1. INTRODUCTION

1.1 Background

Forest is the most important natural resource for rural people and for the maintenance of environmental conditions (MOPE 2001). They are the main reservoirs of the biological diversity both of the floral and faunal origin and constitute genetic resources of immense value. Timber, fuel wood, herbal medicine, fiber and animal fodder are supplied from different types of forest. Forest catchments are the main sources of drinking water. It can also conserve soil and prevent landslide and flooding. Five categories of national forests are recognized under the forest Act (1993) in Nepal; they are: Government forest, Protected forest, Community forest, Leasehold forest and Religious forests, excluding private forests, whether marked or unmarked with forest boundary markers (Chaudhary 1998)

Vegetation, the total plant cover of a region (Forberg 1961), depends on local environmental variables like altitude, aspect, climate, moisture and soil. Soil, as an integrated and essential part of terrestrial ecosystem, determines the type of plant community that can grow on it and plants in turn affects the soil. The type of soil, the climate and the vegetation are all associated and interrelated (Chapman and Reiss, 1999)

About 29% of the total area of Nepal is covered with forest with additional 10.6% categorized as shrubs (MFSC, 1999). The forest area has declined from 45% in 1966 to 29% by the end of the 20th century. The quality of forest has also declined as the shrub land area has doubled from 4.8% in mid 1980s to 10.6% in mid 1990s. Despite huge efforts in conserving and utilizing forest resources, forests of Nepal continue to degrade both in area and productivity. Nepal’s forests continue to decrease at an annual rate of 2.3 percent in hills and 1.3 percent in the Terai.The total forest area of the country has also gone down considerably from 5.5 million hectares to 4.27 million ha.during 1987-1998.This comprises to only 39 percent of the country’s total area under some kind of forest area-not ‘forest’ having 10 percent or more crown cover. The latter is only 29.6 percent.

Forest and people have been and still are intimately connected, economically as well as socially. The process of exploiting forest resources beyond the sustainable capacity has lead to a number of environmental problems such as loss of habitat and biodiversity. Deforestation induced soil erosion, landslides and floods have affected forest structure and sedimentation of important ecosystem both terrestrial and aquatic ecosystems. Increasing human population is exerting heavy pressure on forests. Especially the fragile environment of mountains of Nepal is facing serious problems of resources degradation. The destruction and degradation of forests is now recognized as one of the greatest environmental threats and tragedies of all times (Bist, 1999). Environmental degradation is one of the major challenges in Nepal as well and deforestation is mainly responsible for this.

The forest products are used to meet energy requirement, food, fodder, timber and medicines. Over the last decades the condition of the forests has changed. Extensive deforestation has taken place. Forests being very culturalised and integrated with people's life, the latter are dependent on forest for food, fuel-wood, shelter and many other things. Increasing population has led to increasing pressure on the forest; land use change has been found to be the biggest factors to cause deforestation. Human activities such as timber extraction, conversion of forest and grasslands into agricultural land are the major factors responsible for change in land use pattern. Forests are also cleared through Hill-terai migration and settlement programmes. Between 1996 and 1999, about 0.155 million ha of forest area were used for settlement, agriculture expansion institutional building and road construction (MFSC, 1999). Commercial use and forest fires are equally responsible for depletion of forests. The existing pastureland is not sufficient for supporting the increasing livestock and they should depend on forests. Forests provide about 62% of fodder supply to livestock and most of this pressure is in the Terai and Hills.

The community forestry programme envisions ensuring the power of the community to protect, manage and utilize the forest resources after its handing over with the ultimate objective of raising the living standards of local community (Arnold, 1992). This underpins the notion that the state and the local community can jointly manage forest resources to the benefit of both parties (Anderson, 1995). To date 28.57 percent of the lands in the Midhills and Terai are being managed as community forests, which correspond to 68 and 17 percent of total land area of the country respectively (HMGN, 2003). Recently, it has been estimated that active forest management could increase forest products supplies and take-off levels of fuel wood for example by 100 percent (FFMP,

2000) and in this situation community forest management will reduce the pressure on deforestation and degradation of forest resources.

1.2 Forest and vegetation pattern in Nepal

Forest contributes as an important 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. Latest data available reveal that the country has 29 percent forest spread over 4.26 million hectare and 10.6 percent shrub land or so called degraded forest occupying 1.559 million hectare area. Distribution of forest in Nepal is not uniform. Forest area in Nepal has declined considerably; the annual deforestation rate is estimated to be 1.7 percent (DFRS, 1999).

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

Schima-Castanopsis forest lies in subtropical zone, which prevails to an elevation of 1000-2000m. It comprises the outer foothills, lower part of Mahabharat range, midland areas and Himalayas. Chilaune (*Schima wallichi*) and Katus (*Castanopsis indica*) type of forest is dominant between 1000-1700m on both the north and south facing slopes in east and central Nepal. Most of the natural forests in this zone are cleared for cultivation purpose. At its upper limit above 1,700m *Castanopsis tribuloides* is dominant that occasionally forms pure Katush forest with *Castanopsis hystrix* in East Nepal.

The associated tree species are *Acer oblongum, Michelia kisopa, Persea oderatissima, Litsea doshia, Ficus auriculata, F. semicordata* etc. The undergrowth surface is dominated by *Maesa chisia, Eurya acuminata, Oxyspora paniculata, Barleria cristata* and *Eupatorium adenophorum*, an exotic weed, which is encroaching upon most of the open and disturbed area. Some striking epiphytic Orchids include *Rhynchostylis retusa, Coelogyne corymbosa, C.cristata* etc.

1.3 Natural Regeneration

The term natural regeneration embraces all methods employed by plants in producing 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 its life cycle (Fatubarin, 1987). Natural regeneration is therefore, of importance in the maintenance of a stable age structure in the species of plant in a community. Natural regeneration is a slow process. However, applying silvicultural tool can increase the regeneration of useful and high demanding species. Oliver (1981) and Peet and Christensen (1987) described the progression of forest stands through four sequential stages:

- Stand initiation or regeneration stage.
- Thinning or stem exclusion stage.
- Transition or understorey initiation stage.
- Steady stage or old growth stage.

Population structure of a species in a forest can convey its regeneration behavior (Singh & Singh, 1992). Population structure, characterized by the presence of a sufficient population of seedlings, saplings and young trees indicate a successful regeneration of forest species (Saxena & Singh, 1984)

The regeneration behavior of tree species is characterized by their population structure, which in turn depends upon the presence of adequate number of seedlings, saplings and boles in different girth classes. The interactive influence of biotic and abiotic factors of the environment affects the survival and growth of seedlings and sprouts (Howards, 1973; Sorenson and Forrel, 1979; Muller-Dombios *et.al*, 1980). Dominance of established seedlings and saplings under the adult trees affect the future composition of the forest.

Regeneration of canopy dominants is commonly assessed by the distribution of size-classes measured as diameter at breast height (DBH) (Leak, 1964; Schmelz & Lindsey, 1965; Harcombe & Marks, 1978; West *et.al*, 1981). This is based on the survivorship curves and the density diameter relationships developed by applied forest scientists (Pearl & Miner, 1935; Leak, 1964). It is supported by the tenet that fecundity and population growth in plants may be more dependent on size than on age (Harper &White, 1974;

Buchholz & Pickering, 1978). Undisturbed old-growth forests with sustainable regeneration are found to have inverse J-shaped size-class distribution (West *et.al*, 1981; Parker & Peet, 1984; Rao *et.al*, 1990; Bernadzki *et.al,* 1998). A bell-shaped size-class distribution has been attributed to disturbed forest where regeneration is hampered (Parker & Peet, 1984, Saxena *et.al.*1984).

The natural regeneration of Sal (*Shorea robusta*) has been considered to be a slow, yet unpredictable process. In Nepal, the regeneration potential of Sal from the Terai to Mountain valleys has been noticed (Lamichaney 1982, Gautam 1990, Mathema 1991), but not much measured data are available. The recent trials of the Forest Management and Utilization Development Project have, in practice, shown this regeneration potential (Rautiainen and Suoheime 1995). The natural regeneration of sal is normally divided into two phases: recruitment phase and establishment phase. Dieback is the phenomenon linked to the recruitment phase. The shoot dies annually due to unfavorable growing conditions, but the root remains alive and continues to send up new shoots each year until, eventually, a very strong root stock develops producing a shoot which continues to grow and forms a tree.

Betula utilis D.Don (*bhojpatra* birch) forms treeline vegetation all along the Nepal Himalayas, and extensive stands of this species can be found on northern shady slopes and ravines (TISC 2002). *Betula* spp.show a high freezing tolerance (Sakai and Larcher 1987) which enables them to form a treeline in the Himalayas (Zobel and Singh 1997;TISC 2002) as well as in the Scandinavian region (Cairns and Moen 2004). Regeneration of *Betula utilis* forest and spatial patterns of seedling distribution in the Central Himalayas have not been studied, though the regeneration of *Betula* spp.has been studied extensively elsewhere in the world (Marquis 1965; Houle 1998; Catovsky and Bazzaz 2000).

Quercus semecarpifolia Sm. (Fam.Fagaceae; local name khasru) is one of the dominant trees of upper temperate and sub alpine forest of Himalaya. Due to over-exploitation and an inherently slow growth rate, khasru oak forest is failing to regenerate and shrinking in Nepal and the adjoining Himalayan region (Metz 1997, Shrestha and Paudel 1996, Singh and Singh 1992). Annual lopping, acorn herbivory, seedling and sapling browsing, litter collection and forest fire are important factors preventing regeneration of khasru in disturbed forests. In a nearly undisturbed forest of central Nepal (Langtang National

Park), the regeneration of khasru is continuous (Vetaas 2000) but the preliminary observation (Siluwal *et al*.2001) of the other forest in the same region (Shivapuri National Park, central Nepal) revealed that the regeneration was not continuous in the protected forest too.

Very scarce of study of natural regeneration of dominant tree species in Nepal is found and most of them are focused upon tropical tree species Sal (*Shorea robusta*). Regeneration of *Schima-Castanopsis* forests has not been studied. Therefore, this study stands an additional contribution in case of forest ecology in Nepal and it would be helpful to know the effect of different aspects and other environmental factors in vegetation composition and regeneration of forest.

1.4 Justification of the study

The quantitative information concerning the ecology of most of the forest types in Nepal is largely undocumented. In the study area, there was no detailed vegetation study so far carried out. Therefore, this study stands as an inventory documentation concerning the forest regeneration. The study will establish important baseline ecological data and regeneration pattern of forest, which would assist in subsequent research work and estimating the sustainability of the forest. Study of sustainability of forest outstands as a prime issue in case when the local people are intimately dependent on the forest product.

1.5 Objectives

The specific objectives of the present work are:

- To elucidate the natural regeneration patterns of *Schima wallichi* and *Castanopsis tribuloides.*
- To correlate the vegetation and regeneration process with edaphic factors.
- To analyze the different parameters of soil.
- To determine the diversity and species composition of tree species at east, west, north and south facing slopes.

1.6 Limitation of the study

Due to adverse political situation of the country during the sampling period frequent field visit could not be done. It is based on field data collected in a short period, and the sample size was small. Thus the results of this work should be considered as preliminary and deserve more detailed and long-term observations.

2. LITERATURE REVIEW

Department of medicinal plants, Godavari (HMG) carried out an extensive study of Phulchwoki and Godavari forest area between 1967 to 1968m.It had reported that the area comes under the warm temperate zone. The vegetation comprises of three distinct evergreen broad-leaved forest types in accordance with altitudinal gradients and vegetation composition. The forest communities are as follows:

- Mixed forest of *Schima-Castanopsis* at the base from 1500-1800m altitudes.

- Oak-Laurel forest at 1800-2400m and Evergreen oak forest at the top above 2400m.

Similarly, the department also carried out vegetation study of Nagarjun forest area in 1968.The *Schima wallichi* occupies most part of the hills. They have categorized the whole forest into four types of communities.

a) *Schima* forest
b) Pine forest
c) Mixed broad leaved forest and
d) Dry oak forest.

Stainton (1954-1971) extensively explored the vegetation of Nepal. He reported that the variation of vegetation of Nepal is greatly influenced by different environmental factors like rainfall, aspect, slope, altitude and exposure. Further, he pointed out that the central midland region has got low temperate mixed broad-leaved forest in between 1501 to 2103m altitude. *Schima-Castanopsis* forest is confined between 600m to 1801m altitudes.

Berg Seth (1977) reported close relation between the type of vegetation and the acidity of upper forest soil horizon of Norwegian forest. He also found the decreasing tendency of the influence of vegetation on pH with decreasing depth of the soil.

Bhatt (1978) carried out vegetational analysis of Nagarjun Royal forest. He reported that *Schima wallichi* a shade loving tree of North Slope, shows a tendency of invasion towards south slope, which is more exposed, and possess highest radiation than North Slope.

Sharpe (1981) collected seeds and studied propagation of Chestnuts (*Castanopsis)* and Oaks *(Quercus*), he collected seeds for storage as early as possible before the natural fall and before insects and rodents could do much damage. It was confirmed that *Castanopsis indica* could produce seedling within one to two years and it is propagated from direct seed as well as nursery seedling.

Lal and Dakwale (1984) studied structural changes in a forest along centripetal gradients from forest periphery to inner forest area of Khangsara, India. The result of the study indicated that tree density and regeneration was markedly less near villages than on distant ones. These structural changes were due to the human and cattle pressure on the forest.

Upreti *et al.* (1985) studied composition, diversity and regeneration of oak forest in Kumaon (western part of Himalayan range) and reported that (β) diversity was lower in the tree layer than the shrub indicating rapid rate of composition change in shrub layer.

Maithani *et.al*. (1989) discussed various causative factors of the extensive mortality and lack of natural regeneration occurring in the forests, which included drought, frost and biotic factors.

Heikkien (1991) analyzed the relationship between the forest vegetation and major environmental factors. They concluded that aspect and inclination were the important factors, which affect the vegetation. Nitrogen and Phosphorus were slightly higher in soils under the tree canopies than in grasslands. The other major factors were pH, thickness of humus and tree canopy.

Manandhar (1996) studied high altitude forest in terms of regeneration behavior and found the reverse J-shaped size class distribution diagram of *Abies spectabilis*. Very low seedlings density was found even in relatively undisturbed forest but good in elevated surfaces.

Takashi (1997) studied the regeneration process of *Castanopsis* and *Persea* evergreen broadleaved climax forest in Miyake, Jima, Izu Island, Japan. There were more sapling of *Persea thunbergii* than those of the *Castanopsis cuspidate* Var.seiboldii.The later canopy trees had large crown areas and many sprouts reaching the canopy layer. It seems that sprouting and canopy expansion are advantageous to the survival of *C.cuspidate* in the canopy layer and this compensate for the low regeneration ability from sampling on the other hand. Consequently *Persea thunbergii* seems to be able to dominate only in the patches of young phase forest in the regeneration complex of the climax forest.

Li-feng *et.al*. (1998) studied the effect of OM, N and P in soil of Northwest China. They indicated that the total N content was correlated positively with OM content significantly at 5% level. Available phosphorus content was unaffected with increased OM content.

Rajwar *et.al* (1999) studied regeneration status of an Oak forest in Garhwal Himalaya and concluded that only 88% of the tree species were recorded in seedling stage while sapling percentage was further reduced.

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.

Paudel (2000) compared the vegetation structure and soil characteristic in natural and community forest of Udayapur district. He reported that the total density, basal area, volume and tree species diversity were higher in natural forest than in community forest. Soil of the forest was acidic with the pH value 4.33-5.33,OM value 1.01-2.43%, P value 76.64-126.81 kg/ha and K value 196.8-267.73.

Peng *et.al*. (2000) analyzed seed rain and seed bank of constructive species in evergreen broadleaved forest at Chagquing Sinian Mountain. They found the seed bank of *Castanopsis arthocanthe* and *Schima argenter* was small, only survived a short time and did not sprout next year.

Rangel *et.al*. (2000) analyzed regeneration patterns in relation to canopy species composition and site variables in mixed oak forests and concluded that management alternatives must be prescribed for each ecological situation where the different oak species were growing.

Vetaas (2000) studied the effects of environmental factors on natural regeneration of *Quercus semecarpifolia* in Central Nepal. He found that regeneration is most reliable in the nearly undisturbed forest. The high 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.

Huang *et.al.* (2001) studied the factors affecting seedling establishment in monsoon evergreen broadleaved forest and found seedling establishment increased in plots removing shrub and herb layers and clearing the litter but the species richness of seedling did not increase. High mortality of seedling was seen in dry season, high light intensity and precipitation.

Pereira and Valio (2001) studied the seed size, seed germination and seedling survival of Brazilian tropical tree species differing in successional status. They found that there is no significant correlation between successional status and seed size or seed water content. Light regulated germination was present only in small seeded species.

Chen *et.al.* (2002) studied germination rates of the seeds of *Castanopsis fargessi* under forest and in gaps and observed no obvious difference in the two habitats. Biomass allocation of the seedlings in the gaps tended to be more in the roots while those under forest is more in leaves.

Chettri *et.al*. (2002) studied the effect of various activities upon regeneration in the Trekking corridor of the Sikkim Himalaya. Because of different adverse activities like firewood extraction pressure from the community and tourism enterprises natural regeneration of tree species were affected.

Xiang *et.al*. (2002) transplanted seedlings of *Schima superba* in canopy gaps and under secondary broadleaved forest and found that seedling grew faster in gaps than under forests.

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.

Fekedulegn *et.al.* (2003) made a detailed study at Appalachian watershed, USA and examined relationship between radial growth, topographic aspect and precipitation for four hardwood species-*Rhododendron sp., Quercus rubra, Q.prinus* and *Acer ruvum*.The main objective of the study was to determine variation in growth between northeast and southeast aspects. The study found that all species except *Quercus rubra* showed significant differences in growth between the northeast and southwest aspect.

Hau *et.al*. (2003) suggested that all three factors-seasonal drought, belowground competition and low soil nutrients could significantly impair seedling growth of *Schima* species on a degraded hillside site but their relative importance differed among species.

Liu *et.al*. (2003) concluded that intra-specific competition in *Castanopsis kawakamii* reduced with the increase of diameter class of trees and a remarkable regression model of the relationship between competition intensity and diameter class of objective tree individuals were established.

Masahiro and Yamamota (2003) studied the population structure and dynamics of *Castanopsis cuspidata* and concluded that regeneration in this species occurred more often by sprout formation than by growth of saplings.

Miura and Shin-ichi (2003) studied the structure and dynamics of a *Castanopsis cuspidate* var *sieboldii* population in an old-growth evergreen broad-leaved forest and the importance of sprout regeneration. They found the density of sapling were more abundant in canopy gaps than under closed canopies but large saplings were regenerating more often by sprout formation than by growth of saplings.

Pan and Zhang (2003) studied percentage of soil absolute moisture content at different succession stages of *Castanopsis platycantha, Schima sinensis* formation in central subtropical zone of Sinchuan province: found that different succession phases had significant effects on percentage of soil absolute moisture content.

Peng *et.al*. (2003) studied the effect of litter removal on plant species diversity and found that the mechanism of the effects of litter removal on biodiversity includes three factors:

removing the suitable habitat of microbes and animal decreasing the soil nutrient, changing the special habitat for the germination and growth of invading plants.

Rubino *et.al*. (2003) made a detailed study at southern Ohio forest, USA.They investigated the influence of topography (slope, aspect, percent slope and slope position) as calculated from a landrom index (LI) and plot characteristics (tree height, age and canopy cover0 on the distribution of trees (dbh>10cm), saplings (dbh<10cm). In all the three structural layers, slope aspect and LI were consistently important in explaining individual taxa distributions. Total tree density was significantly negatively correlated with slope position (r=-0.469), aspect (r=-0.328) and canopy cover (r=-0.391) and total sapling density was significantly negatively correlated with height of the dominant tree in each plot (r=-0.283).

Bhuju *et. al.* (2004) analyzed plant community dynamics and human activities in Swoyambhu forest, Kathmandu. They found that the dominant species at canopy stratum were *Schima wallichi; Chariaspondis* species.and *Pinus roxburghii* and study found that *Schima wallichi* has highest seed number.

Da Liang *et.al. (*2004) studied the population structure and regeneration types of dominant species in an evergreen broad-leaved forest in Titan tang National Forest Park, Zhejiang province eastern China. They found sporadic type (multipodal) species such as *Schima superba*, *Symplocos heischanensis; Machitus thunbergii* etc.were late seral stage species that regenerate in large gap and have intermediate shade tolerance. Reverse J type species such as *Castanopsis carlesii*, *C.fergeii, Lithocarpus horlandii* etc are shade tolerant. The successional stage of the forest was classified as a common late seral stage that would develop into a climax community dominated by *Castanopsis carlesii* and *C. fergesii*.

Hau *et.al. (*2004) concluded that *Quercus* seedlings and saplings were positively associated with co-specific adult trees and seed dispersal and vegetative regeneration influenced the spatial patterning of *Quercus* trees.

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.

Karmacharya *et.al*. (2004) studied human activities and vegetation dynamics in Bajrabarahi religious forest, Lalitpur. They found most frequently occurring tree species were *Schima wallichi, Ilex doniance* and *Neolitsea umbrosa* and found *Castanopsis tribuloides* had highest seedling and sapling density. Lastly, he found 3.7% of the trees were damaged due to natural and human disturbance.

Shrestha *et.al*. (2004), studied population structure of *Quercus semecarpifolia* Sm. (Khasru and reported abundant number of small seedlings (density: 3807/ha). But very rare sapling (density: 62/ha) and size class diagram of Khasru resembled bell shaped with higher density of medium sized.

Tiwari (2004) studied provenance variation and its analysis in *Castanopsis indica* (Roxb) in the central Nepal. He found that 90% of the vegetation had *Castanopsis indica* and showed positive correlation between the tree heights, age, thickness of bark and DBH.

Gautam and Watanable (2005) studied composition, distribution and diversity of tree species under different management systems in the hill forests of Bharse Village, Gulmi District, western Nepal. They found that tree density was higher in the controlled cut forest; species richness was highest in the forest opened for cattle grazing while species diversity and evenness were higher in the controlled cutting forest than the forest with grazing and cutting.

Shrestha (2005) studied the impact of forest resource use by the local people on forest community structure and regeneration of dominant species in two hill Sal forests of central Nepal. Regeneration of *Shorea robusta* was continuous in both forests with inverse J-shaped size class distribution. However regeneration of *Schima wallichi* was sporadic in both forests with bell shaped size class distribution.

Shrestha *et.al*. (2007) studied regeneration of tree line birch forest in a trans-Himalayan dry valley in Central Nepal. They found that *Betula utilis* was regenerating in both pure and mixed forests. However, the distribution of seedlings and saplings was spatially heterogeneous and appeared to depend on tree basal area.

3. STUDY AREA

3.1 Location and Physiography

Suryavinak, the present study area, lies on the south of Bhaktapur city at Central Nepal. The area is popular for Ganesh temple made by king Vishnu Dev. People gather every Tuesday for worship. This place is one of the nicest picnic and recreation spots in the Kathmandu valley.

Suryavinayak forest (28°37'-44'N, 85°21'-32'E, elevation: 1460-1585m above sea level, asl) covers an area of approximately 6.5km^2 (Malla, 1981). It is 14.4 km far from Kathmandu . The Suryavinayak hill is a continuous ridge but the cross drainage gully has dissected the area to form two distinct east and west peaks. A track leads through the gully to a small village, Gundu on the south of the east peak. On the north of east peak is a small village Bistagaon.Katunje is on the west of west peak and whole Bhaktapur city lies on the north of Suryavinayak hill. There are no streams in and around the hill but small water channel is present at the middle of the east peak. East, west and north facing slopes of the study area lies near to the human settlements so people continue to collect fuel wood and litter and bring their domestic animals for grazing. Some cut stems and fallen logs were also found in the east and west facing slopes. Army camp lies towards the south facing slope so this site of the study area was less disturbed.

According to Stainton (1972), Suryavinayak forest has subtropical vegetation. Here the soil is brownish yellow. The soil type is silty loam with higher percentage of silt deposited at the bottom due to washing from top by rain. It shows high percentage of potassium with little humus.

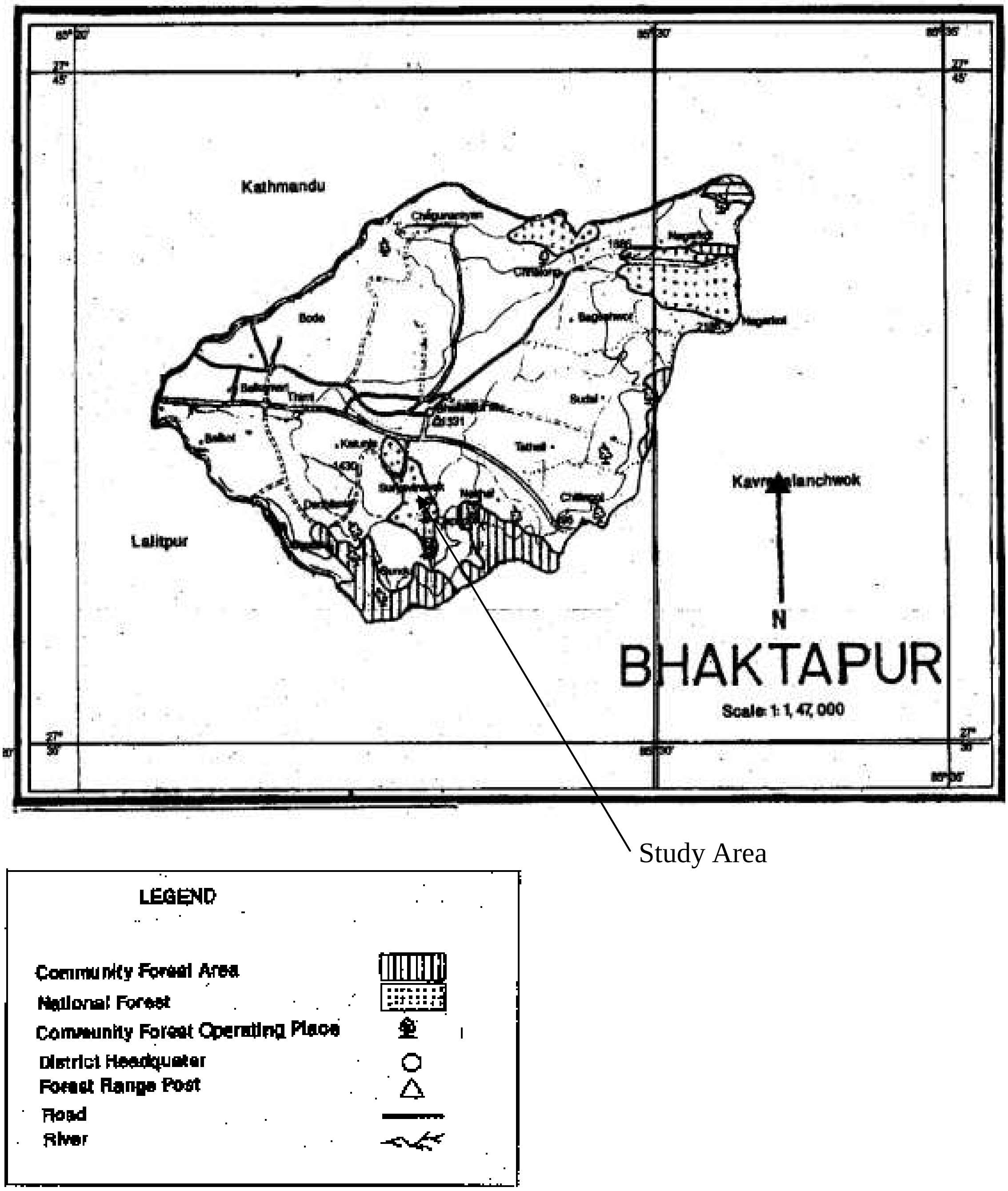


Fig: 1.Map of the Bhaktapur district showing the study area.

3.2. Climate

The study area lies on the eastern part of Kathmandu valley. Climate of Kathmandu valley can be divided into hot and dry summer (February-May), hot and humid rainy season (June-September), and cool and dry winter (October to January). Summer days are misty with poor visibility, and thunderstorm is common during evening. Due to monsoon pattern of rainfall, about 80% of annual rainfall occurred during rainy season. Winter days have foggy morning with few showers of rainfall. According to the nearest weather station, the monthly average minimum temperature ranged from 3.8°C to 16ºC and maximum from 14.1º C to 24.1 ºC (Fig.2). Total annual rainfall was 2849.8 mm and monsoon rainfall constituted 75% of the total rainfall in the year 2004.

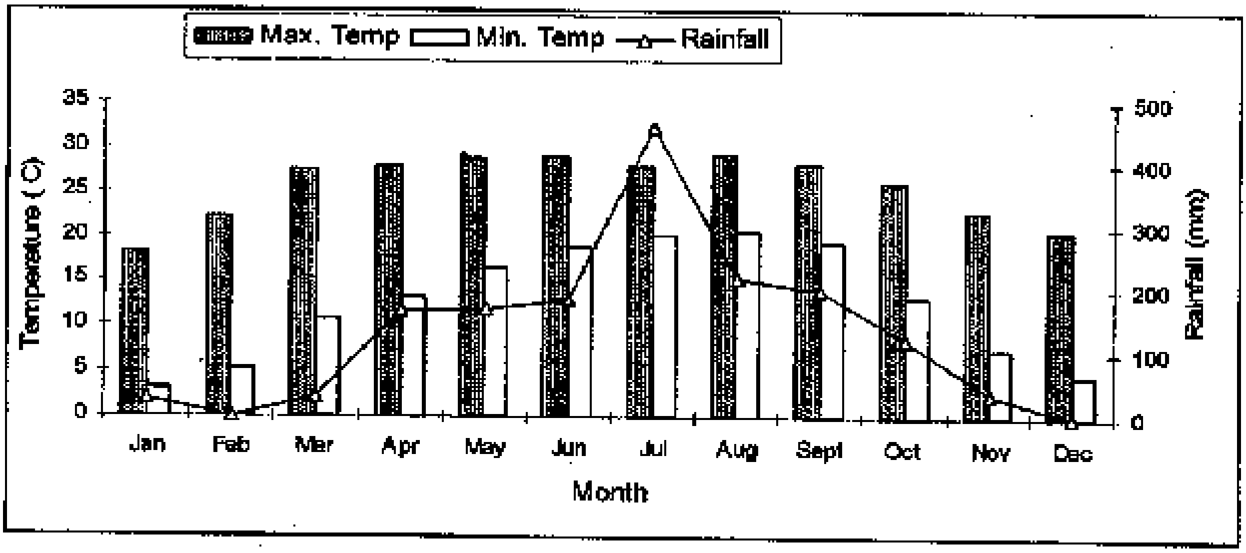


Fig.2: Monthly average temperature and rainfall of Tribhuvan International Airport weather station (27º 42' N, 85º 22'E, alt.1336m), Kathmandu in 2004 (Source: Department of Hydrology and Meteorology, HMG/Nepal). The study area is 9.6 km on the east from the station.

3.3 Soils and Vegetation

Soil layer is thin, erodable and infertile. Mostly, the soil colour is brownish yellow at most of the sites. The area under investigation constituted of mixed broad-leaved forest with dominant species such as *Castanopsis tribuloides, Schima wallichi*. Besides these, *Quercus glauca*, *Rhododendron arboreum, Lyonia ovalifolia* and *Myrica esculenta* are common. Dry localities of the area were usually inhabited by *Albizia lucidor, Berberis aristata*, *Conyza japonica*, *Desmodium concinum*, and *Elaeagnus latifolia*. Among the shrub species *Gaultheria fragrantissima*, *Berberis aristata*, *Rubus ellipticus, Phyllanthus parvifolius, Myrsine semiserrata* are common species.

4. MATERIALS & METHODS

The fieldwork was carried out to obtain a detailed primary quantitative data on the vegetation of the forest area. Studies upon regeneration status of *Schima wallichii* and *Castanopsis tribuloides* have been carried out along with vegetation composition, quantitative data of all tree, shrubs and sapling and soil nutrient determinations.

4.1 Vegetation Sampling

Vegetation was sampled by quadrat method (Kershaw, 1973). Sampling was done in four different slopes i.e. east, west, north and south. The phyto-sociological studies were conducted during the year 2004 using quadrat method. The size of quadrats was determined by species area curve method (Misra, 1968). The distance between two quadrats was made at least 50cm. Square quadrats (10m×10m) were sampled for trees; in each quadrat individual tree (diameter at breast height, dbh≥10cm) of each species were counted and dbh of each individual was measured. Altogether 40 quadrats were sampled for tree species, 10 quadrats in each slope. Each quadrat for trees was divided into four quarters (5m×5m) each and two of them lying diagonally were randomly selected for sampling shrub layer (sapling (dbh<10cm and >2.5cm) and shrub species). Therefore 80 quadrats were sampled for shrubs and saplings, 20 quadrats in each slope. Number of individuals of each species of shrubs, saplings and seedlings within the quadrat were recorded. Few species were identified in the field; for unidentified species herbarium specimens were collected and identified with the help of standard references (Stainton and Poulin 1987, Stainton 1988 and Shrestha 1998). Some specimens were identified by Prof. Dr. Krishna K. Shrestha (CDB, TU). Botanical nomenclature followed Hara *et al.* (1978), Hara and Williams (1979) and Press *et al.* (2000). Author citation was given in Annex 1.

4.2 Quantitative Analysis

The vegetation of the study area was analyzed based on quantitative characters. Quantitative characters for vegetation sampling such as frequency, density, dominance and their relative values were calculated by using the following formulae (Zobel *et.al.* 1987).

4.2.1 Frequency and relative frequency

The frequency of a species is a measure of chance of finding it in any one quadrat in a given area. In general, frequency is a useful measure of abundance where comparisons are to be made on a large scale. Relative frequency (R.F.) is the dispersion of one species in relation to that of total plant species.

$$Frequency(\%) = \frac{Total\ no\ of\ quadrats\ in\ which\ a\ species\ 'A'\ occured}{Total\ no.\ of\ quadrats\ sampled} \times 100$$

$$Relative\ Frequency\,(\%) = \frac{Frequency\ of\ a\ species\ 'A'}{Sum\ of\ frequencies\ of\ all\ the\ species} \times 100$$

4.2.2 Density and relative density

Density is the number of individuals per unit area. It represents the numerical strength of the species in the community. Relative density is a proportion of total number of individuals of species with the total number of individual of all species with area. The density of tree, saplings and seedlings were calculated by using the given formula.

$$Density(pl/ha) = \frac{Total\ number\ of\ individuals\ of\ a\ plant\ species\ 'A'}{Total\ number\ of\ quadrats\ sampled \times area\ of\ a\ quadrat(m^2)} \times 10000$$

$$Relative\ Density\,(\%) = \frac{Density\ of\ a\ species\ 'A'}{Total\ density\ of\ all\ the\ species} \times 100$$

4.2.3 Basal area and Relative dominance

Basal area of a species is the sum of basal area of all individuals of that species in the sampling plot.

$$Basal\ Area = \frac{®\,(dbh)^2}{4}$$

$$Relative\ Dominance\ (RDo,\%) = \frac{Basal\ Area\ of\ a\ species}{Total\ Basal\ Area\ of\ all\ species} \times 100$$

For cover of shrub layer the ground surface area occupied by each species, when canopy was vertically projected down, was visually estimated using the scale value given in Table 1 (Zobel *et al*.1987). Based on the range of cover mid point for each species was determined and used to calculate relative cover.

Table 1: Scale values used to estimate cover of shrub layer.

Scale	Range of cover (%)	Mid point of cover (%)
1	0-1	0.5
2	1-5	2.5
3	5-25	15
4	25-50	37.5
5	50-75	62.5
6	75-95	85
7	>95	97.5

$$Cover(\%) = \frac{Sum\ of\ mid\ po\mathrm{int}\ values\ of\ a\ species\ 'A'\ from\ all\ quadrats}{Toal\ number\ of\ quadrats\ sampled}$$

$$Relative\ cover\ (\%) = \frac{Cover\ of\ a\ species\ 'A'}{Toal\ \mathrm{cov}er\ of\ all\ species} \times 100$$

Importance Value Index (IVI) was determined as the sum of relative values of frequency, density and basal area (cover for shrub layer).

IVI= RD + RF + RDo (For trees)

IVI = RD + RF + RC (For shrubs)

Where, RD= Relative density

RF= Relative frequency

RDo = Relative dominance

RC = Relative coverage.

4.3 Species Diversity

Among the several indices, most commonly used two indices of species diversity are Simpson’s index (Simpson 1949) and Shanon-Wiener’s index (Shanon and Weaver 1949). Simpson’s index (C) reflects dominance and Shanon-Weaver index (H’) reflects species diversity; thus Simpson’s index is also called Index of Dominance. They were calculated as follows:

$$C = \sum_{i=1}^{s} (Pi)^2$$

$$H' = -\sum_{i=1}^{s} (Pi)(\ln Pi)$$

Where, C= Simpson index of dominance

S= Total number of species

Pi= Proportion of all individuals in the sample that belongs to species i.

H’= Shanon-Wiener index.

4.4 Similarity Index

To compare vegetation composition among various slopes similarity index (SI) was calculated following Sorenson (1948). It gives the degree of similarity between any two stands, which depends in the qualitative phyto-sociological characters of species common to both stands.

$$SI = \frac{2C}{A+B} \times 100$$

Where, A=Total number of species on site A.

B= Total number of species on site B.

C = Number of species common to both sites A and B.

4.5 Beta ( ) Diversity

Beta (β) diversity is a measure of species turnover across various habitats; therefore it is also called inter habitat diversity. It is the difference in species diversity between areas or communities, which represents difference in species composition. It was calculated using following formula (Whittaker 1972)

$$= \frac{Sc}{S}$$

Where, Sc = Total number of species that occurred in two facing slopes.

S = Average number of species in two facing slopes

4.6 Size-class distribution

Circumference at breast (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 (height<30cm) (Sundriyal and Sharma, 1996). All the tree species were divided into different size classes based on DBH of 5cm intervals, given a total of 9 size classes.

4.7 Soil Sampling and Laboratory Analysis

Forest soil was sampled to determine some physical and chemical characters. A single soil sample was collected from each quadrat (10m×10m) at 15cm depth; it was the mixture of five sub-samples (each about 100g) collected each from four corners and the center of each quadrat. All soil samples collected from each quadrat were mixed thoroughly and divided into three sub samples (replicas). Soil samples were collected in airtight plastic bags, later the soil was air dried in shade. Soil moisture was analyzed at laboratory of Ecology, Central Department of Botany while total Nitrogen (N, %), available Phosphorus (P, kg/ha), available Potassium (K, kg/ha), pH and Organic matter (OM, %) were determined at Soil Science Division of Agriculture Department, Harihar Bhawan (Lalitpur). Details of the methods used for soil analysis are given below.

4.7.1 Soil Moisture

10 g fresh soil sample was taken in pre weighed crucible with lid and oven dried at 80°C for 48 hours; it was cooled and weighed by physical balance (0.1g). Soil moisture was calculated as the percentage of dry mass (Zobel *et al*.1987).

$$Soil\ Moisture\ (\%) = \frac{F-D}{D} \times 100$$

Where, F= Fresh mass of the soil (g)

D= Oven dry mass of the soil (g)

4.7.2 Soil pH

Soil pH was measured in 1:1 mixture of soil and distilled water using electric pH meter. The pH meter was calibrated using standard buffer solution of pH 4.0 and 6.86.

4.7.3 Soil Organic matter (OM)

Organic matter (OM) was determined by Walkley and Black Method. 1g air-dried soil was taken in a conical flask (500ml) and 10 ml 1N $K_2Cr_2O_7$ (Potassium dichromate) solution was added to it. Then 20 ml conc. H_2SO_4 was added to the mixture with gentle rotation. The mixture was allowed to stay for half an hour. A standardized blank without soil was also run in the same way. After half an hour, 200ml distilled water, three drops diphenylamine indicator and 0.2 g NaF (Sodium fluoride) was added and titrated with 0.5N $(NH_4)_2SO_4.6H_2O$ (ferrous ammonium sulphate, FAS) solution. The end point was noted when the color became brilliant green, OM (%) was calculated using following formula:

$$OM(\%) = \frac{(B-S)N}{M} \times 0.0067 \times 100$$

Where, B= Volume of FAS used up for blank titration

S= Volume of FAS used up for sample titration

N= Normality of FAS

M= Mass of soil.

4.7.4 Nitrogen (N)

Total Nitrogen content in the soil was determined by micro-Kjeldahl method.1g air-dried soil was taken in Kjeldahl digestion flask (50ml) and 2g catalyst (Sodium sulphate and anhydrous copper sulphate in 20:1) and 10ml conc. H_2SO_4 was added to it. The mixture was heated to 410ºC in Block digester until the color changed to greenish blue. The flask was cooled and 20ml distilled water was added to it. The solution was transferred in 100ml volumetric flask. 20ml aliquot was taken in distillation flask, added 20mL 40% NaOH and subjected to distillation. The distillate containing ammonia was collected in 10 ml 4% boric acid solution containing two drops of mixed boric acid indicator with ammonia was titrated with HCl (0.01N). A blank without soil was run for each batch of 12 samples.

$$Nitrogen(\%) = \frac{(T-B) \times N \times 14}{S} \times 100$$

Where, T= Volume of HCl used for sample titration (ml)

B= Volume of HCl used for blank titration (ml)

N= Normality of Hydrochloric acid (N)

S= Sample mass (mg)

4.7.5 Available Phosphorus (P)

Available phosphorus was determined by Olsen's modified carbonate method. 2.5 g of air-dried soil was taken in a 100ml polyethylene bottle. One teaspoon of activated charcoal (Darco G-60) and 50 ml 0.5 N $NaHCo_3$ extracting solution was added to it. It was shaked for 30 minutes in a shaker and filtered through Whatman no.42 filter paper.10 ml of aliquot was taken in 50ml volumetric flask and acidified with 5N H_2SO_4 to pH 5.0 using nitro phenol indicators till the yellow color just disappeared. H_2SO_4 was further added till it became colorless. Distilled water (40ml) was added washing the wall of the flask followed by 8ml of reagent prepared by dissolving 1.056 g ascorbic acid in 200ml ammonium molybdate and shaked well. Blue color was obtained in this final volume. The color intensity was measured in the spectrophotometer using red filter (660 nm) including the blank solution at each batch. Standard curve was prepared by taking 2ppm phosphorus standard solution (0, 1, 2, 4, 6, 8, 10, 12), $NaHCo_3$ solution was added to it and run out like test solution. 2ppm phosphorus standard solution was prepared by diluting 20ml of 50 ppm phosphorus to 500ml. 50 ppm phosphorus was prepared by dissolving 0.2195g of KH_2PO_4 in 400ml distilled water and adding 25ml, 7N H_2SO_4 and making the volume 1L by adding more distilled water. The value of P was determined from this graph.

Phosphorus (kg/ha) = F X R

Where, F= Coefficient factor calculated from blank solution.

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

4.7.6 Available Potassium (K)

Potassium (K) was measured by flame photometer method. 2g air-dried soils was taken in a 125 ml conical flask; 20ml of normal neutral ammonium acetate was added, shaked for 5 minutes in a mechanical shaker and filtered through Whatman No. 42 filter paper. A standard curve of potassium standard solution (0, 5, 10, 15, 20 and 25 ppm K) was prepared. To prepare the potassium standard solution 0, 5, 10, 20 and 25 ml of 100-ppm potassium solutions were dissolved in 0.1905g-dried KCl in 1L volumetric flask. Soil solution was aspirated, flame photometer reading was noted and value of K in the soil solution was noted from graph. It was calculated by using following formula.

$$K_2O(kg/ha) = R \times \frac{20}{2} \times 1.2 \times 2 \times 1.12 = R \times 26.88$$

Where, R=Potassium of soil extract in ppm (from the standard curve)

1.2= Conversion factor for K to K_2O

2x1.2= Conversion factor for ppm to kg/ha

20/2= Dilution factor

4.8 Statistical Analysis

All statistical analysis was done on various parameters using statistical packages for social science (SPSS) software version 10 for windows. For this, correlation was considered. For the better comparative study of soil parameters and other vegetative characters was used in order to view if there was any relation between two different parameters.

5. RESULTS

5.1. Vegetation

5.1.1 Tree

Total tree density in the study area ranged from 640 to 1115 pl/ha (Tables 2 to 5). In east, north and south facing slopes, *Schima wallichii* had highest density (610.5 pl/ha, 862.5 pl/ha and 262.5 pl/ha respectively), frequency (75%, 100% and 87.5% respectively) and basal area (28.2m^2/ha, 10.87m^2/ha and 15.91m^2/ha respectively). In west facing slope, *Castanopsis tribuloides* had highest density (137.5pl/ha), frequency (62.5%) and Basal area (23.64m^2/ha) (Tables 2- 5).

The IVI was highest for *Schima wallichii* (200.81) in north facing slope followed by *Castanopsis tribuloides* (72.04) in west facing slope. *Schima wallichii*, *Castanopsis tribuloides* and *Rhododendron arboreum* were present in all four slopes. West and south facing slopes had the largest number (Eight) of common species; IVI of most of the common species were higher at south facing slope. *Eurya accuminata* was present only in south facing slope. *Alnus nepalensis* was present in west and south facing slopes and *Quercus lanata* was present in north facing slope only.

Table: 2. Density (D, Pl/ha), Relative Density (RD%), Frequency (F, %), Relative Frequency (RF, %), Basal Area (m^2/ha), and Relative Dominance (RDom, %) of tree layer at East facing slope.

Name of species	D (Pl/ha)	RD (%)	F (%)	RF (%)	BA (m^2/ha)	RDom (%)	IVI
Schima wallichii	610.50	67.12	75.0	31.58	28.20	41.49	140.19
Castanopsis tribuloides	125.00	13.70	50.0	21.05	15.30	22.50	57.25
Rhododendron arboreum	62.50	6.85	37.5	15.79	10.71	15.75	38.39
Myrica esculenta	50.00	5.48	37.5	15.79	6.11	9.00	30.27
Quercus glauca	37.50	4.11	25.0	10.53	4.58	6.75	21.39
Quercus lamellose	25.00	2.74	12.5	5.26	3.06	4.50	12.50
Total	911	100	238	100	68	100	300

Table: 3. Density (D, Pl/ha), Relative Density (RD, %), Frequency (F, %), Relative Frequency (RF, %), Basal Area (m^2/ha) and Relative Dominance (RDom, %) of tree layer at West facing slope.

Name of species	D (Pl/ha)	RD (%)	F (%)	RF (%)	BA (m^2/ha)	RDom (%)	IVI
Castanopsis tribuloides	137.5	21.57	62.5	16.67	23.64	33.81	72.04
Schima wallichii	113.5	17.65	62.5	16.67	19.06	27.26	61.57
Alnus nepalensis	50	7.84	37.5	10	16.04	22.95	40.79
Rhododendron arboreum	100	15.69	50.0	13.33	2.66	3.81	32.83
Quercus semicarpifolia	87.5	13.73	37.5	10	0.84	1.21	24.93
Quercus lamellose	62.5	9.80	50.0	13.33	0.75	1.07	24.21
Pyrus pashia	37.5	5.88	37.5	10	4.91	7.02	22.90
Quercus glauca	37.5	5.88	25.0	6.67	1.90	2.72	15.27
Myrica esculenta	13.5	1.96	12.5	3.33	0.12	0.16	5.46
Total	640	100	375	100	70	100	300

Table: 4. Density (D, Pl/ha), Relative Density (RD, %), Frequency (F, %), Relative Frequency (RF, %), Basal Area (m^2/ha), and Relative Dominance (RDom, %) of tree layer at North facing slope.

Name of species	D (Pl/ha)	RD (%)	F (%)	RF (%)	BA (m^2/ha)	Rdom (%)	IVI
Schima wallichii	862.5	77.53	100	44.44	10.87	78.84	200.81
Castanopsis tribuloides	75	6.74	37.5	16.67	0.68	4.96	28.37
Quercus lanata	50	4.49	25	11.11	0.72	5.25	20.86
Rhododendron arboreum	52	4.49	25	11.11	0.34	2.46	18.06
Lyonia ovalifolia	37.5	3.37	25	11.11	0.42	3.02	17.50
Quercus semecarpifolia	37.5	3.37	12.5	5.56	0.76	5.47	14.40
Total	1115	100	225	100	14	100	300

Table: 5. Density (D, Pl/ha), Relative Density (RD, %), Frequency (F, %), Relative Frequency (RF,%), Basal Area (m^2/ha), and Relative Dominance (RDom, %) of tree layer at South facing slope.

Name of species	D (Pl/ha)	RD (%)	F (%)	RF (%)	BA (m^2/ha)	RDom (%)	IVI
Schima wallichii	262.5	28	87.5	21.87	15.91	46.30	96.18
Castanopsis tribuloides	150	16	62.5	15.62	4.28	12.47	44.10
Quercus lamellose	87.5	9.33	37.5	9.37	6.36	18.51	37.21
Rhododendron arboreum	138.5	14.66	50	12.50	1.99	5.81	32.98
Pyrus pashia	50	5.33	37.5	9.37	1.56	4.54	19.25
Myrica esculenta	38.5	4	37.5	9.37	1.78	5.20	18.58
Quercus glauca	75	8	37.5	9.37	0.01	0.03	17.37
Lyonia ovalifolia	63.5	6.66	25	6.25	1.15	3.37	16.28
Alnus nepalensis	50	5.33	12.5	3.12	0.88	2.57	11.03
Euriya accuminata	25	2.66	12.5	3.12	0.41	1.20	6.99
Total	941	100	400	100	35	100	300

5.1.2 Shrub/Sapling

Total density of the shrub/sapling was highest in west facing slope (7904 pl/ha) and lowest in north facing slope (3275 pl/ha) (Tables 7 and 8). In case of shrub, *Phyllanthus parvifolius* had the highest density in south, east and west facing slopes (2100pl/ha, 1015pl/ha and 3725pl/ha respectively) and its density increased from 1015 pl/ha in east facing slope to 3725pl/ha in west facing slope. In case of sapling layer, saplings of *Castanopsis tribuloides* dominated the forest at almost all slopes, followed by *Schima wallichii*. *Castanopsis tribuloides* had highest density (370 pl/ha, 350 pl/ha, 575 pl/ha and 500pl/ha respectively) in all four east, west, north and south facing slopes, followed by *Schima wallichii* (Tables 6-9)

In east facing slope, sapling density of *Schima wallichii* had highest IVI (37.79), followed by *Castanopsis tribuloides* (30.20) where as in case of shrub, *Phyllanthus parvifolius* had highest IVI (49.87) and *Myrica esculenta* had the lowest (2.90) (Table 6). In west facing slope, *Castanopsis tribuloides* had highest IVI (16.89), followed by *Myrica esculenta*

(7.94) where as in case of shrub, *Phyllanthus parvifolius* had the highest IVI (72.51) and *Buddleja asiatica* had lowest (3.23) (Table 7). In north facing slope, *Castanopsis tribuloides* had the highest IVI (40.15), followed by *Schima wallichii* (21.89) where as in case of shrub, *Rubus ellipticus* had highest IVI (71.94) and *Desmodium heterocarpon* had the lowest (10.30) (Table 8).

Similarly, in south facing slope, *Schima wallichii* had the highest IVI (37.14), followed by *Castanopsis tribuloides* (28.32) and *Alnus nepalensis* had the lowest (5.63). *Phyllanthus parvifolius* in south (35.5%) and west (37.5%) facing slope had the highest coverage among all four slopes. Sapling of *Schima wallichii* had the highest coverage in south and east facing slope (18% and 15%). But sapling of *Castanopsis tribuloides* had the highest coverage in north and west facing slope (15%). The number of tree species in their sapling stages was highest in east facing slope. Most of the species in shrub/sapling layer had low coverage (0.50%). Species with lowest relative coverage (0.17%) was found in west facing slope (Table 7). The IVI of shrub/sapling layer showed irregular pattern with facing slopes. Most of the shrub/sapling species present in one slope were absent in other slope. *Phyllanthus parvifolius* had the highest IVI in east, west and south facing slope revealing its ecological importance in these sites and was completely absent in north facing slope (Table 8). Several individual species in east facing slope had low IVI (<10) whereas it was relatively high in north facing slope.

Table: 6. Density (D, Pl/ha), Relative Density (RD, %), Frequency (F, %), Relative frequency (RF, %), Coverage (C, %), and Relative Coverage (RC, %) of shrub/sapling layer at east facing slope.

Name of species	D (Pl/ha)	RD (%)	F (%)	RF (%)	C (%)	RC (%)	IVI
Shrubs							
Phyllanthus parvifolius	1015	20	37.50	6.97	15	22.79	49.87
Melastoma normale	400	7.84	50	9.30	3	4.55	21.70
Osbeckia stellata	250	4.90	31.25	5.81	0.50	0.76	11.47
Gaultheria fragrantissima	225	4.41	25	4.65	0.50	0.76	9.82
Desmodium heterocarpon	300	5.88	45.75	8.14	3	4.59	8.58
Berberis aristata	150	2.94	18.75	3.48	0.50	0.76	7.18
Rubus ellipticus	200	3.92	12.50	2.32	0.50	0.76	7
Rhus javanica	200	3.92	25	4.65	0.50	0.76	5.53
Camellia kissi	125	2.85	12.50	2.32	0.50	0.76	5.53
Myrica esculenta	50	0.98	6.25	1.16	0.50	0.76	2.90

Saplings							
Schima wallichii	250	4.90	42.75	8.14	0.50	22.79	37.79
Castanopsis tribuloides	370	7.15	18.75	3.48	15	22.79	30.20
Myrsine semiserrata	200	3.92	50	9.30	3	4.55	21.21
Eurya accuminata	175	3.63	25	4.65	3	4.55	12.64
Rhus wallichi	175	3.63	25	4.65	0.50	0.76	8.84
Quercus lanata	150	2.94	25	4.65	0.50	0.76	8.35
Prunus cerasoides	150	2.94	18.75	3.48	0.50	0.76	7.18
Rhus javanica	150	2.94	12.50	2.32	0.50	0.76	6.02
Rhododendron arboreum	125	2.85	15.50	2.32	0.50	0.76	5.53
Quercus glauca	75	1.47	12.50	2.32	0.50	0.76	4.56
Pyrus pashia	75	1.47	6.25	1.16	0.50	0.76	3.39
Quercus lamellose	75	1.47	6.25	1.16	0.50	0.76	3.39
Alnus nepalensis	50	0.98	6.25	1.16	0.50	0.76	2.90
Lyonia ovalifolia	25	0.49	6.25	1.16	0.50	0.76	2.41
Myrsine capitellata	25	0.49	6.25	1.16	0.30	0.45	2.10
Total	4985	100	541.5	100	51.1	100	300

Table: 7. Density (D, Pl/ha), Relative Density (RD, %), Frequency (F, %), Relative frequency (RF, %), Coverage (C, %), and Relative Coverage (RC, %) of shrub/sapling layer at west facing slope.

Name of species	D (Pl/ha)	RD (%)	F (%)	RF (%)	C (%)	RC (%)	IVI
Shrubs							
Phyllanthus parvifolius	3725	46.49	100	13	37.5	13.02	72.51
Osbeckia stellata	675	8.42	81.3	10.57	85	29.51	48.50
Gaultheria fragrantissima	775	10.92	100	13	62.5	21.70	45.63
Melastoma normale	775	9.67	62.5	8.10	62.5	21.70	39.50
Berberis aristata	463	5.77	56.3	7.31	15	5.20	18.29
Desmodium concinum	225	2.80	62.5	8.13	0.5	0.17	11.12
Rubus ellipticus	215	2.80	56.3	7.31	5	1.04	3.54
Buddleja asiatica	50	0.62	15.8	2.43	0.5	0.17	3.23

Saplings							
Castanopsis tribuloides	350	4.36	56.3	7.31	15	5.20	16.89
Myrica esculenta	163	2.02	31.5	4.87	5	1.04	7.94
Schima wallichii	125	1.56	31.3	4.06	0.5	0.17	5.79
Quercus glauca	125	1.56	31.3	4.06	0.5	0.17	5.79
Rhododendron arboreum	75	0.93	18.8	2.43	0.5	0.17	3.54
Lyonia ovalifolia	75	0.93	18.8	2.43	0.5	0.17	3.54
Quercus lanata	38	0.46	12.5	1.62	0.5	0.17	2.26
Eurya accuminata	25	0.31	12.5	1.62	0.5	0.17	2.11
Prunus cerasoides	25	0.31	12.5	1.62	0.5	0.17	2.11
Total	7904	100	760	100	292	100	300

Table: 8. Density (D, Pl/ha), Relative Density (RD, %), Frequency (F %), Relative frequency (RF, %), Coverage (C, %), and Relative Coverage (RC, %) of shrub/sapling layer at North facing slope.

Name of the species	D (Pl/ha)	RD (%)	F (%)	RF (%)	C (%)	RC (%)	IVI
Shrubs							
Rubus ellipticus	850	25.95	68.75	22.91	3	23.07	71.94
Camellia kissi	650	19.84	18.75	6.25	3	23.07	49.17
Berberis aristata	100	3.05	18.75	6.25	3	23.07	32.38
Osbeckia stellata	275	8.39	31.25	10.41	0.5	3.84	22.66
Melastoma normale	125	3.81	12.50	4.16	0.5	3.84	11.83
Desmodium heterocarpon	75	2.29	12.50	4.16	0.5	3.84	10.30
Saplings							
Castanopsis tribuloides	575	17.55	56.25	18.75	15	3.84	40.15
Schima wallichii	250	7.63	31.25	10.41	0.5	3.84	21.89
Quercus glauca	200	6.10	25	8.33	0.5	3.84	18.28
Quercus lanata	125	3.81	12.5	4.16	0.5	3.84	11.83
Rhododendron arboreum	50	1.52	12.50	4.16	0.5	3.84	9.54
Total	3275	100	300	100	13	100	300

Table: 9. Density (D, Pl/ha), Relative Density (RD, %), Frequency (F, %), Relative frequency (RF, %), Coverage (C, %), and Relative Coverage (RC, %) of shrub/sapling layer at South facing slope.

Name of the species	D (Pl/ha)	RD (%)	F (%)	RF (%)	C (%)	RC (%)	IVI
Shrubs							
Phyllanthus parvifolius	2100	49.12	91.75	28.30	35.5	51.72	129.14
Berberis aristata	325	7.60	35.50	11.32	3	4.13	23.06
Desmodium concinum	100	2.33	18.75	5.66	5	6.89	16.06
Osbeckia stellata	200	4.67	25	7.54	0.5	0.63	12.91
Camellia kissi	125	2.92	12.50	3.77	0.5	0.69	7.38
Rubus ellipticus	100	2.33	12.50	3.77	0.5	0.69	6.80
Saplings							
Schima wallichii	300	7.01	31.25	9.43	18	20.69	37.14
Castanopsis tribuloides	500	13.65	38.50	11.32	3	4.13	28.32
Quercus lamellose	125	2.92	12.50	3.77	3	4.13	10.83
Rhododendron arboreum	120	2.82	18.75	5.66	0.5	0.69	9.27
Quercus glauca	100	2.33	12.50	3.77	0.5	0.69	6.80
Rhus wallichi	25	0.58	6.25	1.88	3	4.13	6.61
Alnus nepalensis	50	1.17	12.50	3.77	0.5	0.69	5.63
Total	4170	100	328	100	74	100	300

5.1.3 Total number of species, Diversity and Similarity Index

Total number of species (S) in tree layer (10) was the highest in south facing slope where as it was the highest for shrub layer (25) in east facing slope. Simpson’s Index of dominance (C) for tree layer was the highest (0.50) in west facing slope and for shrub layer it was highest (0.25) at south facing slope where Shanon-Wiener Index of species diversity (H’) for tree layer (1.03) was highest at south facing slope and for shrub layer it was equal (0.25) in north facing slope and lowest (0.17) at east facing slope.

Table: 10. Total number of species (S), Simpson's Index of Dominance(C) and Shanon-Wiener Index of species Diversity (H') for tree and shrub/sapling layers.

Facing slopes	S		C		H'	
	Tree layer	Shrub layer	Tree layer	Shrub layer	Tree layer	Shrub layer
East	6	25	0.14	0.07	0.23	0.17
West	9	17	0.50	0.16	0.19	0.24
North	6	11	0.45	0.14	0.25	0.25
South	10	13	0.12	0.25	1.03	0.25

Table: 11. Similarity Index and diversity of tree and shrub/sapling layers among different facing slopes.

Facing slopes	Similarity Index (%)		Diversity	
	Tree layer	Shrub layer	Tree layer	Shrub layer
East and West	30	34	1.65	1.51
West and South	40	20	1.50	1.60
South and North	64.64	48	1.38	1.40
East and South	61.54	38	1.48	1.50
East and North	69.23	56	1.54	1.33
West and North	54.23	52	1.27	1.62

Similarity Index for tree layer (69.23) was highest between east and north facing slope and lowest (30) between east and west facing slope while β-diversity was highest (1.65) between east and west facing slope and lowest (1.27) between west and north facing slope (Table 11). In shrub/sapling layer highest (56) similarity index was between east and north facing slope and lowest (20) between west and south facing slope while β-diversity was highest (1.62) between west and north facing slope and lowest (1.33) between east and north facing slope. β-Diversities of tree and shrub layers for the entire facing slope (from east to south) were nearly equal.

5.2 Soil Characters

Moisture content was highest (64.79%) in north facing slope and lowest (28.21%) in west facing slope. Soil was acidic with average pH 4.01 to 4.2.The average value of soil organic matter and nitrogen was highest (10.09% and 0.44% respectively) in west facing slope and lowest (3.52% and 0.16%) in north facing slope. But phosphorus content was highest (129.33kg/ha) in east facing slope and lowest 51.31kg/ha) in west facing slope. Potassium content was highest (286.05kg/ha) in west facing slope and lowest (118.27kg?ha) in east facing slope (Table 12).

Table: 12. Average soil pH, Organic matter (OM), Nitrogen (N), Phosphorus (P) and Potassium (K) at different facing slopes.

Facing slopes	Moisture (%)	PH	OM (%)	N (%)	P (kg/ha)	K (kg/ha)
East	30.15	4.01	6.03	0.20	129.33	118.27
West	28.21	4.10	10.09	0.44	51.31	286.05
North	64.79	4.20	3.52	0.16	60.59	120.80
South	59.20	4.02	9.0	0.40	90.30	168.30

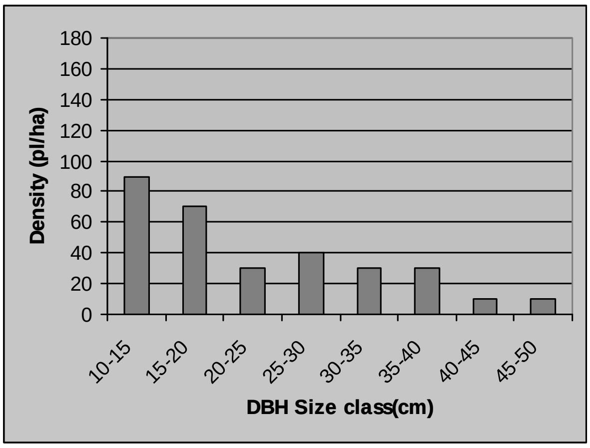
5.3 Regeneration of *Schima wallichii* (DC.) Korth and *Castanopsis tribuloides* (Sm.A.DC.)

5.3.1 Size-class distribution

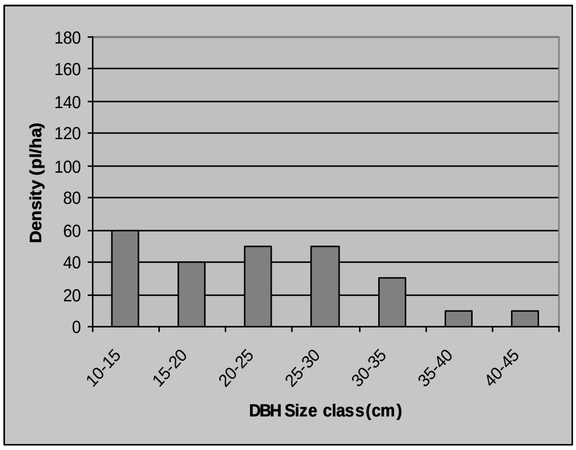
The DBH size classes of all the tree species measured were categorized into diameter class of interval of 5cm.Altogether nine size classes were categorized for the tree species.

The size class distribution of *Schima wallichii* indicated nearly reversed J-shaped structure in east, north and south facing slopes but the diagram resembles a typical bell shape at west facing slope. In contrast to population structure of *Castanopsis tribuloides*, there was representation of all middle girth classes in the population of *Schima wallichii* (Figure: 3).

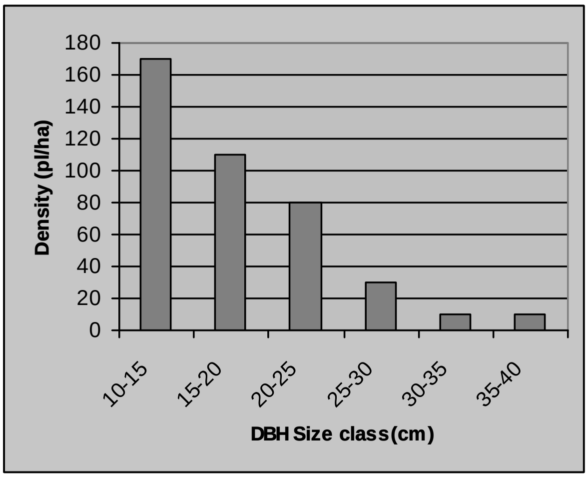
The size class distribution of *Castanopsis tribuloides* resembles nearly reversed J-shaped size class diagram at north and south facing slopes. However, 1-2 middle girth classes were missing in all slopes. Two diameter classes (20-25cm, 25-30cm) in east, one diameter class (15-20cm) in west, one diameter class (35-40 cm) in north and one diameter class (20-25cm) in south facing slope were missing from the population of *C. tribuloides* (Fig: 3). Large trees with dbh>55 cm were absent from all sites. Being community forest people use trees of high girth classes for firewood and for the construction purposes



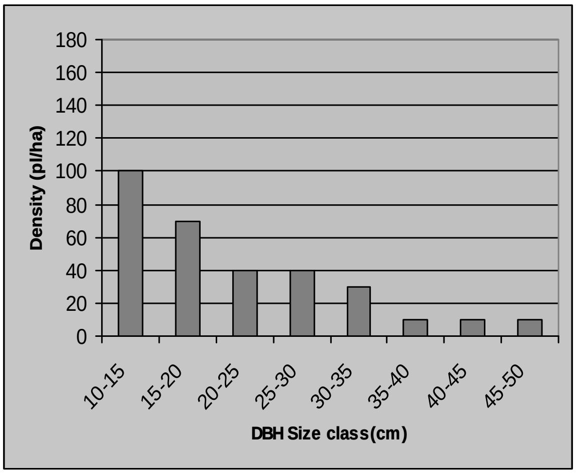
East Facing Slope



West Facing Slope

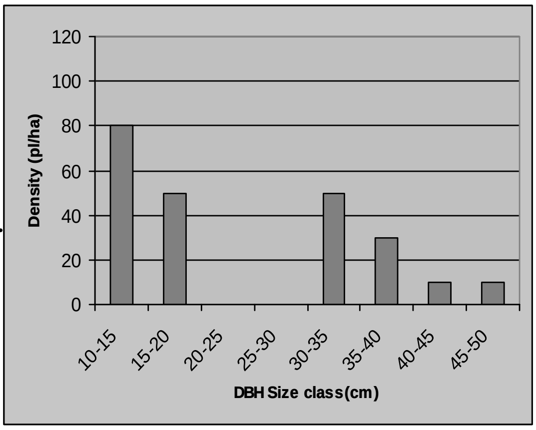


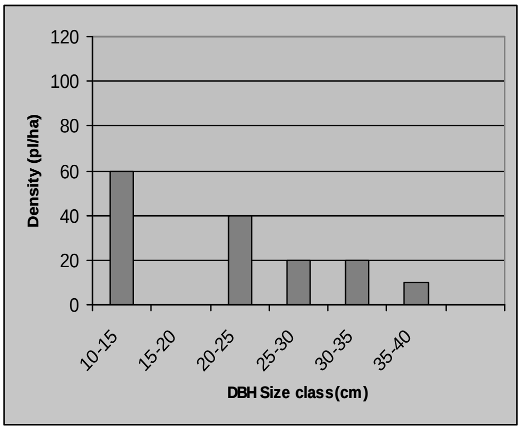
North Facing Slope



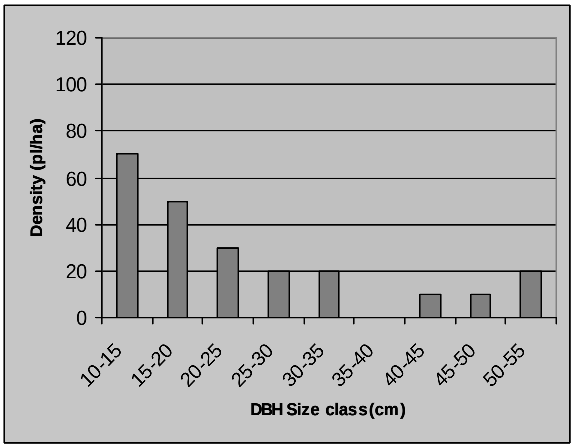
South Facing Slope

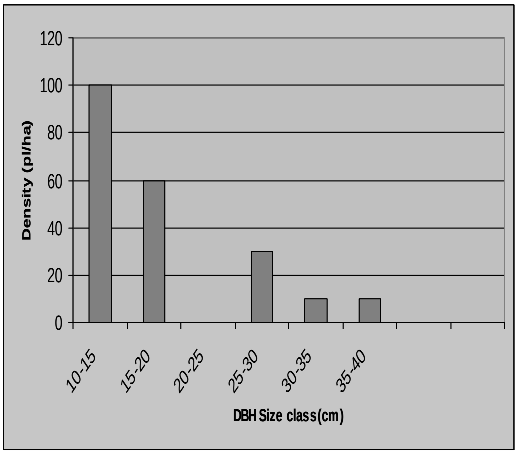
Figure: 3. DBH size class distribution of *Schima wallichii* population in different slopes.





East Facing Slope **West Facing Slope**





North Facing Slope **South Facing Slope**

Figure: 4.DBH size class distribution of *Castanopsis tribuloides* population in different slopes.

5.3.2 Seedling and Sapling density

The density of seedlings and saplings of *Schima wallichii* and *Castanopsis tribuloides* were good in all slopes. Average density of seedlings of *Schima wallichii* ranged from 450 to 1000 pl/ha and that of *Castanopsis tribuloides* ranged from 600 to 1850 pl/ha (Figure 5). The highest seedling density of *Schima wallichii* was found in north facing slope (1000 pl/ha) and the lowest (450 pl/ha) in west facing slope. Similarly, the highest seedling density of *Castanopsis tribuloides* was found at north facing slope (1850 pl/ha) and the lowest (600 pl/ha) on west facing slope (Figure 5).

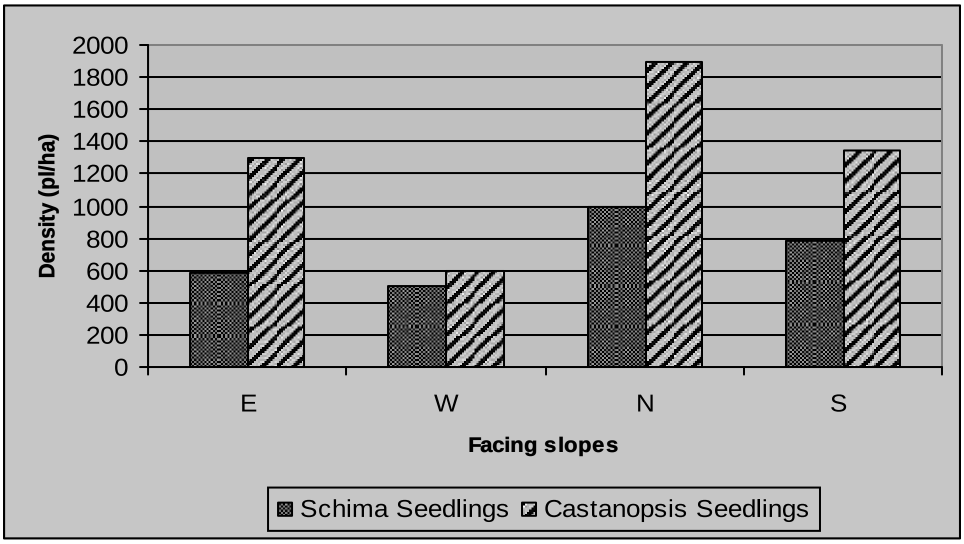


Figure: 5. Seedling densities of *Schima wallichii* and *Castanopsis tribuloides* in different slopes.

Average sapling density of *Schima wallichii* ranged from 120 to 300 pl/ha and that of *Castanopsis tribuloides* ranged from 350 to 590 pl/ha (Figure 6). The highest sapling density of *Schima wallichii* was found in south facing slope (300 pl/ha) where as lowest density was found in west facing slope (120 pl/ha). Similarly, the highest sapling density of *Castanopsis tribuloides* was found in north facing slope (590 pl/ha) and lowest in west facing slope (350 pl/ha).

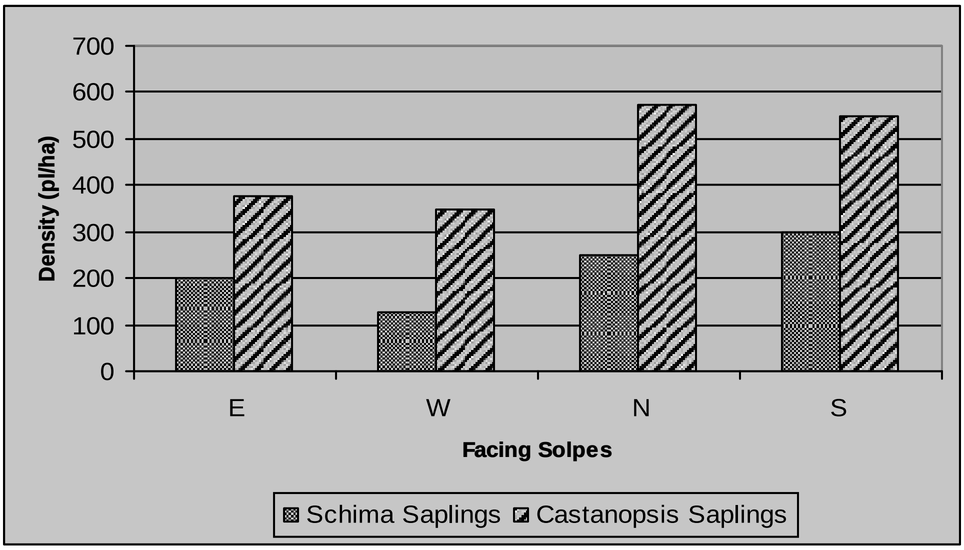


Figure: 6.Sapling densities of *Schima wallichii* and *Castanopsis tribuloides* in different slopes.

5.4. Statistical Analysis (Correlation Coefficient)

The correlation between soil parameters and vegetation characteristics for *Schima* and *Castanopsis* species (Tables 14 to 17) showed that in east facing slope, seedling density of *Schima wallichii* was negatively correlated with seedling density of *C.tribuloides* (p=0.01) and soil phosphorus (p=0.05) but positively correlated with soil moisture (p=0.05). Sapling density of *Schima wallichii* was negatively correlated with seedling density of *C. tribuloides* (p=0.01) and organic matter (p=0.05). *C. tribuloides* seedling was negatively correlated with soil pH (p=0.01) and soil nitrogen (p=0.01). *C. tribuloides* sapling was positively correlated with soil nitrogen (p=0.01) and negatively correlated with soil organic matter (p=0.05).

Table: 13. Correlation coefficient between different variables with *Schima-Castanopsis* seedlings and saplings at east facing slope.

	SSEED	SSAP	CSEED	CSAP	pH	MOIST	OM	N	P	K
SSEED	1									
SSAP	0.232	1								
CSEED	-0.647**	-0.580**	1							
CSAP	-0.108	0.013	0.288	1						
pH	-0.115	0.020	-0.510*	-0.204	1					
MOIST	0.432*	0.244	0.313	-0.297	-0.237	1				
OM	-0.124	-0.421*	-0.152	-0.362*	-0.032	-0.171	1			
N	-0.199	-0.124	-0.594**	0.671**	-0.081	-0.137	0.295	1		
P	-0.434*	-0.337	0.294	-0.338	-0.331	0.276	-0.305	-0.335	1	
K	0.200	0.247	-0.278	0.077	-0.130	-0.172	-0.088	-0.083	0.138	1

SSEED: *Schima* seedlings, SAP: *Schima* sapling, CSEED: *Castanopsis* seedling, CSAP*:* *Castanopsis* sapling, MOIST: Moisture, OM: Organic matter, N: Nitrogen, P: Phosphorus, K: Potassium

***Correlation is significant at the 0.05 level (two tailed)**

****Correlation is significant at the 0.01 level (two tailed)**

(Pearson's correlation Coefficient Method)

In west facing slope, seedling density of *S.wallichii* was negatively correlated with seedling density of *Castanopsis tribuloides* (p=0.05), positively correlated with organic matter and soil nitrogen (p=0.05). Seedling density of *C.tribuloides* was positively correlated with sapling density of *C.tribuloides* (p=0.05) and negatively correlated with soil nitrogen (p=0.01). Sapling density of *C.tribuloides* was positively correlated with organic matter (p=0.05). Sapling density of *S.wallichii* was positively correlated with seedling and sapling densities of *C.tribuloides* (p=0.01) and negatively correlated with organic matter (p=0.05). Soil pH was negatively correlated with soil moisture (p=0.01) and soil nitrogen was negatively correlated with soil phosphorus (p=0.05).

Table: 14. Correlation coefficient between different variables with *Schima-Castanopsis* seedlings and saplings at west facing slope.

	SSEED	**SSAP**	**CSEED**	**CSAP**	**pH**	**MOIST**	**OM**	**N**	**P**	**K**
SSEED	1									
SSAP	0.329	1								
CSEED	-0.587*	0.757**	1							
CSAP	-0.128	0.628**	0.665**	1						
pH	-0.226	-0.183	0.272	0.053	1					
MOIST	0.053	0.004	-0.163	0.030	-0.726**	1				
OM	0.539*	-0.648**	-0.211	0.593*	0.338	0.003	1			
N	0.454*	0.065	-0.752**	0.048	-0.035	-0.059	-0.007	1		
P	-0.319	-0.335	0.217	-0.387	0.184	0.285	-0.075	-0.465*	1	
K	-0.227	-0.266	-0.011	-0.168	0.139	-0.072	-0.176	-0.233	0.037	1

SSEED: *Schima* seedlings, SAP: *Schima* sapling, CSEED: *Castanopsis* seedling, CSAP*:* *Castanopsis* sapling, MOIST: Moisture, OM: Organic matter, N: Nitrogen, P: Phosphorus, K: Potassium

***Correlation is significant at the 0.05 level (two tailed)**

****Correlation is significant at the 0.01 level (two tailed)**

(Pearson's correlation Coefficient Method)

In north facing slope, seedling density of *Schima wallichii* was positively correlated with seedling and sapling density of *Castanopsis tribuloides* (p=0.05, p=0.01 respectively) and negatively correlated with sapling density of *Schima wallichii* (p=0.01), organic matter (p=0.05) and Phosphorus (p=0.05). Sapling density of *Schima wallichii* was positively correlated with soil moisture (p=0.01). Seedling density of *Castanopsis tribuloides* was positively correlated with sapling density of *C.tribuloides* (p=0.01) and soil organic matter (p=0.05) but negatively correlated with soil phosphorus (p=0.01). Sapling density of *C.tribuloides* was negatively correlated with nitrogen (p=0.05). Soil pH was positively correlated with soil phosphorus (p=0.01).

Table: 15. Correlation coefficient between different variables with *Schima-Castanopsis* seedlings and saplings at North facing slope.

	SSEED	SSAP	CSEED	CSAP	pH	MOIST	OM	N	P	K
SSEED	1									
SSAP	-0.680**	1								
CSEED	0.479*	0.037	1							
CSAP	0.682**	-0.020	0.970**	1						
pH	0.275	-0.092	-0.290	0.311	1					
MOIST	0.018	0.631**	-0.198	0.188	-0.200	1				
OM	-0.410*	-0.233	0.456*	0.320	-0.347	0.315	1			
N	0.115	0.060	0.008	-0.516*	-0.211	-0.240	0.285	1		
P	-0.490*	0.135	-0.842**	-0.349	0.798**	0.314	-0.355	-0.189	1	
K	0.123	-0.081	0.071	0.270	-0.383	0.097	0.302	0.272	-0.263	1

SSEED: *Schima* seedlings, SAP: *Schima* sapling, CSEED: *Castanopsis* seedling, CSAP*: Castanopsis* sapling, MOIST: Moisture, OM:Organic matter, N: Nitrogen, P: Phosphorus, K: Potassium

***Correlation is significant at the 0.05 level (two tailed)**

****Correlation is significant at the 0.01 level (two tailed)**

(Pearson's correlation Coefficient Method)

In south facing slope, seedling density of *S.wallichii* was negatively correlated with seedling density of *C.tribuloides* (p=0.05) and soil potassium (p=0.01) but positively correlated with sapling density of *C.tribuloides* (p=0.01) and soil nitrogen (p=0.05). Sapling density of *S.wallichii* was negatively correlated with seedling density of *C.tribuloides* (p=0.01) but positively correlated with sapling density of *C.tribuloides* (p=0.01). Soil moisture was positively correlated with soil nitrogen (p=0.01) and soil nitrogen was positively correlated with soil potassium (p=0.05).

Table: 16 Correlation coefficient between different variables with *Schima-Castanopsis* seedlings and saplings at South facing slope.

	SSEED	**SSAP**	**CSEED**	**CSAP**	**pH**	**MOIST**	**OM**	**N**	**P**	**K**
SSEED	1									
SSAP	0.152	1								
CSEED	-0.541*	-0.770**	1							
CSAP	0.806**	0.975**	0.386	1						
pH	0.114	-0.311	-0.159	0.210	1					
MOIST	-0.363	0.157	-0.104	0.377	-0.159	1				
OM	-0.055	0.302	0.198	-0.117	0.136	0.157	1			
N	0.472*	-0.116	0.142	0.050	0.112	0.621**	0.257	1		
P	0.356	-0.178	0.165	0.152	0.189	0.112	-0.211	0.005	1	
K	-0.756**	0.052	-0.141	0.306	0.210	-0.235	-0.070	0.457*	-0.189	1

SSEED: *Schima* seedlings, SAP: *Schima* sapling, CSEED: *Castanopsis* seedling, CSAP: *Castanopsis* sapling, MOIST: Moisture, OM: Organic matter, N: Nitrogen, P: Phosphorus, K: Potassium

***Correlation is significant at the 0.05 level (two tailed)**

****Correlation is significant at the 0.01 level (two tailed)**

(Pearson's correlation Coefficient Method)

6. DISCUSSION

6.1. Tree

Present research has been carried out to point out the effect of environmental factors on distribution and regeneration of plant species in the Suryavinayak forest of Bhaktapur district. In the study area the numbers of plant species were more or less equal on all four facing slopes; however composition of plant species were different. All together 29-plant species (tree and shrub) were found in the study area.

The total tree density ranged from 640 to 1115 pl/ha (Tables 2-5) which is within the range of reported values for Nagarjun Hill (550-2600 pl/ha, Yadav and Shah, 1998) but lower than the density found by Sigdel (2004) with the value 1413 to 2670 pl/ha in Shivapuri.It may be due to anthropogenic disturbance in the study area. But this value was more than that of the density estimated by Ghimire (1985) in Godawari hill with the density 583.15 pl/ha. It may be due to change in aspect of study. This value was close to the value 1200 to 1800 pl/ha reported by Saha *et.al*. (1994). Similarly, this finding was also close to the value 1193.64 pl/ha reported by Gewali (1999) in Biruwa community forest. The lowest basal area in north facing slope despite the higher tree density was due to the higher percentage of small trees with low DBH, as also reported for Navegaon National Park (Ilokar and Khatri, 2003) and Satpura National Park (Khatri *et.al*.2004). The basal area was highest in the west-facing slope though the tree density was lowest (Table: 3); it was due to presence of large trees (high DBH) in mature forest stands at sampling sites. *Schima wallichii* was the most dominant species in east, north and south facing slopes (highest IVI) indicating the most successful plant species in that area.

Castanopsis tribuloides was dominant in west facing slope. Relatively low IVI of dominant tree species of west and south facing slopes indicated that the forest was mixed type with nearly equal share of many species in that ecosystem. Relatively high IVI of dominant species in east and north facing slopes imply their high ecological success and competence over other less common associated species (Ilorkar and Khatri, 2003).

6.2 Shrub/ Sapling

The total shrub density ranged from 3275 to 7904 pl/ha which was higher than the shrub/sapling density (973-1458 pl/ha) reported by Nepal (2001) but close to the value (2460-4745 pl/ha) reported by Shrestha (2001). The variation in shrub density was due to altitude and various environmental factors. West facing slope had highest shrub/sapling density 7904 pl/ha but lowest 3275 pl/ha in north facing slope. The greater shrub/sapling density in west facing slope might be due to open tree canopy, as reported by Shrestha (2005). A more open canopy allows more light into the under storey herbs and shrubs to exceed their ecological compensation point (Givnish 1988, 1995). In the north-facing slope, tree density was high which allowed less light to pass for the growth of shrub and sapling (Table 3).

Castanopsis tribuloides had highest density of seedlings with the value of 1300 pl/ha at east, 600 pl/ha at west, 1900 pl/ha at north and 1350pl/ha at south facing slope. It may be due to dominant tree species and may be production of more seedlings and its maturation. This value was more than value reported by Shrestha (2005) in two community managed hill sal forests (133 pl/ha and 505pl/ha respectively).

Among the shrub species *Phyllanthus parvifolius* had the highest density 1015 to 3725 pl/ha. It may be due to production of more viable seeds and seeds may germinate in any soil condition.

6.3 Total number of species, Diversity Index and Index of Similarity

Among the species in the community, relatively few species like *Schima wallichii* and *Castanopsis tribuloides* were abundant while other species were scattered. Number of tree species and their relative importance determine the species diversity of the community. Species richness is a simple interpretable indicator of biological diversity that represents the total number of species within an area (Hulbert, 1971; Whittakar, 1977). The number of tree and sapling were less than shrubs.

Total number of tree was highest at south facing slope (Table 10). Shrub/sapling layer was highest at east facing slope and lowest at north facing slope. Highest number of species at east facing slope may be due to open tree canopy, which gives more light to pass through it to forest floor. Lowest shrub/sapling layer at north facing slope might be due to closed canopy, which reduced light to forest floor. This finding is similar to the findings of Yadav and Shah (1998) and Pandit (1999)

Shannon-Wiener Index of diversity (H) of tree layer was higher at south facing slope and lowest at west facing slope (Table: 10). Index of similarity (H) is similar to the reported value by Bankoti *et.al*. (1986) in Kauman Himalaya (1500-2300 m asl) in the Pine-Oak, and Oak forest (1500-2300 m asl). The lowest value of tree species diversity at west facing slope was due to dominance of two main species *Schima wallichii* and *Castanopsis tribuloides* because higher the dominance lower is the diversity; highest Simpson's Index of dominance was found at this site. The higher value of species diversity in south facing slope suggested that nearly equal contribution of several species (high species evenness) increased the species diversity.

The ß-diversity for tree layer at different slopes ranged from 1.27 to 1.65 and for shrub/sapling layer 1.33 to 1.62.This value was lower than the range 1.80-2.19 for tree and 2.17-2.44 for shrub/sapling layer in protected forest of Annapurna region (Shrestha 2001). The less value in the present study may be due to higher disturbances in forest and more or less homogenous forest condition. The low difference in ß-diversity of tree and shrub/sapling layer (Table 11) indicated that both growth forms responded to environmental factors in similar fashion (Adhikari *et.al*.1991)

6.4 Soil

The pH of the soil revealed that the whole study area possesses acidic soil and the value ranged from 4.01 to 4.20. Leaching of the basic cations such as Ca^+, Mg^+, K^+ and Na^+ and replacement by H^+ ions at exchange sites can reduce soil pH (Miller and Donahue, 1997).

Soil organic matter is an important parameter of soil that determines the nature of soil and vegetation distribution. Soil organic matter (OM) was more in west facing slope (10.09%) and less in north facing slope (3.52%). High soil OM at west facing slope might be due to more litter fall and litter decomposition in north facing slope than rest of the slopes. The value of OM indicates that the soil of the forest was fertile since according to Sutheimo (1995) the value of 1.7%-2.33% of OM is an indicator of a low fertility status of the soil.

OM is higher in poor regenerating area (Bhatnagar 1965). Soil under the dense tree canopy used to be significantly higher in OM and nitrogen (Isichei and Monghalu, 1992). OM content increases with the maturation of the forest (Aweto, 1981)

The soil nitrogen content ranged from 0.16% to 0.44%. This value was less than the value reported from the forest in Nagarkot (18.28%) by Juwa (1987). The average value of nitrogen and potassium in west facing slope was higher followed by south facing slope (Table 13). High soil nitrogen (N) and potassium (K) at these facing slopes was due to high organic matters. The phosphorous content ranged from 51.31 kg/ha to 129.33 kg/ha. The estimated value was nearly equal to the value (76.64-126.81kg/ha) as reported by Paudel (2000) in Udaypur. Average soil phosphorous (P) content was highest at the east facing slopes and lowest at west facing slopes. This irregular change in soil phosphorous could not be explained by data of this study. Similar irregular pattern in soil nutrient (N, P, K) were obtained by Pandit (1999) and Pandey (2001). The soil moisture was highest in north facing slope and lowest in west facing slopes (Table 13). It may be due to high decomposition of humus in north facing slope.

6.5 Regeneration of *Schima wallichii* and *Castanopsis tribuloides*

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) are dominated by strong environmental influences: intra and inter specific competition and environmental stresses. For the regeneration study, seedling counts are often taken as regeneration potential. However, it cannot give actual figure of population structure and dynamics. 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 curve obtained by plotting the diameter distribution was used to interpret the characters of vegetation.

The size class distribution of the study sites showed a larger number of trees individual in smaller dbh class, and low number of tree individual with larger dbh class. The decrease or absence of trees in middle size class may be due to higher mortality rate because of competition for nutrient between sapling and canopy of tree and their removal by humans. The density diameter distribution of both *Schima wallichii* and *Castanopsis tribuloides* in north facing slopes resembled reversed J shaped curve, which indicates the sustainable regeneration which was indicted by the higher seedling and sapling density at north facing slopes (fig 3 and 4). Reversed J shaped size class diagram is the indication of sustainable regeneration (Vetaas, 2000). Acharya (2004) also suggested that north aspect is more sustainable for the regeneration of *Pinus wallichiana* in Pisang, Manang forest. It may be due to high soil moisture and less solar radiation in north facing slopes. Soil moisture plays a vital role in the germination and establishment of seedling. In the forest under the study, it was found that the area with high soil moisture had higher density of seedlings. Higher seedling and sapling densities of both *Schima wallichii* and *Castanopsis tribuloides* at north facing slopes may be due to higher soil moisture content at north facing slope. Lower seedling and sapling densities of both species in west facing slopes may be due to lower soil moisture and heavy pressure on forests due to human interference. In disturbed forest lopping reduced seed production and litter collection damaged the seedling and sapling (Shrestha and Poudel, 1996).

Population structure of *Castanopsis tribuloides* from seedling to mature tree revealed that the regeneration was hampered even if the trees were producing abundant number of viable seeds, as evident from seedling density. The major problem appeared to be the survival of large seedling and sapling. A wide range of biotic and abiotic factors have been proposed to be responsible for large scales death of seedling, sapling and recruit, and thus the poor regeneration of *Castanopsis tribuloides*. Poor regeneration of *Castanopsis tribuloides* is not the result of single factors. Perhaps a set of biotic and abiotic factors, combined with inherent slow growth rate is responsible for it. Relative role of different factors may depend on disturbance intensity, source of disturbance, maturity of forest stand and site specific variation in herbaceous cover and litter thickness. But I was unable to observe herbaceous growth and litter thickness. I have no information on the survival of large seedling and sapling. It requires long term monitoring of seedling/sapling growth in permanent plot. This type of study is still lacking particularly in central Nepal.

There was positive correlation of seedling density of *Schima wallichii* with moisture content at east facing slope and with sapling density of *Schima wallichii* at north facing slope. But they do not show significant correlation at west and south facing slopes (Tables 15 and 17). Tabita *et.al* (1993) also found higher number of seedling in higher moisture contain of soil.

Organic matter is an important parameter of soil that determines the nature of soil and vegetation distribution. OM is higher in poor regenerating areas (Bhatnagar, 1965). There was significant negative correlation (p=0.05) with sapling density of both *S.wallichii* and *C.tribuloides* in east facing slope but in west facing slope it was negatively correlated (p=0.01) with sapling density of *S.wallichii* and positively correlated with sapling density of *C.tribuloides*.There was positive correlation with seedling density of *C.tribuloides* in north facing slope where as both seedling and sapling did not give significant value in south facing slope. OM content increases with the maturation of the forest (Aweto, 1981).

pH also showed negative correlation (p=0.05) with seedling density of *C.tribuloides* in east facing slope but in west, north and south facing slopes both seedling and sapling did not correlate significantly with pH.

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, light and viability of seeds. In nature seed on the ground experienced repeated desiccation and re-hydration. 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 regenerations. It may be affected by environmental factors for the establishment and also the seedlings must compete with herbaceous flora for limited resources.

Among the environmental factors human interference is the main factor affecting regeneration as well as population structure of the forest. 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 *Castanopsis tribuloides* and *Schima wallichii* for construction and fuel wood and leaves of *Castanopsis tribuloides* for fodder. Some cut stems and fallen log were also found in the study area.

7. CONCLUSION AND RECOMMENDATION

7.1. Conclusion

The present study is mainly focused on the vegetation composition and regeneration of *Schima-Castanopsis* forest in Suryabinayak, Bhaktapur district. Altogether 17 tree species and 10 shrub species were recorded from all four slopes. There were not much noticeable differences in vegetation composition in all slopes. The result showed that *Schima wallichii* was the most dominant and frequent species, which is associated with *Castanopsis tribuloides* and other tree species and shrubs. *Schima wallichii* had the highest value of density, frequency and importance value index followed by *Castanopsis tribuloides* in all four slopes. In case of shrubs, *Phyllanthus parvifolius* had the highest density and frequency in east, west and south facing slopes but *Rubus ellipticus* had highest density and frequency in north facing slope.

The result showed that largest number of trees layer was found in north facing slope where highest Simpson's Index of dominance was found in west facing slope. Higher degree of similarity indexes for both tree and shrub/sapling layer was found between east and north facing slopes. The lower value of Similarity Index of tree layer was found between east and west facing slope and lower value of Similarity Index of shrub layer was found between west and south facing slope where highest β- diversity for tree layer was found between east and west facing slope and for shrub it was found between west and north facing slope. Lowest β-diversity for tree was found between west and north facing slope and for shrub, it was found between east and north facing slope.

There was better regeneration of *Schima wallichii* than that of *Castanopsis tribuloides* in all four slopes. Absences of high girth class of both species in all four slopes indicate over exploitation of the species. The results of DBH size class analysis indicate frequent regeneration of *Schima wallichii* in all four slopes but in case of *Castanopsis tribuloides* some of diameter classes were missing. Less number of *Castanopsis tribuloides* tree of middle girth classes indicate seedling die before they reach the canopy state due to anthropogenic activities. Larger numbers of seedlings and saplings were found in north facing slope and lesser number in west facing slope for both *Schima wallichii* and *Castanopsis tribuloides* species.

Less variation in the soil characters was found among the slopes. The soil of the whole study site was acidic. West and south facing slopes of the study area were found to be more nutrient rich (high OM, N and K) compared to east and north facing slopes. But highest Phosphorus content was found in east facing slope.

Since the forest in the study area was closer to the village settlements, there was high disturbance. There were various limiting factors for tree distribution and regeneration; however, there was no single factor that actually affects the distribution and regeneration of tree in all studied area. Human interferences for grazing, trampling, litter collection also play a role in distribution and regeneration of tree species.

7.2 Recommendation

Based on the results of present study, following recommendations have been given for the maintenance of proper regeneration:

- Though the forest is under the District forest office, anthropogenic as well as natural disturbances have been noticed. Human interference, grazing, fuel wood collection, litter collection and collection of plant for medicinal purpose were common in the forest because the forest is close to the human settlement. So to conserve the biodiversity, these activities should be controlled.

- Very few of studies of natural regeneration of dominant tree species in Nepal are found and most of them are focused upon tropical tree species *Shorea robusta*. So, study upon natural regeneration of other dominant tree species should be carried out.

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9. ANNEX

Annex 1. List of the plant species found in the study area.

S.No.	Scientific Name	Family	Habit
1	*Alnus nepalensis* D.Don	Betulaceae	T
2	*Berberis aristata* Roxb.ex.Dc.	Berberidaceae	S
3	*Buddleja asiatica* Lour.	Loganiaceae	S
4	*Camellia kissi* Wall.	Theaceae	S
5	*Castanopsis tribuloides* (Sm.) A.Dc.	Fagaceae	T
6	*Desmodium concinum* Dc.	Leguminosae	S
7	*Desmodium heterocarpon* (L.) Dc.	Leguminosae	S
8	*Eurya acuminata* Dc.	Theaceae	T
9	*Gaultheria fragrantissima* Wall.	Ericaceae	S
10	*Lyonia ovalifolia* (Wall.) Drude	Ericaceae	T
11	*Melastoma normale* L.	Melastomataceae	S
12	*Myrica esculenta* Buch-Ham ex D.Don	Myricaceae	T
13	*Myrsine capitellata* Wall	Myrsinaceae	T
14	*Myrsine semiserrata* Wall.	Myrsinaceae	T
15	*Osbeckia stellata* Buch-Ham ex. D.Don	Melastomataceae	S
16	*Phyllanthus parvifolius* Buch-Ham ex.D.Don	Euphorbiaceae	S
17	*Prunus cerasoides* D.Don	Rosaceae	T
18	*Pyrus pashia* Buch-Ham, ex D.Don	Rosaceae	T
19	*Quercus glauca* Thunb	Fagaceae	T
20	*Quercus lamellose* Sm.	Fagaceae	T
21	*Quercus lanata* Sm.	Fagaceae	T
22	*Quercus semecarpifolia* Sm.	Fagaceae	T
23	*Rhododendron arboreum* Smith	Ericaceae	T
24	*Rhus javanica* L.	Anacardaceae	T
25	*Rhus wallichi* L.	Anacardaceae	T
26	*Rubus ellipticus* Sm.	Rosaceae	S
27	*Schima wallichi* (Dc.) Korth	Theaceae	T