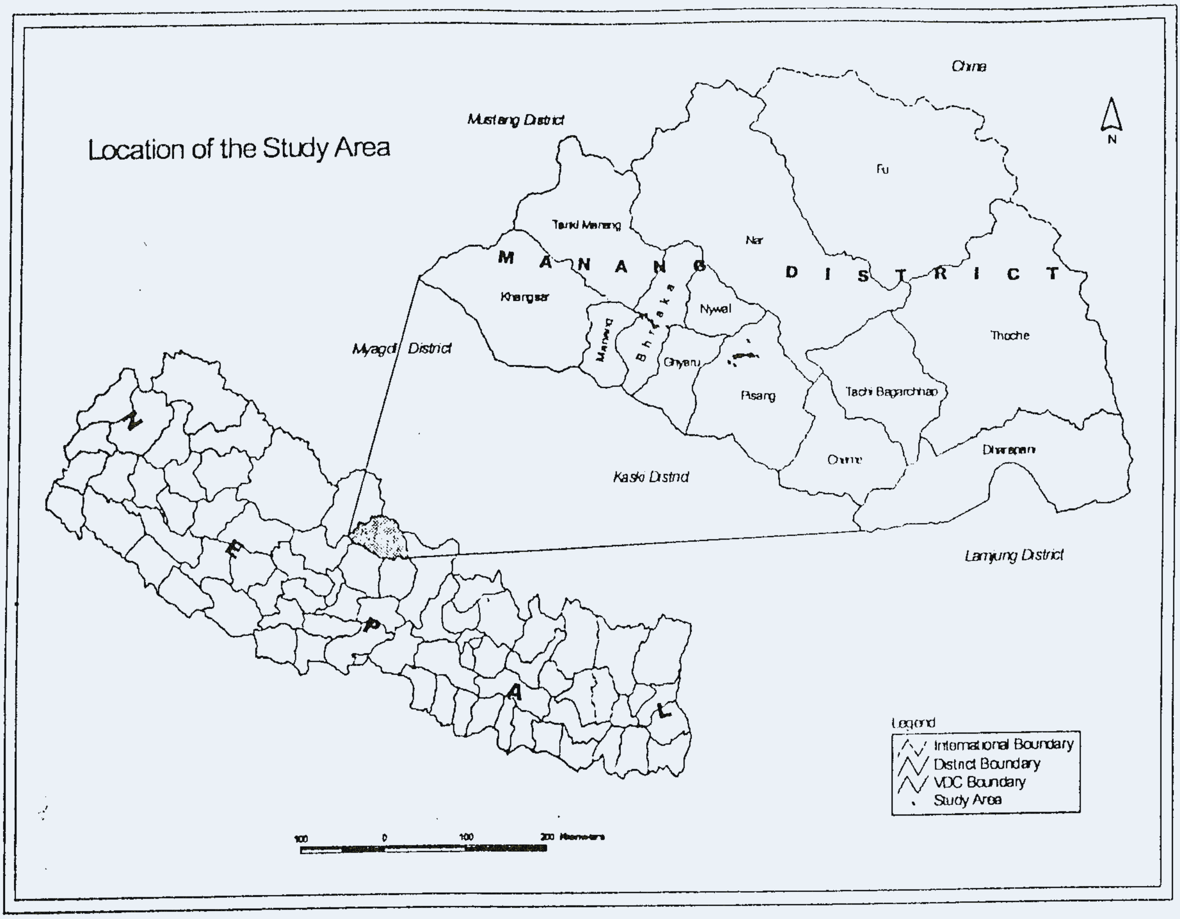
Manang district lies within the Annapurna Conservation Area in Central Nepal. It is situated at Gandaki zone covering an area of 2190 sq. km. The district lies between 28° 27' to 28°43' N latitude and 83°44' to 84°34'E longitudes. The altitude rises from 1830m a.s.l. (6000 feet) to 8029m a.s.l. (26,500 feet) (Koirala, 1981). The district headquarter Chame is located at an altitude of 2660m a.s.l. The district borders on South to Lamjung and Kaski districts and north to Tibet, West to Mustang and on the east to Gorkha district.

Southern part of the district is bounded by the main chain of the Himalayas, formed by Annapurna and Lamjung Himal, Western part by the mountain ranges of Damodar and Muktinath Himal, eastern part by Manaslu Himal, while in the north Peri, Himlung and Cheo Himal at the same time forms the border to Tibet (Pohle, 1990). The Marsyandi river together with its tributaries, Jhar Khola, Nar Khola and Dudhkhola drains the entire district area towards south. There are two main valleys made by the Marsyandi River and its tributaries. The U-valley or upper part of district called Nyeshang and the V-valley or the lower part of the district called Gyasumdo or Teen gaun.

Manang district is one of the most sparsely settled district of Nepal. Nearly 84% of total area of Manang district is high mountain and hills and only 4.5% of total land area is covered by forest and shrubs (Shrestha *et al.*, 1995). There are 13 VDCs in Manang and the total population of Manang district is 9587 (CBS, 2002).

3.3 Study Location

The present study was conducted on north and south aspects of U-valley between 3300m-4000m a.s.l. from Pisang to Khangsar in Upper Manang (Nyeshang). The Trans-Himalayan U valley lies between 28° 37' 56" - 28° 39' 55" N latitude and 83°59'83"-84°7'97" E longitude, north part of Annapurna Conservation Area with rain shadow.



Map of the study area. Source: Land Resource Map Project (LRMP).

Scale 1:150000

There are three villages in the study site; these are Hongde, Braga and Manang of U-valley. Hongde is a mispronunciation of the Tibetan word, from meaning milk. There is airport (Mahendra airport) and some Hotels and lodges.

Braga is another major village of Nyeshang, which lies in between Hongde and Manang. The name refers to the white cliffs under which it is built, 'Bra' means 'cliff' in the local language.

Manang is the most important village of the Nyeshang. There are large and beautiful hotels and lodges for tourist. There is Gangapurna Glacier Lake near the Manang village.

3.4 Climate

The most influencing factors of climate of central Nepal are two Great mountain ranges, the great Himalaya and the Siwalik range. Great variation in altitude of Manang district causes the variations in climate as well. Generally the climate of Manang district ranges from temperate to cold alpine type.

The climate of the study site–Nyeshang region is cold sub-alpine in nature. The area lies in north of the massive Annapurna range. It receives little of the monsoon rain that comes from the south east. The mean annual precipitation during the year is ca 400mm (Anonymous, 1995). There is decreasing moisture from east to west in the upper Manang Valley, and the south facing slopes are significantly drier than those facing north (Bhattarai *et al.* 2004). Snow is common during winter.

There is no meteorological station in the study area. Only one meteorological station of the district is in Chame, the districts headquarter of Manang. The meteorological data were taken from Chame meteorological station.

The meteorological data of the year 2004 shows that the highest maximum temperature reaches up to 21° C during May and minimum temperature up to -3.1°C during December. Similarly highest precipitation was recorded during July (258.4 mm), followed by August (186 mm) and September (185 mm). There was no precipitation during November and December (Source: DHM).

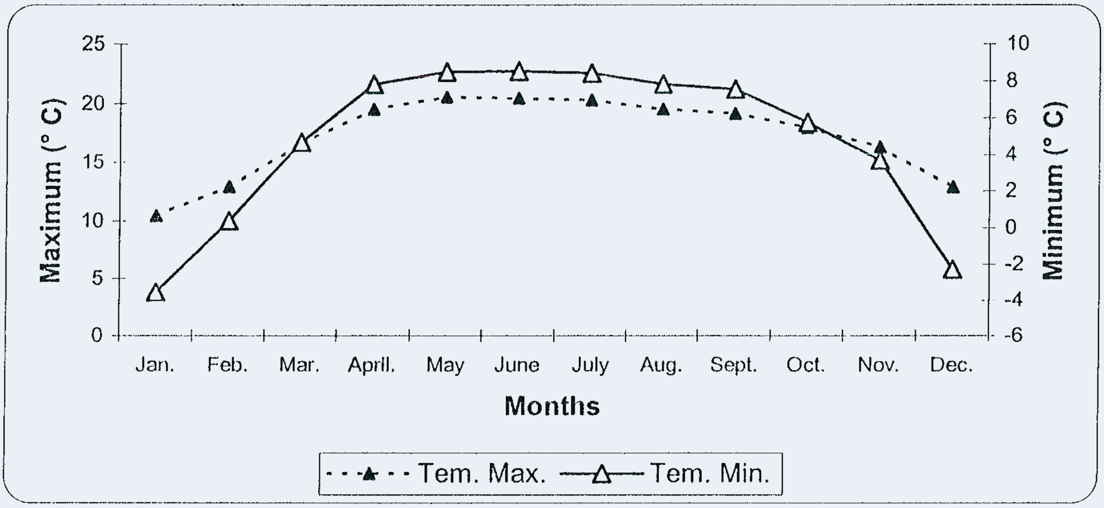


Figure 3.1. Monthly average maximum and minimum temperature of Chame (2000-2004).

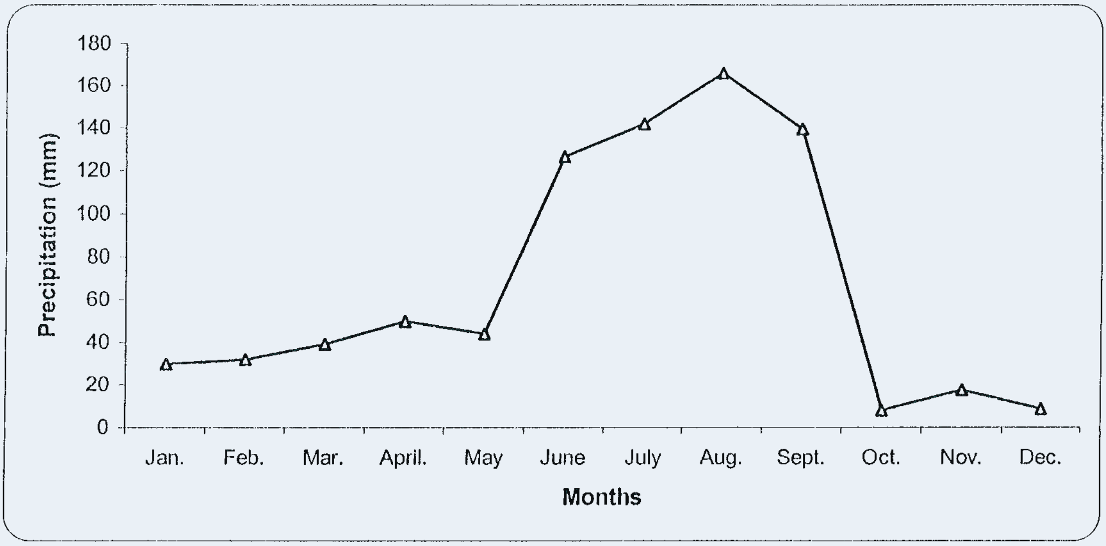


Figure 3.2. Monthly average precipitation of Chame (2000-2004)

3.5 Vegetation

Due to high range of altitude from 1830 a.s.l. to 8029m a.s.l., there is vast difference in climate of the district. Due to climatic variation in different places of the district, there is also variation in vegetation types from subtropical to temperate, Xerophilous and alpine formations (Pohle, 1990). The forest of Nyeshang valley is mainly dominated by blue Pine and silver fir trees. These forests are green throughout the year. With the increase in elevation, forest becomes less dense and height of tree decreases up to 3900m a.s.l. Above this elevation, the tree species are replaced by bushy shrubs mainly *Caragana brevispina, Berberis* spp., *Rosa* spp., *Juniperus* spp., *Astragalus* spp.

In Nyeshang valley, the vegetation of north facing slope is totally different from south facing slope. In northern slope of Annapurna Himal there are five tree species *Pinus wallichiana, Abies spectabilis, Betula utilis, Juniperus indica* and *Salix* sp. But in southern slope of Pisang peak (south facing slope of study area Nyeshang valley), tree species *Betula utilis* and *Abies spectabilis* are found only at moist gullies. Tree line also lies at lower altitude in comparison to northern slope.

Forest of *Abies spectabilis* and *Betula utilis* in northern slope of Annapurna Himal is interspersed with patches of *Rhodoendron* spp., that form a band and run solidly (Dobremez and Jest, 1969). The lower elevation of Marsyangdi valley carry the stand of *Pinus wallichiana, Abies spectabilis* and *Juniperus indica,* while the upper elevation carry the stand of *Abies spectabilis* and *Betula utilis.* The Manang distrct possesses following five types of vegetation (Anonymous, 2002)

1) Dry Alpine Scrub.
2) Moist Alpine Scrub
3) Birch-Rhodedendron Forest
4) Fir Forest
5) Temperate Forests

1) Dry Alpine Scrub

In an altitude of 3600m a.s.l. to above the northern part of Manang, the vegetation is dominated by dry alpine scrub. Occurrence of dwarf and prostrate *Juniperus* species is the characteristic of the dry alpine scrub. Three species of *Juniperus (J. indica, J. squamata, J. communis)* are found in dry alpine scrub, which are associated with *Ephedra gerardiana, Potentilla fruticosa, Verbascum thapsus, Berberis* species and herb *Anaphalis* spp., *Potentilla* spp., *Saxifraga* spp., etc.

2) Moist Alpine Scrub

Dominant species in moist alpine scrub are *Rhododendron* spp. and dwarf shrub of *Juniperus indica, Lonicera ovobata,* etc. The riverine areas and shady river gullies are generally dominated by *Salix* spp. Associate species in moist alpine scrub are *Astragalus, Berberis, Caragana, Lonicera, Hippophae,* etc. and herbaceoius flora consists of species of *Bistorta, Geranium, Primula, Aconitum, Pedicularis* and different species of orchids.

3) Birch-Rhododendron Forest

Birch *(Betula utilis)* and *Rhododendron* spp. are the most common species of the sub-alpine (3000-4000m) forest. Typically *Birch-Rhododendron* association is the sign of tree line vegetation. *Birch- Rhododendron* forest is supplemented by blue pine *(Pinus wallichiana)* in drier areas that are sheltered from the full force of monsoon. More blue pine association than rhododendron is found in some parts, which makes the forests dominated by blue pine. Other species of dry habitats such as *Juniperus indica, Caragara* spp., *Hippophae* spp. are often mixed with tree line vegetation of the trans-Himalayan region (Miechal, 1982).

4) Fir Forest

Fir trees generally appear at about 2800m to 3800m, however, the pure fir forest is found at 3000m to 3500m (Smidt-Vogt, 1990). Fir trees are widespread in north facing slopes. In dry valleys and parts of the trans-Himalayan region, fir trees are suppressed by *Pinus wallichiana* and *Juniperus* species. The associated shrub species are *Rhododendron Caragana, Lonicera, Berberis,* etc.

5) Temperate Forest

The lower part of Manang with altitudinal range 2000m to 3000m is categorized as temperate forest. The temperate zone in mostly rich in forest type and mainly dominated by conifer and oak. The temperate forest of Manang is dominated by blue pine *(Pinus wallichiana)* and associated species are *Picea smithiana, Tsuga dumosa, Taxus baccata* as pure conifer forest and Khasru oak *(Quercus* species) as mixed forest.

4. MATERIALS AND METHODS

Vegetation composition and regeneration of dominant tree species along an altitudinal gradient were studied. The fieldwork was carried out to find out the detailed quantitative data on the vegetation of forest as far as possible.

4.1 Reconnaissance

The study site was selected on the basis of available information, and several criteria were considered so that it represented the high altitude region of the Himalayas in general. For the study two sites of U-valley of Nyeshang separated by Marshyangdi river were selected. The fieldworks were carried out during pre-monsoon (May-June, 2004) and post-monsoon (Sept.-Oct. 2004) periods.

4.2 Primary Data Collection

Two sites site I (north aspect) and site II (south aspect), were selected for the study. Altitude of the study area ranged from 3300m a.s.l. to 4000 m a.s.l. on both sites. Both sites were divided into three altitudinal zones (3500m, 3800m and 4000m) for vegetation study and into seven altitudinal zones with 100m difference for regeneration study. To obtain the suitable and accessible place for sampling both sites were divided into two transects. In the north slope one transect was placed south to Hongde and another transect was placed west to Manang (above the Gangapurna lake). Similarly, in the south slope one transect was placed east to Hongde towards Nagwal, and another transect was placed just above Braga, towards tracking route to Ice lake.

The stratified random sampling method was used in all transects of both sites. The phyto-sociological analysis of each was carried out in randomly placed 10m × 10m quadrats. Requisite size of the quadrat was determined by species area curve method (Mishra, 1968). Each quadrat of 10m × 10m was divided into four sub-plots from the centre of the quadrat and two sub-plots of opposite corner were studied for shrubs and saplings. Altogether 70 quadrats (35 each site) for trees and 140 quadrats (70 each site) for shrubs and saplings were studied. In each quadrat number and size of individuals of each species were recorded. Circumference at breast height (cbh) of each tree was measured 1.37m above the ground by using measuring tape and converted it into diameter at breast height (dbh). Population of each tree species was divided into tree (dbh>10cm), sapling (dbh<10cm, height >30cm) and seedling (dbh 0, height <30cm) (Sundriyal and Sharma, 1996). All the tree species were divided into different size classes based on DBH of 10cm intervals. Canopy cover of each plot was determined by visual estimation. Soil samples were collected from each quadrat.

Specimens of all the tree and shrub species from the quadrat were collected for identification. Most of the plant specimens were identified in the field with the help of local names provided by local people and with the help of standard reference (Stainton and Polunin, 1987, Stainton, 1988 and Shrestha, 1998). Unidentified species were collected and tagged and identified in Tribhuvan University Central Herbarium (TUCH), Central Department of Botany, T.U., Kirtipur. Botanical nomenclature follows Hara *et al.* (1978), Hara and Williams (1979) and Press *et al.* (2000).

Table 1. Description of study area

Site	Transect	Locality	Altitude m	Dominant tree species	No. of quadrat studied
I	1	Above Hong-de	3300-3500	*Pinus wallichiana, Juniperus indica*	10
		Above Hong-de	3500-3800	*P. wallichiana* *A. spectabilis*	15
	2	Opposite Manang	3800-4000	*Betula utilis* *Pinus wallichiana*	10
II	3	Nagwal side	3300-3500	*Pinus wallichiana, J. indica*	10
		Nagwal side	3500-3800	*J. indica*	15
	4	Above Braga	3800-4000	*J. indica*	10

4.3 Quantitative Analysis

There are some important parameters for describing community structure in precise quantitative terms. These are frequency, density basal area and abundance. These quantitative parameters were calculated by the following formula (Zobel *et al.*, 1987).

$$\text{Frequency (\%)} = \frac{\text{No. of plots in which the species occured}}{\text{Total no. of plots studied}} \times 100$$

$$\text{Density (D) pl/ha} = \frac{\text{No. of individuals of a species in all plots}}{\text{Total no. of plots studied} \times \text{Size of the plot}} \times 10000$$

$$\text{Abundance (A)} = \frac{\text{Total no. of individuals of a species in all plots}}{\text{Total no. of plots in which a species occured}}$$

$$\text{Basal Area (BA)} = \pi r^2$$

$$= \pi \frac{(dbh)^2}{4}$$

$$= \frac{(cbh)^2}{4\pi}$$

Where, r = radius, dbh = diameter at breast height, cbh = circumference at breast height $\pi = 3.1416$,

Basal area (m^2/ha) =Density of species plot per ha×Average basal area per tree

Important Value Index (IVI)

In any community structure, the quantitative value of each of the frequency, density, abundance and basal area has its own importance. But the total picture of ecological importance cannot be obtained by any one of these. Therefore, in order to have a really overall picture of ecological importance of a species with respect to the community structure, the percentage values of the relative frequency, relative density and relative dominance are added together and this value out of 300 is called the importance value index or IVI of the species. The term Important Value Index (IVI) was introduced by Curtis and McIntosh (1951) as an index of the vegetational importance of a tree within a stand. The original importance value would 300 percent for all species of a stand; it is divided by 3, so that no species or combination of species can be more than 100 percent important (Holdridge *et al.*, 1971).

$$\text{Relative Frequency (RF) (\%)} = \frac{\text{Frequency of a species}}{\text{Sum of frequency of all species}} \times 100$$

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

$$\text{Relative Abundance (RA) (\%)} = \frac{\text{Abundance of a species}}{\text{Total abundance of all species}} \times 100$$

$$\text{Relative Basal Area (RBA) (\%)} = \frac{\text{BA of a species}}{\text{Total BA of all species}} \times 100$$

RBA = Rdom (where, Rdom = relative dominance)

$$IVI = \frac{(RF + RD + RBA)}{3} \text{ (Holdridge } et\ al.\text{, 1971)}$$

Index of Dominance (cd)

Those species which have strongest control over energy flow and the environment in given habitat are known as ecological dominants. Simpson (1949) has given the following formula to estimate the index of dominance.

$$c = \Sigma \left(\frac{ni}{N}\right)^2$$

Where, ni = importance value of the species

N = Total IVI of all species

Index of Diversity (H)

Species diversity index is the ratio between the number of species and importance value of individual (Odum, 1971). It is important to recognize that species diversity has a number of components, which may respond differently. Major components are species richness or variety component and species evenness or equability. Different kinds of indices for species diversity are given by a number of workers. Shannon index of diversity, also referred as Shannon,Weaver and Shannon-Wiener index given by Shannon and Weaver (1949), which is derived from information theory as:

$$\overline{H} = -\Sigma \left(\frac{ni}{N}\right) \log_2 \left(\frac{ni}{N}\right)$$

Where, $\overline{H}$ = Shannon's index

ni = total importance value for the species i

N = total importance value of all the species

The following formula derived by mathematical manipulation, is easier to use (Zobel *et al.*, 1987).

$$H = 3.3219 \left\{ \frac{N \log_{10} N - \sum_{i=1}^{k} n_i \log_{10} n_i}{N} \right\}$$

3.3129 is a factor converting $\log_{10}$ values to $\log_2$.

Species Richness and Evenness

Species richness is simply the number of species per unit area (Whittaker, 1960, Pielou, 1975). Evenness (j) stated by Magurran (1988) as another component of diversity was calculated using diversity index:

$J = \frac{H}{H_{max}}$, where H_{max} = lnS and ln is log base n.

4.4 Soil Analysis

Soil is a mixture of mineral matter, organic matter water and air. Of the six major factors affecting the growth of plants, only light is not supplied by soils. Soil supplies water, air, mechanical support and all the nutrients that are essential for plant growth.

Soil samples were collected from the four corners and centre of the 10m×10m quadrat by following the method given by Saxena (1989). The collected soil samples were mixed homogenously and packed in an airtight plastic bag.

Following physio-chemical characteristics of the soil were analysed.

4.4.1 Soil moisture

Soil moisture is defined as the amount of water content in unit weight of soil. Soil moisture was measured by the use of the instrument called soil pH and moisture tester (Model DM 15, Takemura Electric Works Ltd., Japan) at the field and further calibration was done at CDB laboratory, T.U. The instrument contains the grade from one to eight and above. To find out the percentage content of moisture, 10g soil samples of different moisture grade were taken in petridishes and these were kept in the oven at 80°C for 48 hours and weighed.

For the calculation, the formula proposed by Zobel *et al.* (1987) was followed.

$$\text{Moisture Content (\%)} = \frac{(b-a)-(c-a)}{(c-a)} \times 100$$

Where, a is the weight of petridish

b is the weight of petridish+moist soil

c is the weight of petridish+soil after heating

(b-a) is the weight of moist soil

(c-a) is the weight of soil after heating

4.4.2 Soil pH

The particular pH measured in a soil is caused by a particular set of chemical conditions. Therefore, a determination of soil pH is one of the most important tests that can be made to diagnose plant growth problems (Foth and Turk, 1972). Soil pH was measured by using the pH meter called soil pH and Moisture Tester (Model DM 15), Takamura Electric Works Ltd. Japan at the field.

4.4.3 Soil organic matter

Almost all of the life in the soil is dependent on organic matter for energy and nutrients. Furthermore, it supplies energy and body building constituents. Organic matter was determined by Walkey-Black method in the Laboratory of

Soil Analysis Section, Agricultural Division, Harihar Bhawan, HMG/N and Nepal Agricultural Research Coulcil (NARC), Khumaltar, Lalitpur.

$$\text{OM \%} = \frac{(B-S)N}{\text{Weight of dry soil}} \times 0.067 \times 100$$

Where,

B = Vol. of FAS used up for blank titration

S = Vol. of FAS used up for sample titration

N = Normality of FAS from blank titration

FAS = 0.5N Ferrous ammonium sulphate

4.4.4 Nitrogen (N)

Nitrogen is an integral component of many compounds essential for plant growth processes including chlorophyll and many enzymes. Total nitrogen content of the soil was determined by modified Kjeldahl method (PCARR, 1980).

$$\text{Nitrogen content (\%)} = \frac{(T-B)\times N \times 4}{S} \times 100$$

Where,

T = Sample titration (ml) of standard acid

B = Blank titration (ml) of standard acid

N = Normality of standard acid

S = Oven dry weight of sample

4.4.5 Phosphorous (P)

Phosphorous has been called "the key to life" because it is directly involved in most life processes. Phosphorous occurs in the soil in both organic and inorganic forms. Available phosphorous was determined by using Olsen's modified carbonate method (PCARR, 1980).

Phosphorous (kg/ha) = R×F

Where,

F = Coefficient factor, calculated form blank solution

R = Reading in spectrophotometer (co-efficient factor = 3615.15)

4.4.6 Potassium (K)

Potassium is the third most likely nutrient element to limit plant growth and is therefore a very common constituent of fertilizers. Plants absorb large amounts of potassium, all of it in the form of the K^+ ion.

It was measured by flame photometer method.

Potassium kg/ha = $\frac{R20}{7} \times 1.2 \times 2$ where, R = Reading in photometer

Statistical Analysis

All the statistical analysis was done from the Computer Program SPSS (Statistical Package for the Social Science).

5. RESULT

5.1 Composition of the Forest

Forest is the natural vegetation of that area. In that area there is no care about conservation of forest. Forest is destroyed and destructed through timber extraction, firewood collection, forest fire and grazing, etc. Mainly *Pinus* and *Abies* are used as timber, where as *Betula* and *Juniperus* are used for firewood. Cattle are left freely in the forest for grazing.

Vegetation composition of the two sites was very contrasting. Lower belt was dominated by *Pinus- Juniperus* forest on both sites. The middle altitude forest constitute the mixed forest of *Pinus wallichiana, Betula utilis, Abies spectabilis* and *Juniperus indica* in site I, whereas in site II it was *Juniperus* forest. In high altitude the forest was *Betula* forest in site I and *Juniperus* forest in site II. Interesting thing was that there were no *Abies spectabilis* and *Betula utilis* at site II. Similarly composition of the shrub species also differed along the altitudinal gradient as well as on north and south aspects.

In the forest, plant community consists of trees, shrubs, herbs, mosses, lichens, etc. They form different layers on the forest called strata on vertical as well as in horizontal plane. The top canopy layer consists of tall trees like *Pinus wallichiana* and *Abies spectabilis,* which receive the light directly from the sun. The sub canopy is occupied by *Betula utilis*, *Juniperus indica* and *Salix* spp. The third layer is made up of shrub species like *Berberis,Lonicera, Rosa, Caragana* etc.and fourth and last layer is ground layer made mainly by herbaceous species like *Androsace, Artimisia Polygonatum, Anemone, Stellera* etc.

5.2 Density and Basal Area

Density is the total number of individuals of species per unit area. The tree density in both sites decreased from low to high altitude. The density of trees in site I ranged from 575 pl/ha at altitude 3800m-4000m to 2625 pl/ha at altitude 3300m-3500m (Annex 5). In site I, maximum density of *Pinus wallichiana* (2225 pl/ha) was found at altitude 3300m-3500m (Annex 1a). On the other hand, there was no regular decrease or increase in density of shrub and sapling layers. It ranged from 5486.6 pl/ha at 3500m-3800m to 10890pl/ha at 3800-4000m (Annex 5). It decreased from 3300m-3800m but after that it was maximum. The highest density of *Rhododendron lepidotum* 2690 Pl/ha followed by 2425 Pl/ha was found at 3800m-4000m (Annex 1c).

Similarly, the basal area of tree gradually decreased with the increase in the elevation. In site I, the total basal area of tree ranged from 5.38 m^2/ha at 3800m-4000m to 19.04 m^2/ha at 3300m-3500m (Annex 5). In site I the highest basal area (18.6m^2/ha) of *Pinus wallichiana* was found at 3300-3500m (Annex 1a).

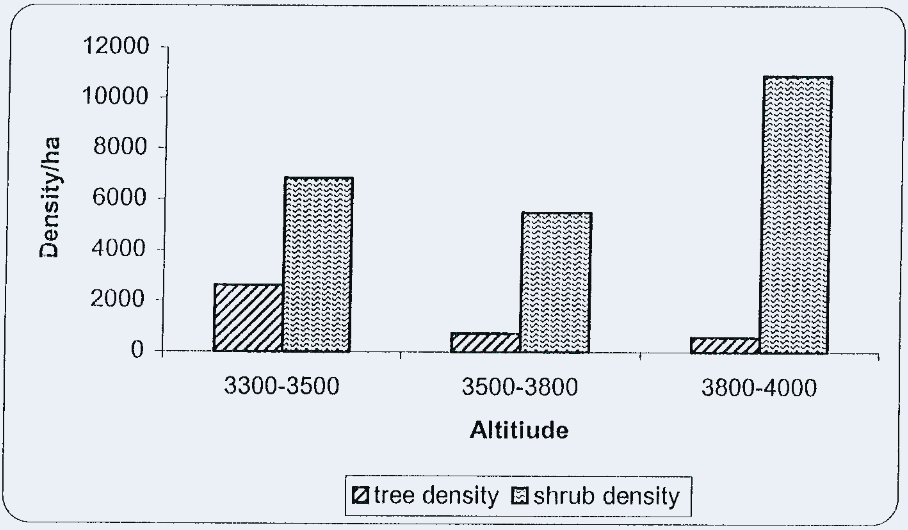


Figure 5.1. Total tree and shrub/sapling density in different altitudinal range of site I

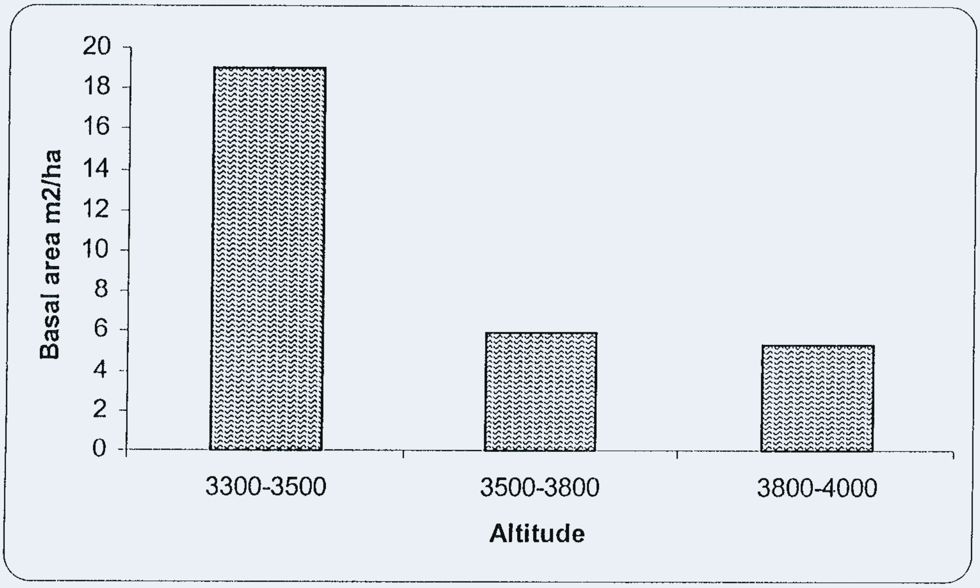


Figure 5.2. Total basal area of tree in different altitudinal range in site I

Similar trends were observed in site II. The total tree density ranged from 375 pl/ha at altitude 3800m-4000m to 845 pl/ha at altitude 3300m-3500m (Annex 5). The highest tree density (525pl/ha) of *Pinus wallichiana* was found at 3300m-3500m (Annex 2a). The total shrub density ranged from 5169.95 pl/ha at 3500-3800m to 10705 pl/ha at 3800m-4000m (Annex 5). The highest shrub density (2700 pl/ha) was obtained for *Berberis aristata* at 3300m-3500m (Annex 2a).

In case of basal area, the total tree basal area ranged from 0.674 m^2/ha at 3500m-3800m to 16.815 m^2/ha at 3300m-3500m (Annex 5). The highest basal area (11.8 m^2/ha) of *Pinus wallichiana* was found at 3300m-3500m (Annex 2a). Above 3700m the *Juniperus indica* was found as bushy or scrubby nature, therefore they did not form basal area.

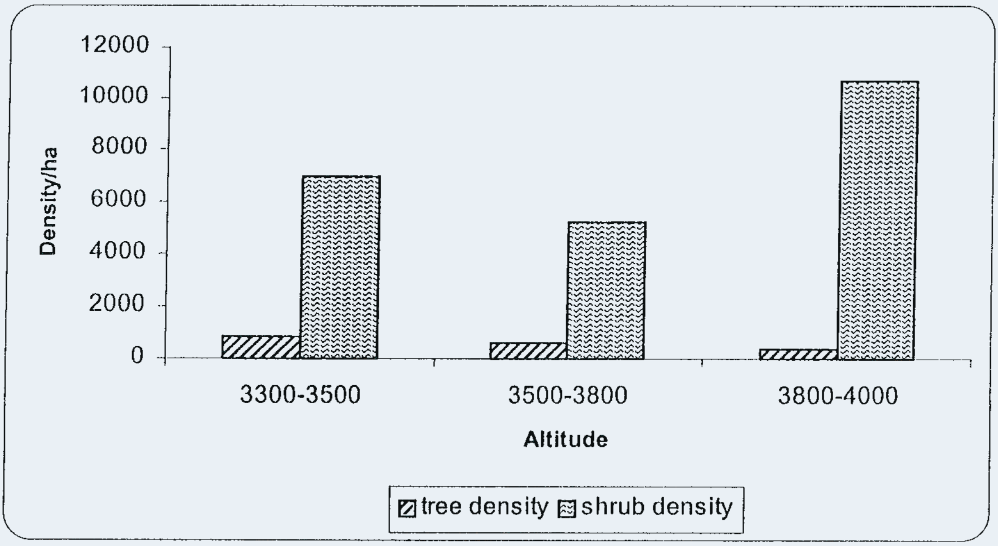


Figure 5.3. Total tree and shrub/sapling density in different altitudinal range of site II

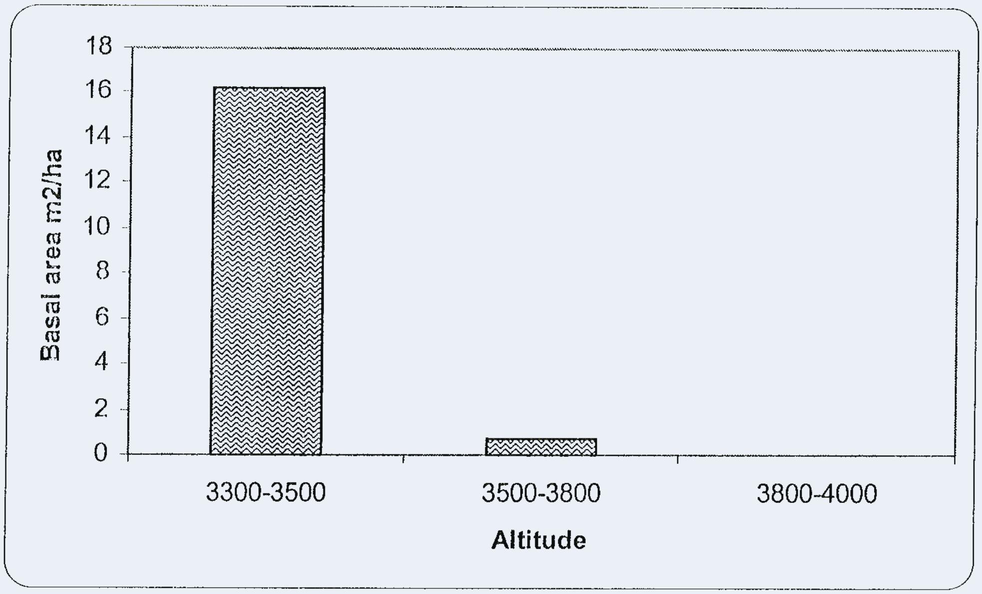


Figure 5.4. Total basal area of tree in different altitudinal range in site II

5.3 Importance Value Index (IVI)

5.3.1 Tree layer

The importance value index of the tree species showed that mainly, *Pinus wallichiana, Juniperus indica* and *Betula utilis* were dominant in different habitat. On the basis of IVI, *Pinus wallichiana* had highest IVI (75.63) and most important species on site I at 3300-3500 m followed by *Juniperus indica* (11.86) and lowest IVI (3) was obtained for *Betula utilis* (Annex 3a). In altitude 3500-3800m at site I *Betula utilis* had highest IVI (38.9) followed by *Pinus wallichiana* (28.09) and *Salix* sp. had lowest IVI (3.98) (Annex 3b). Similarly, in highest altitudinal zone 3800-4000m *Pinus wallichiana* had highest IVI (41.82) followed by *Betula utilis* (39.16) and *Abies spectabilis* (19.00). There was no *Juniperus indica* (Annex 3c).

In case of Site II, there were only three tree species present in the sampling plots. Out of them *Salix* sp. was not frequent in all altitude and also it was not a large tree. In 3300-3500m, the highest IVI was found for *Pinus wallichiana* (61.64) followed by *Juniperus indica* (38.35) (Annex 4a). In 3500-3800m, *Juniperus indica* showed highest IVI (60.95), followed by *Pinus wallichiana* (33.01) and *Salix* sp. (5.18) (Annex 4b). In 3800-4000m only *Juniperus indica* was found in bushy form.

5.3.2 Shrub and sapling layer

In case of shrub and sapling layer, mostly saplings of *Pinus* dominated the forest at lower belt forest. In altitudinal gradient 3300-3500m of site I sapling of *Pinus wallichiana* had highest IVI (26.57) (Annex 3a). In case of shrub *Berberis aristata* had highest IVI (14.12) followed by *Lonicera webbiana* (12.63), *Juniperus communis* (9.27), *Hippophae tibetana* (7.4) and *Cotoneaster microphyllus* had lowest IVI (1.35) (Annex 3a). At 3500-3800m sapling of *Pinus wallichiana* had highest IVI (36.64), followed by *Abies spectabilis* (22.44), whereas, in case of shrub, *Lonicera webbiana* (11.63) had highest IVI, followed by *Berberis aristata* (8.9), and *Cotoneaster microphyllus* had lowest IVI (0.88) (Annex 3b). In altitude 3800-4000m, *Rhododendron lepidotum* had highest IVI (18.4), followed by *Spirea canescence* (16.23), *Berberis angulosa* (11.36), *Berberis aristata* (9.6), whereas, *Rhododendron anthopogon* had loweast IVI (1.74) (Annex 3c).

Berberis aristata had highest IVI (26.85) at altitude 3300-3500m of site II followed by sapling of *Pinus wallichiana* (14.88) and *Juniperus indica* (10.56). *Myricaria rosea* (1.45), *Viburnum cotnifolium* (1.47) and *Caragana sukiensis* (2.33) had lowest IVI (Annex 4a). In altitude 3500-3800m, *Berberis aristata* (15.02) was followed by sapling of *Juniperus indica* (14.62), *Lonicera webbiana* (14.33), *Cotoneaster microphyllus* (9.8) and lowest IVI had (1.31) for *Caragana sukiensis* and *Spirea canescence* (Annex 4b). Similarly, at altitude 3800-4000m, *Berberis aristata* had highest IVI (17.6), followed by *Lonicera webbiana* (16.5), *Berberis angulosa* (14.93), *Ephedra gerardiana* (10.62) and *Juniperus squamata* (10.51). *Spirea canescence* had lowest IVI (1.59) followed by *Cotoneaster affinis* (1.75) (Annex 4c).

5.4 Species Richness and Species Diversity

Species richness, evenness, plant species diversity and index of dominance for tree and shrub/sapling of different forest sites are shown in Table 5.3 and 5.4. The maximum tree species richness was found at 3300-3500m and 3500-3800 of site I and minimum was found at 3800-4000m of site II. In case of shrub/sapling it was maximum at 3300-3500m of site I and 3500-3800m of site II and minimum at 3500-3800m of site I. However, the maximum evenness for tree was found at 3800-4000m of site I and zero evenness was found at 3800-4000m of site II where only *J. indica* was found. The evenness of shrub/sapling was found maximum at 3500-3800m of site II and minimum at same altitude of site I. The maximum tree species diversity was recorded at 3500-3800m of site I and minimum at 3800-4000m of site II. Similarly maximum shrub/sapling diversity was found at 3300-3800m of site II and minimum was found at same altitude of site I. Index of dominance was maximum at 3800-4000m of site II and minimum at 3500-3800m of site I for tree, whereas, for shrub/sapling it was maximum at 3500-3800m of site I and was minimum at same altitude of site II.

Table 5.1. Species richness (S), Evenness (J), Diversity (H) and index of dominance (cd) in different altitude of site I.

Altitude	S		H		J		cd	
	Tree	Shrub/ sapling	Tree	Shrub/ sapling	Tree	Shrub/ sapling	Tree	Shrub/ sapling
3300-3500m	5	14	0.88	3.2	0.37	0.84	0.58	0.13
3500-3800m	5	11	2.10	2.55	0.9	0.73	0.28	0.20
3800-4000m	4	13	1.57	3.12	0.99	0.84	0.36	0.10

Table 5.2. Species richness(S), Evenness (J), Diversity (H) and index of dominance (cd) in different altitude of site II

Altitude	S		H		J		cd	
	Tree	Shrub/ sapling	Tree	Shrub/ sapling	Tree	Shrub/ sapling	Tree	Shrub/ sapling
3300-3500m	2	12	0.96	2.71	0.95	0.75	0.52	0.15
3500-3800m	3	14	0.70	3.89	0.44	0.99	0.51	0.10
3800-4000m	1	12	0.00	2.89	0.00	0.80	1.00	0.12

5.5 Soil Analysis

Soil characters (pH, moisture, organic matter, nitrogen, phosphorus and potassium) of every 100 m altitudinal interval were analyzed for both sites. Regarding the soil moisture, site I was highly moist than that of site II. Soil moisture content increased with increase of elevation in site I, but there was no significant relation of moisture and altitude in site II. The highest moisture in site I was 55% at highest altitude and lowest moisture was 18.25% at lowest altitude (Table 5.3). In case of site II it was 36.75% and 15%, respectively (Table 5.4).

pH of soil indicated that it was slightly acidic in nature. In comparison of two sites, pH of site I was slightly less than that of site II. pH of site I ranged from 6.25 to 6.65 (Table 5.3), where as in site II it ranged from 6.25 to 6.7 (Table 5.4).

Organic matter of site I was slightly higher than the site II. There was no significant relation of organic matter with altitude on both sites. The Organic matter in site I ranged from 3.37% to 4.77% (Table 5.3). On the other hand it ranged from 2.422% to 3.76% in site II (Table 5.4).

The total nitrogen in soil ranged from 0.17% to 0.24% in site I (Table 5.3) where as it ranged from 0.12% to 0.19% in site II (Table 5.4). There was no significant relation of soil nitrogen with altitude, however soil nitrogen in site I was slightly higher than that of site II.

The total available phosphorus in site I was less than that of site II. In site I it ranged from 6.12kg/ha to 24.46 kg /ha (Table 5.3). Similarly the available phosphorus of site II ranged from 6.12 kg/ha to 36.69kg/ha (Table 5.4).

The total potassium content in soil ranged from 57.93 kg/ha to 263.91 kg/ha in site I (Table 5.3) and from 167.36kg/ha to 379.77 kg/ha in site II (table 5.4). The highest potassium content was 379.77 kg/ha in site II and lowest was 57.93 kg/ha in site I (Table 5.3 & 5.4).

Table 5.3. Average value of different soil parameters in site I.

Altitude	Moisture %	pH	OM %	Nitrogen %	Potassium Kg/ha	Phosphorus Kg/ha
3300-3400	18.25	6.65	4.25	0.21	180.23	6.12
3400-3500	20.8	6.5	4.58	0.23	141.61	3.06
3500-3600	18.25	6.55	3.69	0.18	212.41	6.12
3600-3700	26.12	6.35	4.35	0.22	263.91	18.35
3700-3800	47	6.25	3.55	0.18	205.98	24.46
3800-3900	39.37	6.3	3.37	0.17	205.98	9.17
3900-4000	55	6.25	4.77	0.24	57.93	6.12
Mean	32.11	6.41	4.08	0.20	181.15	10.49

Table 5.4. Average value of different soil parameters in site II.

Altitude	Moisture (%)	pH	OM (%)	Nitrogen (%)	Potassium (Kg/ha)	Phosphorus (Kg/ha)
3300-3400	15.5	6.55	3.76	0.19	167.36	12.23
3400-3500	15.5	6.6	3.76	0.19	173.79	6.12
3500-3600	15.5	6.7	2.84	0.14	379.77	36.69
3600-3700	36.75	6.25	2.71	0.14	141.61	6.12
3700-3800	26.5	6.7	3.69	0.18	225.29	12.23
3800-3900	15.5	6.7	2.47	0.12	244.6	36.69
3900-4000	15.5	6.8	2.42	0.12	167.36	12.23
Mean	20.11	6.61	3.09	0.15	214.25	17.47

5.6 Regeneration of *Pinus wallichiana* A.B. Jackson

5.6.1 Size class distribution

All the trees were divided into different size classes based on DBH of 10 cm intervals. Altogether nine size classes in site I and eight size classes in site II were recognized at different altitudinal zones (Table 5.5). The DBH class distribution of *Pinus wallichiana* showed more or less reverse J-shaped structures in both sites and in all altitudinal zones. However, the regeneration of *Pinus wallichiana* was better in site I than that of site II. In site II above 3700m there were no *Pinus* trees.

Table 5.5. DBH Classes of Tree Species

DBH class	DBH in cm
1	10-20
2	20-30
3	30-40
4	40-50
5	50-60
6	60-70
7	70-80
8	80-90
9	90-100

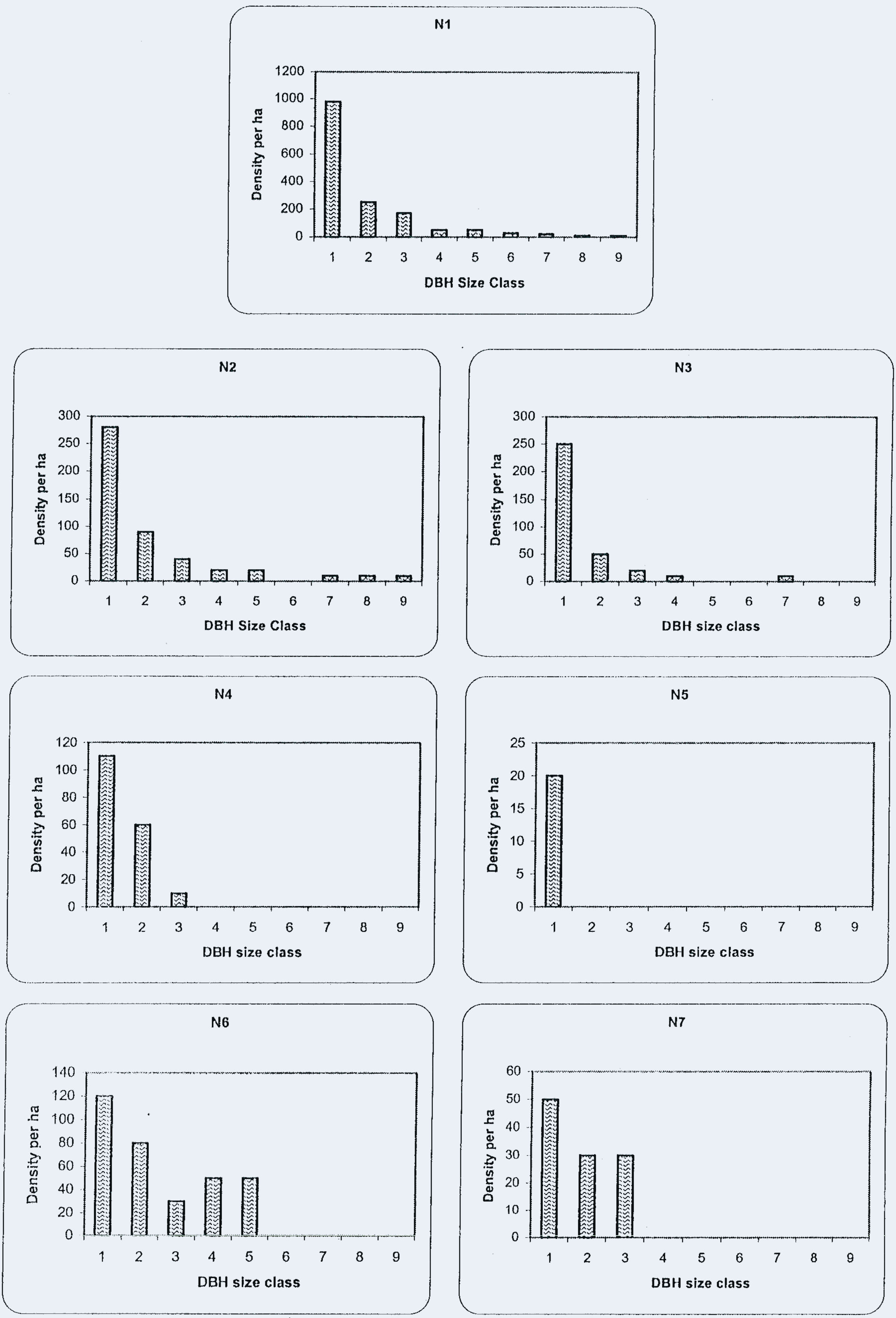


Figure 5.5. DBH size class distribution of *Pinus wallichianana* in different altitudes of site I.

N1=3300m-3400m, N2=3400m-3500m, N3=3500m-3600m, N4=3600m-3700m, N5=3700m-3800m, N6=3800m-3900m and N7=3900m-4000m.

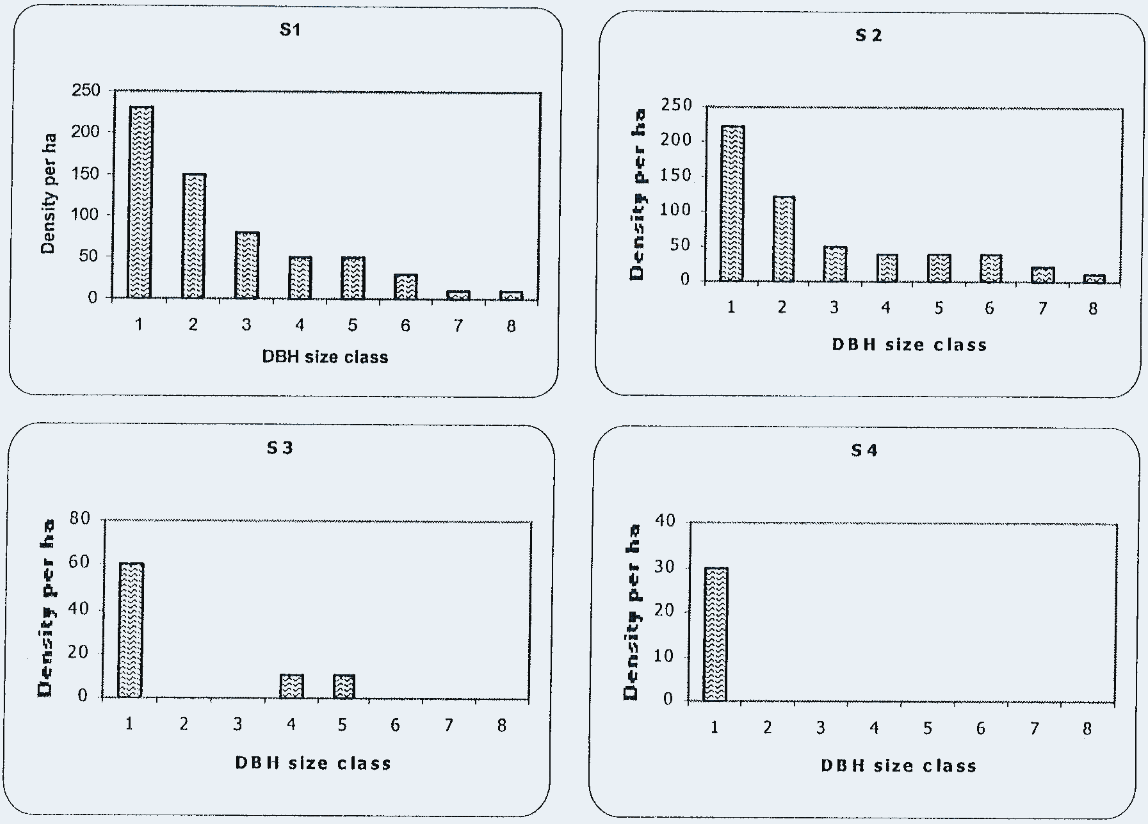


Figure 5.6. DBH size class distribution in different altitudes of site II.
S1=3300m-3400m, S2=3400m-3500m, S3=3500m-3600m, S4=3600m-3700m, S5=3700m-3800m, S6=3800m-3900m and S7=3900m-4000m

5.6.2 Seedling and sapling density

The density of seedling and sapling showed good regeneration of *Pinus wallichiana*. The average seedling density of *Pinus wallichiana* in site I ranged from 180/ha in altitude N7 to 3500/ha in N3, where as the average density of sapling ranged from 260/ha in N7 to 6060/ha in N3 of site I (Annex 9).

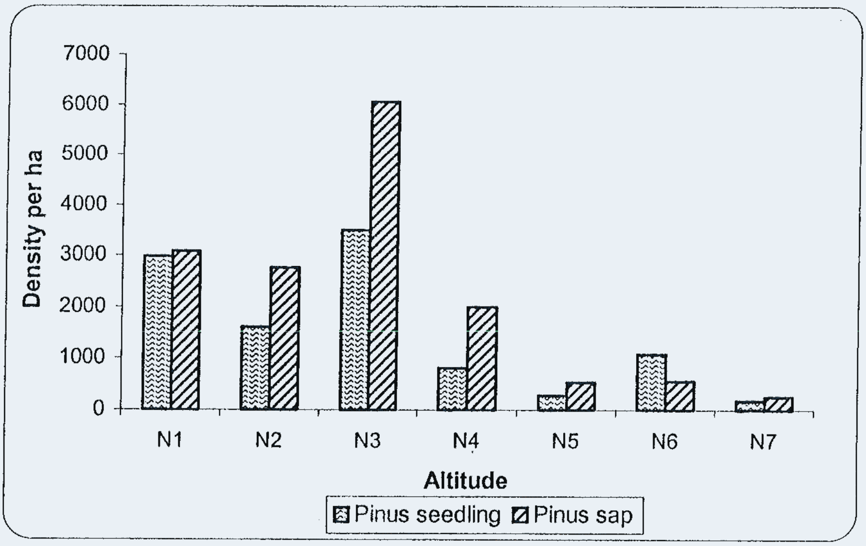


Figure 5.7. Seedling and Sapling density of *P.wallichiana* in different altitudes of site I

In case of site II the average seedling density of *P. wallichiana* ranged from 60 pl/ha in altitude S3 to 1200 pl/ha in altitude S2 and the average density of sapling ranged from 80 pl/ha in S4 to 840 pl/ha in S1 (Annex 9).

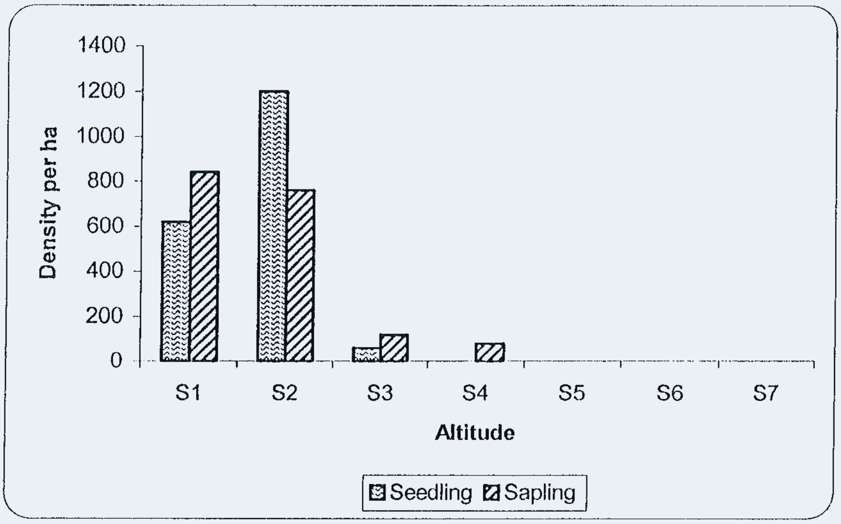


Figure 5.8. Seedling and Sapling density of *P. wallichiana* in different altitudes of site II

In site I the highest seedling density, of *P. wallichiana* was found 6200 pl/ha and the lowest was found 200 pl/ha of which 4 quadrats were without seedlings. (Annex 6). Similarly the highest sapling density was found 10200 pl/ha and the lowest was found 100 pl/ha and no sapling was found in one quadrat (Annex 6).

In site II the highest seedling density of *P. wallichiana* was found 3000 pl/ha and the lowest density was found 300 pl/ha. Similarly the highest sapling density was found 3650 pl/ha and the lowest was found 100 pl/ha. (Annex 6). In site II 24 quadrats were without seedling and 15 quadrats were without saplings.

5.7 Statistical Analysis

5.7.1 Correlation (Pearsons correlation)

Seedling and sapling density of *P. wallichiana* was negatively correlated with altitude (p=0.01), soil moisture (p=0.05) and soil phosphorus (p=0.01,p=0.05 respectively) (Table 5.6). Some soil properties also changed significantly along the elevation gradient, soil pH decreased (p=0.01) and moisture increased (p=0.01) with rising elevation (Table 5.6).

Table 5.6. Correlation coefficient between different variables with *Pinus* seedlings and saplings in site I

	PSEED	PSAP	ALT	COV	SLOPE	PH	MOIST	OM	N	P	K
PSEED	1										
PSAP	0.732**	1									
ALT	-0.647**	-0.580**	1								
COV	-0.108	0.013	-0.054	1							
SLOP	-0.115	0.020	0.288	0.128	1						
PH	0.432**	0.244	-0.500**	0.194	-0.231	1					
MOIST	-0.356*	-0.421*	0.617**	-0.170	-0.104	-0.437**	1				
OM	-0.124	-0.053	-0.152	0.323	-0.155	-0.032	-0.171	1			
N	-0.199	-0.124	-0.094	0.331	-0.135	-0.081	-0.137	0.995**	1		
P	-0.434**	-0.337*	0.294	-0.156	-0.093	-0.531**	0.276	-0.395*	-0.335*	1	
K	0.200	0.247	-0.278	-0.279	0.103	-0.130	-0.172	-0.588**	-0.583**	0.538**	1

** Correlation is significant at the 0.01 level (2-tailed).
Correlation is significant at the 0.05 level (2-tailed)
* Pseed=Pinus seedling, Psap=Pinus sapling, Alt=Altitude, Cov=Coverage

Correlation analysis of the vegetation and environmental parameters in site II (Table 5.7) showed there was significantly positive correlation of *P. wallichiana* seedling density with sapling density (p=0.01), coverage (p=0.01), organic matter (p=0.01), nitrogen (p=0.01) and negatively correlated with slope (p=0.05). Similarly, sapling density was positively correlated with coverage (p=0.01), organic matter (p=0.01), nitrogen (p=0.01), and negatively correlated with altitude (p=0.01) and phosphorus (p=0.05). Canopy coverage, soil organic matter and soil nitrogen declined (p=0.01) with increasing altitude. Soil properties were also closely linked with coverage; soil organic matter and nitrogen increased (p=0.01) and phosphorous decreased with increasing coverage (p=0.01) (Table 5.7).

Table 5.7. Correlation coefficient between different variables with *Pinus* seedlings and saplings in site II

	PSEED	PSAP	ALTI	COV	SLOPE	PH	MOIST	OM	N	P	K
PSEED	1										
PSAP	0.529**	1									
ALTI	-0.550**	-0.730**	1								
COV	0.587**	0.757**	-0.855**	1							
SLOP	-0.349*	-0.322	0.204	-0.165	1						
PH	-0.226	-0.183	0.272	-0.226	0.053	1					
MOIST	0.053	0.004	-0.163	0.030	0.024	-0.726**	1				
OM	0.528**	0.628**	-0.711**	0.593**	-0.338*	0.003	-0.037	1			
N	0.554**	0.665**	-0.752**	0.648**	-0.335*	-0.059	-0.007	0.995**	1		
P	-0.319	-0.335*	0.217	-0.387**	0.184	0.285	-0.075	-0.465**	-0.520**	1	
K	-0.227	-0.266	-0.011	-0.168	0.139	0.308	-0.072	-0.176	-0.233	0.837**	1

** Correlation is significant at the 0.01 level (2-tailed).

Correlation is significant at the 0.05 level (2-tailed).

* Pseed=Pinus seedling, Psap=Pinus sapling, Alt=Altitude, Cov=Coverage

5.7.2 Regression analysis

Regression analysis is the mathematical measure of the average relationship between two or more variables in terms of the original units of the data. Regression analysis shows that there was significant relationship of *P. wallichiana* seedling and sapling with altitude, canopy, slope, moisture and soil pH.

Table 5.8. Multiple Regression of *Pinus* seedlings and saplings with different environmental factors in site I (ANOVA Table).

Model	Df	F	Sig.	
Regression Residual Total	2 32 34	25.033	.000 p<0.001	Predictor (constant): Alti, Psap. Dependent: seed
Regression Residual Total	2 32 34	.362	.699 ns.	Predictor (constant): Slope, Cover. Dependent: seed
Regression Residual Total	2 32 34	4.537	.018 p<0.05	Predictor (constant): Moist, pH. Dependent: seed
Regression Residual Total	2 32 34	8.120	.001 p<0.01	Predictor (constant): Alti, Cover. Dependent: sap
Regression Residual Total	2 32 34	3.553	.040 p<0.05	Predictor (constant): Moist, pH. Dependent: sap
Regression Residual Total	1 33 34	.013	.910 ns.	Predictor (constant): Slope. Dependent: sap

ns=non significant

Table 5.9. Multiple Regression of *Pinus* seedlings and saplings with different environmental factors in site II (ANOVA Table).

Model	Df	F	Sig.	
Regression Residual Total	2 32 34	8.139	.001 p<0.01	Predictor (constant): Alti, Psap. Dependent: seed
Regression Residual Total	2 32 34	11.124	.000 p<0.001	Predictor (constant): Slope, Cover. Dependent: seed
Regression Residual Total	2 32 34	1.333	.278 ns.	Predictor (constant): Moist, pH. Dependent: seed
Regression Residual Total	2 32 34	23.906	.000 p<0.001	Predictor (constant): Alti, Cover. Dependent: sap
Regression Residual Total	2 32 34	1.176	.322 ns.	Predictor (constant): Moist, pH. Dependent: sap
Regression Residual Total	1 33 34	3.830	.059 ns.	Predictor (constant): Slope. Dependent: sap

ns=non significant

Table 5.10. Multiple Regression of *Pinus* seedlings and saplings with different environmental factors in site I & II (ANOVA Table).

Model	Df	F	Sig.	
Regression Residual Total	2 32 34	.443	.646 ns.	Predictor (constant): Alti, Psap. Dependent: seed
Regression Residual Total	2 32 34	20.962	.000 p<0.001	Predictor (constant): Slope, Cover. Dependent: seed
Regression Residual Total	2 32 34	.575	.568 ns.	Predictor (constant): Moist, pH. Dependent: seed
Regression Residual Total	2 32 34	10.510	.000 p<0.001	Predictor (constant): Alti, Cover. Dependent: sap
Regression Residual Total	2 32 34	49.872	.000 p<0.001	Predictor (constant): Moist, pH. Dependent: sap
Regression Residual Total	1 33 34	.450	.507 ns	Predictor (constant): Slope. Dependent: sap

ns=non significant

6. DISCUSSION

6.1 Community Composition

Structural and functional analysis of natural plant communities provide a valuable source of information for understanding relationships between plant form, vegetation structures and environment. The different landforms with varied climate and soils support array of vegetation types characterized by sub- tropical to temperate and alpine conditions. Furthermore, vegetation within a forest type is greatly affected by differences in the microclimate, aspect and altitude (Pande *et al.* 1996). The varied vegetation in Himalayas provide scope for quantification of vegetation, status and other ecological studies (Pande, 2001) and a detailed vegetation analysis provide information about species diversity, community organization, niche resource apportionment and turn over rate of species in a forest ecosystem.

Present research has been carried out to point out the effect of environmental factors on distribution and regeneration of plant species in trans- Himalayan zone. In the study area the number of plant species were more or less equal on both sites, i.e. 21 (5 tree, 16 shrub) in site I (north aspect) and 19(3 tree, 16 shrub) in site II (south aspect), however composition of plant species were different. Altogether 24 plant species (tree and shrub) were found in the study area (5 tree and 19 shrub).

The total tree density ranged from 575 pl/ha to 2625 pl/ha in site I, where as it ranged from 375 pl/ ha to 845 pl/ha in site II (Annex 5). This range was more or less same as reported by Khadka (2004) in Pisang forest. However, the value was less than that of value reported by Nepal (2001) in north -east slope of Ghandruk forest (1700m-2700m). These variations may be due to variation in environmental condition in different areas. Manandhar (1996) found 672 pl/ha to 1030 pl/ha in Kaski (2900m-3500m), which was similar to that of site II, but was less than that of site I. Result of site II was similar to that of values reported by Pande *et al.* (2002) in western Himalayan forest in Uttranchal, which was less than site I. Duwadee (2000) found 1124.92 pl/ha to 2189.28 pl/ha trees in Arun river basin, which was similar to that of site I but more than that of site II. It was found that total tree density decreased along the altitude on both sites. Similar results were obtained by Nepal (2001) in Ghandruk and Raya-Chhetri (1981) in Chandragiri Hill. Khatri *et al.* (2004) in Satpura National Park (Madhya Pradesh) also found that density of tree decreased with increase in elevation. The decreasing tree density along altitude may be due to cold climate and associated harse environmental condition for the development of tree in higher altitude. However, Yadav and Sah (1998) in Nagarjun Hill found that there was increase in total tree density along with altitude.

Regarding shrub/sapling density, there was no clear cut relation with altitude, however, maximum shrub density was found at highest altitude on both sites. The total shrub/sapling density ranged from 5486.66 pl/ha to 10890 pl/ha in site I and 5169.95 pl/ha to 10705pl/ha in site II (Annex 5). It was found that shrub density showed same trend on both sites. It was slightly higher than the value in Pisang as reported by Khadka (2004) and less than in Shivapuri Hill (Sigdel, 2004). The result was in the range as reported by Shrestha (1996) in Reyale, and by Khatri *et al.* (2004) in Satpura National Park, India. The total shrub density at first decreased along with altitude up to 3800m, however above that it increased. It may be due to high soil moisture, less tree density and open canopy at higher altitude. Within the given forest type, the dominant shrub species varied with change in aspect and at a single site with differences in altitude.

The total basal area of tree was decreasing along with elevation in both sites. Total basal area ranged from 5.38m^2/ha to 19.04 m^2/ha in site I and 0.674m^2/ha to 16.18m^2/ha in site II (Annex 5). In site II it was observed that there was no measurable basal area of *Juniperus indica* at highest altitude

(3800m-4000m) due to their scrubby nature. This value for basal area was more or less close to the value as reported by Khadka (2004) in Pisang forest, and Yadav and Sah (1998) in Nagarjun Hill. In contrast, basal area was higher than the value reported by Shrestha (1996) in Reyale forest, Manandhar (1996) in Kaski and Khatri *et al.* (2004) in Satpura National Park. However, it was less than that of the value reported by Shrestha (2001) in Landruk, and Sigdel (2004) in Shivapuri Hill. Also these values were less than that obtained by Adhikari *et al* (1991) in Kumaun Himalaya, Pande (2001) in Garhwal Himalayas forest and Pande *et al.* (2002) in western Himalaya (Uttranchal). These variations in the basal area of different places may be due to composition, density and size of tree species which further may be due to various environmental and edaphic factors that directly or indirectly affect the vegetation of any area. The value for density and basal area are well within the reported range in sub-alpine forest, however, higher density and basal area values for site I, between two sites are reflection of variation in moisture and prevailing microclimatic conditions.

The basal area showed reverse relation with altitude. Similar result was found by Nepal (2001) in north east slope of Ghandruk forest and Khatri *et al* (2004) in Satpura National Park in India. It may be due to the highest tree density and large tree size in the lower altitude.

Among individual species *Pinus wallichiana* attain highest basal area in both sites, 18.6m^2/ha in site I (Annex 1a) and 11.8m^2/ha in site II (Annex 2a), which was higher than that of values reported by Khadka (2004) in Pisang forest. The highest basal area may be due to high density of *Pinus wallichiana* and also due to large trunk size.

In case of shrub and sapling, *Berberis aristata, Lonicera webbiana* and sapling of *Pinus wallichiana* were frequently abundant on both sites; it may be due to suitable environmental condition for them. Frequency of shrub and sapling was more or less similar in both sites however, frequency of tree was higher in site I than that of site II. The most frequent species are more important than less frequent species, therefore, the common species have greater role on similarity and dissimilarity between two stands (Podani, 1978).

On the basis of IVI, *Pinus wallichiana* was most prominent species in lower belt of both sites. Khadka (2004) also found highest IVI of *P. wallichiana* in Pisang forest however, in high altitude it was found mixed with other species. In case of site I, it was mixed with *Abies spectabilis* and *Betula utilis*. High altitude of Site I was mostly preferred by *Betula utilis,* which may be due to high moisture content. In case of site II, *P. wallichiana* was mixed with *Juniperus indica* up to certain elevation (3700m a.s.l.) after that only *J. indica* was found. The highest altitude (3800m-4000m) of site II was totally dominated by *J. indica* and it was found in scrubby nature. It may be due to low soil moisture, high solar radiation and adverse condition for the development of tree in south aspect. It may also be due to high wind velocity in south aspect.

A comparison of vegetation of two sites revealed that the north aspect was more important than south aspect. Slope angle, aspect and microclimate considerably affect the heat regime at that site, in turn influencing the soil water regime, which plays important role in determining the gradient of vegetation (Waring and Major, 1964; Wali and Krajina, 1973). Wikum and Wali (1974) have stated that the solar radiation received at a site largely determines the composition of vegetation of that site. In the study area, composition of tree as well as shrubs along an altitude is different. It may be due to variation in different environmental factors like soil moisture, solar radiation along with altitude. The variation in species composition that occurs with change in elevation leads to the change in physiognomy of communities (Singh and Singh, 1992).

6.2 Species Richness and Species Diversity

Species richness is the total number of species within the geographical area and it is usually expressed as an enumeration of the species occurring within a particular area (Chaudhary, 1998). Moisture and vegetation cover are the best explanatory variables for species richness. Regarding the species richness, tree species richness was less than that of shrub species richness (Table 5.3&5.4). Same result was found by Khadka (2004) in Pisang forest. However, Manandhar (1996) found higher richness of tree species than shrub in Kaski. These variations in different places may be due to high altitude and associated environmental factors. In the present study the species richness decreased along with elevation. Same result was found by Nepal (2001) in Ghandruk, Yadav and Sah (1998) in Chandragiri and Pandit (1999) in Chhimkeswori. In alpine and sub alpine region cold temperature determine the pool of the potential species. In addition the effect of vegetation itself on habitat heterogeneity is lower at higher elevations (Theurillat *et al.* 2003).

In humid climates the number of species declines with altitude, but this decline is often not linear and diversity peaks have been reported for some taxonomic groups at medium altitudes, a phenomenon which becomes enhanced when the low lands are dry (Korner, 2004)

Evenness of species is expressed as relationship of species to each other. In the present study, species evenness was found highest at higher altitude (Table 5.3 and 5.4). The higher altitude had more even distribution of tree and shrub/sapling than that of lower altitude. It may be due to less human interference in high altitude. Manandhar (1996) reported less evenness of tree in disturbed forest of Kaski.

Species diversity is a function of the number of species in a particular area (Sai and Mishra, 1986). There was no particular relationship between diversity index (H) of tree and shrub/sapling with altitude in the present study. The value of diversity index (H) was in the range of value reported by Manandhar (1996) in Kaski and Khatri *et al.* (2004) in Satpura National Park India. But the value was less than the value reported by Nepal (2001) in Ghandruk and higher than that as reported by Khadka (2004) in Pisang. The diversity index of shrub is slightly higher than that of tree (Table 5.3 and 5.4); it may be due to high species richness of shrub than tree. Higher species diversity is an indication of maturity in the ecosystem (Marglef, 1963; Odum, 1969) and low species diversity is a result of incorporation of some species through competition.

The value of index of dominance (cd) in respect of tree species varies from 0.28-0.58 in site I and 0.512-1.0 in site II. The maximum index of dominance was obtained at 3300-3500m in site I, where the forest was dominated by *Pinus wallichiana,* and minimum was obtained at 3500-3800m, where the *P. wallichiana* was mixed with *Betula utilis* and *Abies spectabilis.* In case of site II, it showed higher value than that of site I, because the lower belt of forest was dominated by *P. wallichiana* and upper belt from 3500-4000m was dominated by *Juniperus indica.* In case of shrub/sapling it raged from 0.10-0.20 in site I and 0.10-0.15 in site II. The index of dominance in case of shrub/sapling was less than that of tree; it may be due to equal distribution of shrub/sapling indicating that there was no single species that dominated the shrub/sapling strata. The index of dominance lies within the range of value as reported by Pande *et al.* (2002) in Uttranchal and it was higher than that reported by Khatri *et al.* (2004) in Satpura National Park, India.

The value of index of dominance is inversely related to diversity. Same result was obtained by Pande *et al.* (2000) in forest of Kumaun Himalayas and Pande *et al.* (2002) in forest of Uttranchal. In communities where one or two species contribute very highly the dominance is quite high indicating the value more than 0.5. It is found that with increase in dominance the diversity decreases (Ambasht and Ambasht, 1996).

6.3 Soil Analysis

Soil moisture in site I (north facing slope) was higher than that of site II (south facing slope) (Annex 7). Similar result was obtained by Khadka (2004) in Pisang forest. It may be due to dense forest in site I, which blocks the solar radiation; also it is fact that solar radiation falls for longer time in south aspect than in north aspect. Soil moisture showed positive correlation with altitude in site I (p=0.01). Similar result was found by Sigdel (2004) in Shivapuri Hill. It may be due to high altitude or it may also due to the melting of snow in the mountain.

The forest soil was slightly acidic in nature. The value was in the range of 6-7, which is in the same range as found by Khadka (2004) in Pisang, Rawat *et al.* (1987) in Garhwal Himalaya. The pH value was more than the value as reported by Juwal (1989) in Nagarkot Hill (4.4-5.8), Singh and Singh (1989) in Central Himalayas. The value was closer to the value reported by Sah *et al.* (1994) in *P. roxburghii* forest of Garhwal Himalaya.

Organic matter of soil in site I was higher than site II. It may be due to high litter fall and litter decomposition in site I than site II, because site I consists broadleaved forest of *B. utilis.* The organic matter content showed negative correlation with altitude in site II (p=0.01), it may be due to high litter production of *P. wallichiana* at lower altitude.

The soil nitrogen content in site I was higher than site II, it ranged from 0.17% to 0.24% in site I and 0.12% to 0.19% in site II. It may be due to high organic mater in site I than site II. Nitrogen showed negative relation with altitude in site II. It may be due to decrease of organic matter along with altitude in site II. Total available phosphorus in site I was less than site II. Same result was found by Khadka (2004) in Pisang. It may be due to higher tree density that use more available phosphorous from soil in site I than site II. The phosphorus showed negative correlation with pH in site I (p=0.01). The potassium content in soil was higher in site II than site I. Potassium showed negative correlation with organic matter (p=0.01), nitrogen (p=0.01) and positive correlation with phosphorus (p=0.01), in site I where as it showed positive correlation with phosphorus (p=0.01) in site II.

6.4 Regeneration of *P. wallichiana*

Forest regeneration, the establishment of a new tree cohort, normally occurs during succession, which involves plants, animals and microbes (Watt, 1947). The first stage of the life of a tree (the seedling and sapling stages) is dominated by strong environmental influences: intra and inter specific competition and environmental stresses.

For the regeneration study, counting of seedling and sapling is often taken as regeneration potential. However, it can not give actual figure of population structure of any community. The diameter distribution of tree gives a better indication and has been generally used to represent the population structure of forest (Saxena *et al.* 1984; Khan *et al.* 1987). The nature of the curve obtained by plotting the diameter distribution was used to interpret the characters of vegetations.

The density diameter distribution of *P.wallichiana* in site I resembled reverse J-shape curve, which indicates the sustainable regeneration (Fig 5.7). Reversed J-shape size class diagram is the indication of sustainable regeneration (Vetaas, 2000). However, in the study area it was found that higher altitude lacked the larger trees. It may be due to adverse environmental conditions for development of tree at high altitude. A reduction in radial growth at higher altitude is related to the shortened growing period largely as a result of delay in start of seasonal growth (Tranquillini, 1979).

The regeneration of *P. wallichiana* was more in site I than site II which was indicated by the higher seedling and sapling density at site I (Annex 9). Acharya (2004) also suggested that north aspect is more sustainable than south aspect for the regeneration of *P.wallichiana* in Pisang forest. Taketay (1997) reported the higher number of seedlings of *Pinus* species in north facing slope and lower in south facing slope. Higher density of seedling and sapling in north facing slope may be due to high soil moisture and less solar radiation. Soil moisture plays a vital role in the germination and establishment of seedlings. In the forest under the study it was found that the area with high soil moisture had higher density of seedling. At higher altitude in site II (above 3700m a.s.l) there was no *P. wallichiana* tree, which may be due to drought climatic condition at higher altitude of south facing slope that do not favors the development of *Pinus* seedling.

With increasing altitude, vegetation types changes from sub-alpine forest to alpine screes. This general effect of altitude is modified by slope direction. In the present study seedlings and saplings of *P. wallichiana* showed significant relation with altitude. The altitude ranged from 3300m to 4000m a.s.l. in both sites. *P. wallichiana* seedlings showed significant relationship with altitude and sapling in site I ($F=25.033$, $p<0.001$) and site II ($F=8.139$, $p<0.01$) (Table 5.8 and 5.9) *P. wallichiana* sapling also showed significant relationship with altitude on both sites (Table 5.8 and 5.9). However, Acharya (2004) did not find significant relation with altitude except *P. wallichiana* sapling in south slope.

In any community canopy cover is a significant factor, probably through its influence on the light intensity reaching the ground (Tilman, 1985). In the present study seedlings of *P. wallichiana* showed significant relation with canopy cover and slope ($F=11.124$, $p<0.001$) in site II but there was no significant relation in site I with canopy and slope (Table 5.8 and 5.9). On the other hand *P. wallichiana* saplings showed significant relation with canopy in both sites ($F=8.120$, $p<0.01$) and ($F=23.903$, $p<0.001$) in site I and II respectively (Table 5.8 and 5.9). Similar result was found by Acharya (2004) in Pisang forest. *P. wallichiana* seedlings and sapling density were higher under the canopy cover 50-70%. Chung *et al.* (1996) found that *Abies koreana* seedlings are best in 25% canopy cover but less in 75% canopy cover. *P. wallichiana* seedling and sapling showed positive correlation with canopy cover in site II, however, they do not give significant correlation in site I (Table 5.6 and 5.7)

P. wallichiana seedlings are generally associated with intermediate soil moisture (26-42%) level (Annex 7). *P. wallichiana* seedling and sapling showed significant relation with moisture content and pH in site I ($F=4.537$, $p<0.05$ for seedling and $F=3.553$, $p<0.05$ for sapling) (Table 5.8 and 5.9). However, in site II, seedling and sapling do not give significant relation with moisture and pH. Tobita *et al.* (1993) also found higher number of seedlings in high moisture content of soil. pH also showed positive correlation with seedlings in site I. Similarly seedlings and saplings were negatively correlated with moisture in site I, however, in site II seedling and sapling did not correlate significantly with moisture and pH (Table 5.6 and 5.7). Similar findings were found by Acharya (2004) in Pisang forest.

Slope in some condition becomes a limiting factor. But in the present study *P. wallichiana* seedling and sapling do not show significant correlation with slope in site I. In site II *P. wallichiana* seedling showed significant negative correlation ($p=0.05$) with slope where as sapling do not give significant value (Table 5.7). In the study area it was observed that more sloppy plot had less number of seedlings. It is probably because of the fact that the pine cones (bearing seeds) can not settle on steep area than on flat lands.

For the better regeneration of any species seed germination and seedling establishment is very important. Germination of seed mostly depends on various environmental factors like temperature, moisture and light and also on the viability of seeds. Temperature was most limiting factor in the study area. In nature seeds on the ground experience repeated desiccation and dehydration. It is important to assess the ability of seeds to germinate after being subjected to varying levels of desiccation (Singh and Singh, 1992). On the other hand, seedling establishment is another important part of regeneration. It may be affected by environmental factors for the establishment and also the seedlings must compete with herbaceous flora for limited resources. In the study area the total seedlings that germinate from the seed did not develop into the saplings which was indicated by the higher density of seedlings than saplings. The possible reason for this condition is that all seedlings cannot tolerate harse environmental condition and can not compete with herbaceous flora.

Along the environmental factors human interference is the main factor affecting regeneration as well as population structure of the forest. Forest is used for firewood, fodder and grazing of animals and some times deliberate fire regimes to improve grazing are implemented. The excessive and continuous grazing over the year has degraded these lands to such an extent that their productivity is very low (Chalise *et al.* 1993). Due to increased human activities such as fires, agriculture, urbanization, roads, and so forth, many ecosystems may never be able to complete the whole successional cycle after disturbances (Guo, 2003).

People use the stumps of *P. wallichiana* and *A. spectabilis* for constructing buildings and bridges. Large numbers of cut stems were observed in the study area. Large numbers of fallen logs were also found there. Interesting thing is that the people do not use fallen logs for timber as well as fuel wood but when they need they cut live tree in that area.

7. CONCLUSION AND RECOMMENDATIONS

The present study is mainly concentrated on vegetation composition and regeneration of *P.wallichiana* along an altitudinal gradient as well as in respect to aspect in the sub-alpine forest of Nyeshang valley, Manang. The study comprises the analysis of soil parameters and their relationship with vegetation distribution and regeneration.

Altitudinal range of the study area was 3300m-4000m a.s.l. (tree line) in both the northern and southern sites. Altogether 5 tree species and 19 shrub species were recorded from both aspect and from all altitudinal zones. There were noticeable differences in vegetation composition in both aspects as well as in different altitude of the same aspect. Total number of tree species in north aspect was more than in south aspect, but the total number of shrub species was same in both aspects. Tree line in north aspect was at higher altitude (4000m) than in south aspect (3750m).

Pinus wallichiana was most frequent and ecologically most important species in lower altitude of both slopes. But at higher altitude it was mixed with *Abies spectabilis* and *Betula utilis* in north facing slope and with *Juniperus indica* in south facing slope. Among shrub species *Berberis aristata* and *Lonicera* sp. were most important in both sites. Total tree density and total basal area of tree decreased along with altitude, where as total shrub/sapling density increased with elevation. Density and basal area of tree were less in south facing slope than that of north facing slope.

Diversity index of tree and shrub/sapling do not show any relation with altitude as well as aspect, however, north facing slope has higher tree diversity than south facing slope. South aspect was mostly dominated by one (*Juniperus indica /Pinus wallichiana*) species, but except in the lower altitude the north aspect was not dominated by a single species. In case of shrub/sapling layer, there was no single species that dominated community on both sites.

There was good regeneration of *P. wallichiana* in both aspects. Absence of tree with high girth class in high altitude indicates adverse climatic condition for the tree development. Canopy cover of tree species is the most important factor for the establishment of seedlings in site II, but in site I it is not significant. Large number of seedlings were found in lower altitude and less sloppy area and lesser number of seedling were found in higher altitude and more sloppy area, because it becomes very difficult to establish seedlings in higher altitude due to harse climatic conditions.

Since there were various limiting factors for tree distribution and regeneration in two slopes and different altitudes, however, there was no single factor that actually affects the distribution and regeneration of tree in all altitude and aspect. Human interferences also play a role in that context. From the above result it has been concluded that in high altitude Himalayan forest, altitude and site factor play a great role in distribution and regeneration of tree species.

Recommendations

High altitude Himalayan regions are geo-dynamically very active and are more sensitive to natural disturbances and human activities due to their steep slopes, variations of precipitations with altitudes and shorter growth periods. Deforestation, landslides, land degradations, desertification and glaciers lake outburst flooding (GLOF) are common environmental problems in mountains.

Following recommendations have been suggested on the basis of the results of present study:

- Unsustainable use of forest products (timber, firewood and fodder) should be checked and alternative energy sources like solar energy and hydro-power should be developed to decrease the dependency of people to the forest.
- Livestock, particularly goats and sheep are dangerous for seedling establishment; hence it should be banned from the forest at least during the period of seedling development.
- Illegal tree cutting and uncontrolled forest fire should be stopped.
- To extract the actual problems and solutions of these problems, further research based on the interaction of vegetation with environmental factors and also human interference is strongly recommended in the high altitude.

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Annex 1a.

Density (D), Frequency (F), and Basal area of tree species and Density (D), Frequency (F) and Abundance (A) of shrub/sapling species at altitude 3300-3500m of site I

Tree

Name of species	Density pl/ha	Frequency %	Basal area m^2/ha
Pinus wallichiana	2225	100	18.6
Juniperus indica	200	60	0.15
Betula utilis	50	15	0.06
Salix sp.	50	25	0.02
Abies spectabilis	100	25	0.21
Total	2625	225	19.04

Shrubs and Saplings

Name of species	Density pl/ha	Frequency %	Abundance
Pinus wallichiana	2550	90	28.33
Juniperus indica	450	65	6.92
Abies spectabilis	45	30	1.5
Betula utilis	25	15	1.66
Berberis aristata	1125	95	11.84
Juniperus communis	600	75	8
Lonicera webbiana	950	95	10
Rosa sericea	275	85	3.223
Hippophae tibetana	425	50	8.5
Cotoneaster microphyllus	25	15	1.5
Rosa macrophylla	25	10	2.5
Myricaria rosea	25	10	2.5
Salix sp.	250	40	6.25
Caragana sukiensis	75	25	3
Total	6840	700	95.73

Annex 1b.

Density (D), Frequency (F), and Basal area of tree species and Density (D), Frequency (F) and Abundance (A) of shrub/sapling species at altitude 3500-3800m of site I

Tree

Name of species	Density pl/ha	Frequency %	Basal area m^2/ha
Pinus wallichiana	190	80	1.46
Juniperus indica	100	33.33	0.037
Betula utilis	266.66	53.33	3.44
Salix sp.	33.33	16.66	0.02
Abies spectabilis	136.66	53.33	1.02
Total	728.65	236.65	5.98

Shrubs and Saplings

Name of species	Density pl/ha	Frequency %	Aundance
Pinus wallichiana	2483.33	90	27.60
Abies spectabilis	866.66	76.66	11.305
Betula utilis	350	80	4.375
Juniperus indica	33.33	13.33	2.50
Juniperus communis	80	60	1.33
Berberis aristata	400	73.33	5.45
Lonicera webbiana	600	93.33	6.42
Lonicera tomentella	100	30	3.33
Spirea canescence	66.66	16.66	4
Cotoneaster microphyllus	6.66	10	0.66
Salix sp.	500	60	8.33
Total	5486.66	603.31	75.321

Annex 1c

Density (D), Frequency (F), and Basal area of tree species and Density (D), Frequency (F) and Abundance (A) of shrub/sapling species at altitude 3800-4000m of site I

Tree

Name of species	Density pl/ha	Frequency %	Basal area m^2/ha
Pinus wallichiana	200	65	2.76
Betula utilis	225	60	2.26
Abies spectabilis	150	40	0.36
Juniperus indica	-	-	-
Salix sp.	-	-	-
Total	575	165	5.38

Shrubs and Saplings

Name of species	Density pl/ha	Frequency %	Abundance
Pinus wallichiana	425	95	4.47
Betula utilis	425	45	9.44
Abies spectabilis	225	45	5
Berberis aristata	1050	85	12.35
Berberis angulosa	1350	35	38.57
Juniperus communis	275	50	5.5
Juniperus squamata	325	50	6.5
Potentilla fruticosa	650	25	26
Lonicera webbiana	775	35	22.14
Spirea canescence	2425	60	40.41
Cotoneaster microphyllus	200	15	13.33
Rhododendron lepidotum	2690	50	53.8
Rhododendron anthopogon	75	15	5
Total	10890	605	2452.01

Annex 2a

Density (D), Frequency (F), and Basal area of tree species and Density (D), Frequency (F) and Abundance (A) of shrub/sapling species at altitude 3300-3500m of site II

Tree

Name of species	Density pl/ha	Frequency %	Basal area m^2/ha
Pinus wallichiana	525	100	11.8
Juniperus indica	320	90	5.015
Total	845	190	16.815

Shrubs and Saplings

Name of species	Density pl/ha	Frequency %	Abundance
Pinus wallichiana	1150	100	11.5
Juniperus indica	625	100	6.25
Juniperus communis	400	45	8.88
Berberis aristata	2700	100	27
Lonicera webbiana	700	60	11.66
Rosa sericea	250	50	5
Cotoneaster microphyllus	650	65	10
Cotoneaster affinis	300	25	12
Viburnum cotinifolium	25	15	1.66
Hippophae tibetana	75	10	7.5
Caragana sukiensis	50	10	5.
Myricaria rosea	25	10	2.5
Total	6950	590	108.95

Annex 2b

Density (D), Frequency (F), and Basal area of tree species and Density (D), Frequency (F) and Abundance (A) of shrub/sapling species at altitude 3500-3800m of site II

Tree

Name of species	Density pl/ha	Frequency %	Basal area m^2/ha
Pinus wallichiana	66.66	33.33	0.42
Juniperus indica	516.66	83.33	0.22
Salix sp.	16.66	13.33	0.017
Total	599.98	130	0.674

Shrubs and Saplings

Name of species	Density pl/ha	Frequency %	Abundance
Pinus wallichiana	83.33	36.66	2.27
Juniperus indica	933.33	90	10.37
Juniperus communis	100	33.33	3
Juniperus squamata	366.66	33.33	11
Cotoneaster microphyllus	516.66	70	7.38
Cotoneaster affinis	370	36.66	10.09
Rosa sericea	250	46.66	5.35
Berberis aristata	983.33	83.33	11.8
Berberis angulosa	450	33.33	13.5
Viburnum cotinifolium	100	30	3.33
Lonicera webbiana	916.66	83.33	11
Caragana sukiensis	16.66	6.66	2.5
Spirea canescence	16.66	6.66	2.5
Lonicera tomentella	33.33	6.66	5
Salix sp.	33.33	10	3.33
Total	5169.95	573.28	102.42

Annex 2c

Density (D), Frequency (F), and Basal area of tree species and Density (D), Frequency (F) and Abundance (A) of shrub/sapling species at altitude 3800-4000m of site II

Tree

Name of species	Density pl/ha	Frequency %	Basal area m^2/ha
Pinus wallichiana	-	-	-
Juniperus indica	375	100	-
Total	375	100	-

Shrubs and Saplings

Name of species	Density pl/ha	Frequency %	Abundance
Juniperus indica	405	100	4.05
Juniperus squamata	1125	95	11.84
Berberis aristata	2430	100	24.3
Berberis angulosa	1920	85	22.58
Lonicera webbiana	2225	100	22.25
Lonicera tomentella	125	20	6.25
Cotoneaster microphyllus	950	60	15.83
Cotoneaster affinis	50	25	2
Rosa sericea	375	60	6.25
Spirea canescence	50	15	3.33
Potentilla fruticosa	100	30	3.33
Ephedra gerardiana	950	35	27.14
Total	10705	725	149.15

Annex 3a

Relative Density (RD), Relative Frequency (RF), Relative Basal Area (RBA) and Importance Value Index (IVI) of tree species and Relative Density (RD), Relative Frequency (RF), Relative Abundance (RA) and Importance Value Index (IVI) of shrub /sapling at altitude 3300-3500m of site I.

Tree

Name of species	RD	RF	RBA	IVI
Pinus wallichiana	84.76	44.44	97.7	75.63
Juniperus indica	7.62	26.26	0.78	11.86
Betula utilis	1.9	6.66	0.31	3.00
Salix sp.	1.9	11.11	0.10	4.37
Abies spectabilis	3.80	11.11	1.1	5.33
Total				

Shrub and Saplings

Name of species	RD	RF	RA	IVI
Pinus wallichiana	37.28	12.85	29.59	26.57
Juniperus indica	6.57	9.28	7.22	7.69
Abies spectabilis	0.65	4.28	1.56	2.16
Betula utilis	0.36	2.14	1.73	1.41
Berberis aristata	16.44	13.57	12.36	14.12
Juniperus communis	8.77	10.71	8.35	9.27
Lonicera webbiana	13.88	13.57	10.44	12.63
Rosa sericea	4.02	12.14	3.37	6.51
Hippophae tibetana	6.21	7.14	8.87	7.40
Cotoneaster microphyllus	0.36	2.14	1.56	1.35
Rosa macrophylla	0.36	1.42	2.61	1.46
Myricaria rosea	0.36	1.42	2.61	1.46
Salix sp.	3.65	5.71	6.52	5.30
Caragana sukiensis	1.09	3.57	3.13	2.60
Total				

Annex 3b

Relative Density (RD), Relative Frequency (RF), Relative Basal Area (RBA) and Importance Value Index (IVI) of tree species and Relative Density (RD), Relative Frequency (RF), Relative Abundance (RA) and Importance Value Index (IVI) of shrub /sapling at altitude 3500-3800m of site I.

Tree

Name of species	RD	RF	RBA	IVI
Pinus wallichiana	26.07	33.80	24.42	28.09
Juniperus indica	18.75	22.53	17.06	19.44
Betula utilis	13.72	14.08	0.62	9.74
Salix sp.	4.57	7.04	0.33	3.98
Abies spectabilis	36.59	22.53	57.55	38.9
Total				

Shrubs and Saplings

Name of species	RD	RF	RA	IVI
Pinus wallichiana	45.26	14.91	36.64	32.27
Abies spectabilis	15.79	12.70	15.00	22.44
Betula utilis	6.38	13.26	5.80	8.48
Juniperus indica	0.61	2.20	3.32	2.04
Juniperus communis	1.45	9.94	1.76	4.38
Berberis aristata	7.29	12.15	7.23	8.9
Lonicera webbiana	1093	15.46	8.52	11.63
Lonicera tomentella	1.82	4.97	4.42	3.73
Spirea canescence	1.21	2.76	5.31	3.09
Cotoneaster microphyllus	0.12	1.65	0.87	0.88
Salix sp.	9.11	9.94	11.06	10.03
Total				

Annex 3c

Relative Density (RD), Relative Frequency (RF), Relative Basal Area (RBA) and Importance Value Index (IVI) of tree species and Relative Density (RD), Relative Frequency (RF), Relative Abundance (RA) and Importance Value Index (IVI) of shrub /sapling at altitude 3800-4000m of site I.

Tree

Name of species	RD	RF	RBA	IVI
Pinus wallichiana	34.78	39.39	51.3	41.82
Betula utilis	39.13	36.36	42.00	39.16
Abies spectabilis	26.08	24.24	6.70	19.00
Juniperus indica	-	-	-	-
Salix sp.	-	-	-	-
Total				

Shrub and Sapling

Name of species	RD	RF	RA	IVI
Pinus wallichiana	3.9	15.7	1.84	7.14
Betula utilis	3.9	7.43	3.9	5.07
Abies spectabilis	2.06	7.43	2.06	3.85
Berberis aristata	9.64	14.05	5.1	9.6
Berberis angulosa	12.39	5.78	15.93	11.36
Juniperus communis	2.52	8.26	2.27	4.35
Juniperus squamata	2.98	8.26	2.68	4.64
Potentilla fruticosa	5.96	4.13	10.74	6.94
Lonicera webbiana	7.11	5.78	9.14	7.34
Spirea canescence	22.26	9.91	16.52	16.23
Cotoneaster microphyllus	1.83	2.48	5.5	3.27
Rhododendron lepidotum	24.7	8.26	22.23	18.4
Rhododendron anthopogon	0.68	2.48	2.06	1.74
Total				

Annex 4a

Relative Density (RD), Relative Frequency (RF), Relative Basal Area (RBA) and Importance Value Index (IVI) of tree species and Relative Density (RD), Relative Frequency (RF), Relative Abundance (RA) and Importance Value Index (IVI) of shrub /sapling at altitude 3300-3500m of site II.

Tree

Name of species	RD	RF	RBA	IVI
Pinus wallichiana	62.13	52.63	70.17	61.64
Juniperus indica	37.87	47.36	29.82	38.35
Total				

Shrub and Sapling

Name of species	RD	RF	RA	IVI
Pinus wallichiana	16.54	16.95	10.55	14.68
Juniperus indica	9.00	16.95	5.73	10.56
Juniperus communis	5.75	7.6	8.15	7.16
Berberis aristata	38.84	16.95	24.78	26.85
Lonicera webbiana	10.07	10.67	10.70	10.51
Rosa sericea	3.6	8.47	4.59	5.55
Cotoneaster microphyllus	9.35	11.01	9.17	9.84
Cotoneaster affinis	4.31	4.23	11.01	6.51
Viburnum cotinifolium	0.36	2.54	1.52	1.47
Hippophae tibetana	1.08	1.7	6.88	3.22
Caragana sukiensis	0.72	1.7	4.59	2.33
Myricaria rosea	0.36	1.7	2.3	1.45
Total				

Annex 4b

Relative Density (RD), Relative Frequency (RF), Relative Basal Area (RBA) and Importance Value Index (IVI) of tree species and Relative Density (RD), Relative Frequency (RF), Relative Abundance (RA) and Importance Value Index (IVI) of shrub /sapling at altitude 3500-3800m of site II.

Tree

Name of species	RD	RF	RBA	IVI
Pinus wallichiana	11.11	25.63	62.3	33.01
Juniperus indica	86.11	64.1	32.64	60.95
Salix sp.	2.77	10.25	2.52	5.18
Total				

Shrub and Sapling

Name of species	RD	RF	RA	IVI
Pinus wallichiana	1.61	6.4	2.21	3.4
Juniperus indica	18.05	15.7	10.12	14.62
Juniperus communis	1.93	5.81	2.92	3.55
Juniperus squamata	7.92	5.81	10.74	8.15
Cotoneaster microphyllus	9.99	12.21	7.2	9.8
Cotoneaster affinis	7.15	6.4	9.85	7.8
Rosa sericea	4.83	8.14	5.22	6.06
Berberis aristata	19.02	14.53	11.52	15.02
Berberis angulosa	8.7	5.81	13.18	9.23
Viburnum cotinifolium	1.93	5.23	3.25	3.47
Lonicera webbiana	17.73	14.53	10.74	14.33
Caragana sukiensis	0.32	1.16	2.44	1.31
Spirea canescence	0.32	1.16	2.44	1.31
Lonicera tomentella	0.64	1.74	3.25	1.87
Salix sp.	0.64	1.16	4.88	2.23
Total				

Annex 4c

Relative Density (RD), Relative Frequency (RF), Relative Basal Area (RBA) and Importance Value Index (IVI) of tree species and Relative Density (RD), Relative Frequency (RF), Relative Abundance (RA) and Importance Value Index (IVI) of shrub /sapling at altitude 3800-4000m of site II.

Tree

Name of species	RD	RF	RBA	IVI
Pinus wallichiana				
Juniperus indica	100	100		
Total				

Shrub and Sapling

Name of species	RD	RF	RA	IVI
Juniperus indica	3.78	13.7	2.71	6.67
Junipers squamata	10.5	13.1	7.93	10.51
Berberis aristata	22.7	13.79	16.03	17.6
Berberis angulosa	17.93	11.72	15.4	14.93
Lonicera webbiana	20.78	13.80	14.91	16.5
Lonicera tomentella	11.67	2.75	4.2	6.2
Cotoneater microphyllus	8.87	8.27	1061	9.25
Cotoneaster affinis	0.46	3.44	1.34	1.75
Rosa sericea	3.5	8.27	4.2	5.32
Spirea canescence	0.46	2.07	2.23	1.59
Potentilla fruticosa	0.93	4.13	2.23	2.43
Ephedra gerardiana	8.87	4.82	18.19	10.62
Total				

Annex 5

Density (Pl/ha) and Basal area (m2/ha) of trees and shrubs in three altitudinal gradient

Site I

Altitude	Density (pl/ha)		Basal area (m^2/ha)	
	Tree	Shrubs	Tree	Shrubs
3300-3500m	2625	6840.2	19.04	-
3500-3800	728.65	5486.66	5.977	-
3800-4000	575	10890	5.38	-

Site II

Altitude	Density(pl/ha)		Basal Area (m^2/ha)	
	Tree	Shrub/sapling	Tree	Shrub/Sapling
3300-3500m	845	6950	16.81	-
3500-3800m	599.98	5169.95	0.674	-
3800-4000m	375	10705	-	-

Annex 6

Seedling and sapling density of *P. wallichiana* in site I and site II

Site I				Site II			
Q.N	Pseed	Psap	Alt.	Q.N	Pseed	Psap	Alti.
1	6200	5300	3310	1	500	800	3330
2	1600	2500	3330	2	400	1700	3350
3	3800	2100	3350	3	1100	400	3310
4	1800	4300	3370	4	600	500	3370
5	1500	1200	3390	5	500	800	3390
6	2400	1900	3400	6	1000	700	3400
7	700	4200	3420	7	800	900	3420
8	900	2500	3450	8	3000	600	3450
9	1500	1700	3470	9	800	1100	3470
10	2500	3500	3490	10	400	500	3490
11	3900	2200	3500	11	300	300	3510
12	3100	6200	3520	12	0	100	3530
13	4500	10200	3550	13	0	0	3550
14	3200	7200	3570	14	0	200	3570
15	2800	4500	3590	15	0	0	3590
16	1200	2000	3600	16	0	0	3600
17	900	2500	3620	17	0	100	3630
18	700	1700	3650	18	0	0	3650
19	600	2200	3670	19	0	200	3670
20	700	1600	3690	20	0	100	3690
21	500	1200	3700	21	0	0	3700
22	400	1200	3720	22	0	0	3730
23	500	200	3750	23	0	0	3750
24	0	100	3770	24	0	0	3790
25	0	0	3790	25	0	0	3800
26	1700	800	3820	26	0	0	3820
27	900	500	3840	27	0	0	3850
28	1500	600	3860	28	0	0	3870
29	700	200	3875	29	0	0	3890
30	600	700	3890	30	0	0	3900
31	200	100	3900	31	0	0	3930
32	500	300	3920	32	0	0	3950
33	200	500	3940	33	0	0	3970
34	0	300	3970	34	0	0	3980
35	0	100	3990	35	0	0	4000

Annex 7

Soil moisture and soil pH of different quadrat of site I and II

Site I				Site II			
Q.N	Alt.	pH	Moist	Q.N	Alti.	pH	Moist
1	3310	6.4	36.75	1	3330	6.6	20.5
2	3330	6.5	36.75	2	3350	6.4	31.5
3	3350	6.7	42	3	3310	6.5	31.5
4	3370	6.7	31.5	4	3370	6.4	36.75
5	3390	6.6	26.25	5	3390	6.6	31.5
6	3400	6.5	26.25	6	3400	6.7	10.25
7	3420	6.3	26.25	7	3420	6.5	20.25
8	3450	6.5	31.5	8	3450	6.5	31.5
9	3470	6.5	31.5	9	3470	6.4	31.5
10	3490	6.4	31.5	10	3490	6.4	26.25
11	3500	6.4	42	11	3510	6.8	10.25
12	3520	6.4	31.5	12	3530	6.8	5
13	3550	6.4	36.75	13	3550	6.6	31.5
14	3570	6.5	36.75	14	3570	6.4	31.5
15	3590	6.3	31.5	15	3590	6.6	36.75
16	3600	6.2	31.5	16	3600	6.6	31.5
17	3620	6.1	36.75	17	3630	6.4	31.5
18	3650	6.2	42	18	3650	6.4	36.75
19	3670	6.2	36.75	19	3670	6.5	26.25
20	3690	6.2	42	20	3690	6.3	36.75
21	3700	6.4	36.75	21	3700	6.1	42
22	3720	6.3	42	22	3730	6.7	36.75
23	3750	6.2	36.75	23	3750	6.6	20.25
24	3770	6.2	67	24	3790	6.6	30.5
25	3790	6.2	67	25	3800	6.7	15.5
26	3820	6.6	31.5	26	3820	6.7	20.25
27	3840	6.2	42	27	3850	6.7	15.5
28	3860	6.3	67	28	3870	6.7	26.25
29	3875	6.6	31.5	29	3890	6.5	31.5
30	3890	6.3	67	30	3900	6.4	31.5
31	3900	6.4	42	31	3930	6.7	20.25
32	3920	6.2	42	32	3950	6.7	20.25
33	3940	6.2	67	33	3970	6.6	31.5
34	3970	6.3	42	34	3980	6.6	20.25
35	3990	6.3	67	35	4000	6.7	20.25

Annex 8.

Canopycover and slope of different quadrats of site I and II

Site I				Site II			
Q.N	Alt.	Cov	Slope	Q.N	Alti.	Cov	Slop
1	3310	65	20	1	3330	55	15
2	3330	60	10	2	3350	60	12
3	3350	60	5	3	3310	40	8
4	3370	70	15	4	3370	55	20
5	3390	60	12	5	3390	60	20
6	3400	60	20	6	3400	65	20
7	3420	80	25	7	3420	65	15
8	3450	80	35	8	3450	60	10
9	3470	70	20	9	3470	40	10
10	3490	75	25	10	3490	60	15
11	3500	55	20	11	3510	50	15
12	3520	60	25	12	3530	50	20
13	3550	65	20	13	3550	25	20
14	3570	55	25	14	3570	30	25
15	3590	60	30	15	3590	20	25
16	3600	60	25	16	3600	40	35
17	3620	50	15	17	3630	25	25
18	3650	65	25	18	3650	20	15
19	3670	70	20	19	3670	45	20
20	3690	65	35	20	3690	35	15
21	3700	50	20	21	3700	20	15
22	3720	75	20	22	3730	15	20
23	3750	60	25	23	3750	15	15
24	3770	60	10	24	3790	10	30
25	3790	70	15	25	3800	10	5
26	3820	70	25	26	3820	0	5
27	3840	30	30	27	3850	0	25
28	3860	70	30	28	3870	10	15
29	3875	75	25	29	3890	0	25
30	3890	55	35	30	3900	15	30
31	3900	70	25	31	3930	10	30
32	3920	75	20	32	3950	10	15
33	3940	60	15	33	3970	15	20
34	3970	75	30	34	3980	20	15
35	3990	55	15	35	4000		

Annex 10
Temperature and precipitation of Chame from 2000 to 2004 A.D.

Months	2000			2001			2002		
	Tem. Max. (°C)	Tem. Min. (°C)	Precip. (mm.)	Tem. Max. (°C)	Tem. Min. (°C)	Precip. (mm.)	Tem. Max. (°C)	Tem. Min. (°C)	Precip. (mm.)
Jan.	6.9	-4.5	11	9.9	-1.2	6.2	13	-5	63
Feb.	7.6	-2.5	25	14	1.2	28.6	14	-1	35
Mar.	10.3	2.5	19	17.1	5	23.8	17.9	4.5	32.8
April.	18.9	7.5	31	19.3	8.3	23	19.6	8.2	74
May	20.5	8.1	20	20.1	9.2	25.2	19.9	9.1	87.2
June	20.5	9.0	116	19.7	7.2	112.6	20.2	9.0	97.6
July	19.8	8.9	136	19.3	7.6	121.8	21.7	10.2	80.2
Aug.	18.8	8.8	140	19.0	7.1	146.4	20.2	9.2	152.5
Sept.	17.4	7.4	76	19.8	7.9	34.0	20.0	8.9	253.1
Oct.	16.2	6.7	0	18.2	5.6	6.2	18.5	7.5	0
Nov.	13.3	4.1	18	17.4	5.2	2.2	16.0	4.4	34
Dec.	8.8	-1.3	0	14.5	-1.4	0	8.2	-3.4	0

	2003			2004		
Jan.	6.7	-4.4	40	15.5	-2.6	27.6
Feb.	11.4	1.2	49	17.5	3.1	22
Mar.	17.6	5	115.5	20	6.5	5
April.	18.9	7.9	72	20.7	7.2	49.2
May	21.2	9.0	40.2	21.	7.1	46.6
June	21.2	10.3	137.8	20.4	7.2	168
July	20.6	9.1	113	19.8	6.4	258.4
Aug.	19.6	7.5	203.8	19.7	6.5	186
Sept.	18.7	7.4	149.4	19.7	6.2	185
Oct.	18.5	6.5	7	18.1	2.4	26
Nov.	16	4.2	32	18.5	0.5	0
Dec.	15.1	-2.2	43	17.6	-3.1	0

Annex 11

List of Plant Species

S.N.	Scientific Name	Family
1	**Abies spectabilis* (D.Don.) Mirb	Pinaceae
2	*Berberis angulosa* Wall. ex. Hook. f. and Thoms.	Berberidaceae
3	*Berberis aristata* DC.	Berberidaceae
4	**Betula utilis* D.Don.	Betulaceae
5	*Caragana sukiensis* C.K. Schneid.	Leguminosae
6	***Cotoneaster affinis* Lindl.	Rosaceae
7	*Cotoneaster microphyllus* Wall. ex Lindl.	Rosaceae
8	***Ephedra gerardiana* Wall. ex. stapf	Ephedraceae
9	*Hippophae tibetana* Schlecht.	Elaegnaceae
10	*Juniperus communis* L.	Cupressaceae
11	*Juniperus indica* Bertol.	Cupressaceae
12	*Juniperus squamata* Buch.-Ham. ex. D.Don.	Cupressaceae
13	*Lonicera webbiana* Wall. ex. DC.	Caprifoliaceae
14	*Lonicera tomentella* Hook. f.	Caprifoliaceae
15	*Myricaria rosea* W.W. Sm.	Tamaricaceae
16	*Pinus wallichiana* A.B. Jacks	Pinaceae
17	*Potentilla fruticosa* var. *ochreata* Lindl. ex. Lehm.	Rosaceae
18	**Rhododendron anthopogon* D.Don	Ericaceae
19	**Rhododendron lepidotum* Wall. ex. G. Don	Ericaceae
20	**Rosa macrophylla* Lindl.	Rosaceae
21	*Rosa sericea* Lindl.	Rosaceae
22	*Salix* sp.	Salicaceae
23	*Spirea canescence* D.Don.	Rosaceae
24	***Viburnum cotinifolium* D.Don.	Sambucaceae

* Only found in site I

** Only found in site II

Plate 1. Nagwal Village of Manang District

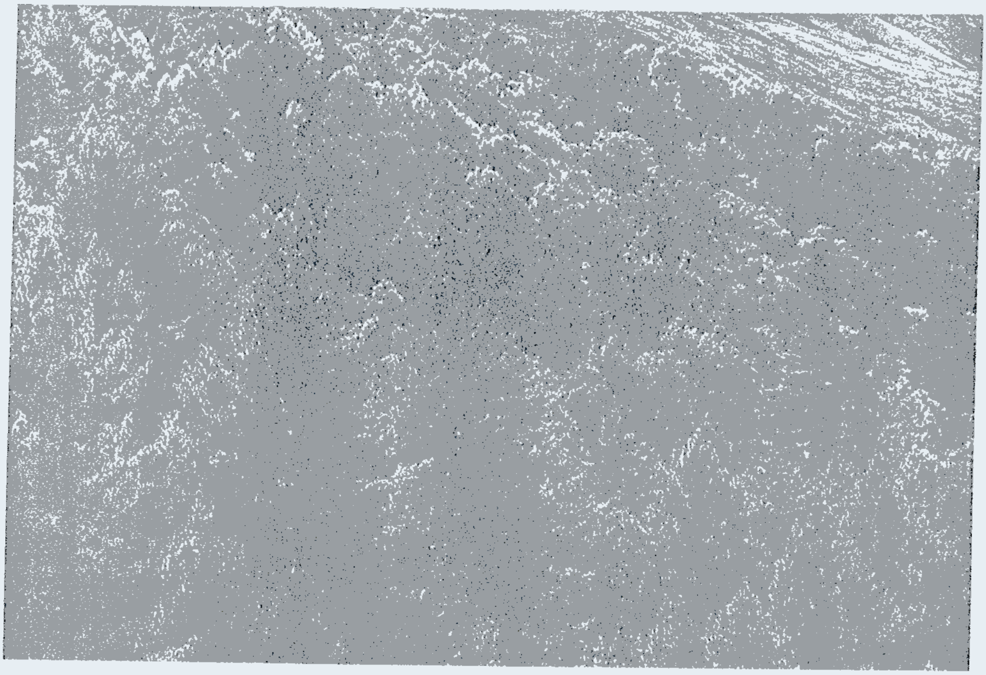

Plate 2. Mixed Forest of *Pinus wallichiana* and *Betula utilis* in Site I

Plate 3. Upper Tree Line in Site I above Gangapurna Glacier Lake

Plate 4. Scrubby form of *Juniperus indica* in Site II