PLANT COMMUNITY STRUCTURE AND REGENERATION OF *Quercus semecarpifolia* Sm. FORESTS IN DISTURBED AND UNDISTURBED AREAS

A Dissertation Submitted for

the Partial Fulfillment of Master of Science in Botany

Institute of Science and Technology

Tribhuvan University

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Submitted by

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May, 2010

ACKNOWLEDGEMENTS

I receive much help and encouragement from many people in completing this work. Although, it is not possible to mention all by names, I would like to extend my sincere and special gratitude to the following individuals.

I express my sincere and deep gratitude to my research supervisor Mrs. Anjana Devkota, Lecturer of Central Department of Botany, Tribhuvan University, Kirtipur, who guided me with her valuable suggestions to make this thesis possible.

I express my sincere and deep gratitude to my research Co-supervisor Mr. Bharat Babu Shrestha, Lecturer of Central Department of Botany, Tribhuvan University, Kirtipur, for scholastic guidance, invaluable suggestions, regular encouragement throughout research period and preparation of manuscript.

I am extremely grateful to Dr. Krishna Kumar Shrestha, Professor and Head of the Central Department of Botany, TU, Kirtipur for his administrative support. I am grateful to Prof. Dr. P.K. Jha, Former Department Head, for providing the administrative help during the initial stage of the research work. I am very grateful to Associate Prof. Dr. Suresh K. Ghimire and Prof. Dr. Mohan Shiwakoti for their help during herbarium identification. I am also thankful to Sushim Ranjan Baral, Chief, National Herbarium and Plant Laboratories, Godawari, for allowing me to consult herbarium specimens deposited at KATH for plant identification.

My special thank goes to Mr. Devendra Karki and Niranjan Bhakta Ranjitkar for their help and cooperation during field visits and laboratory work, without their help field visits were impossible in time. Similarly, I am thankful to Mr. Ekananda Paudel who assisted me during field visit as well as during the preparation of manuscript.

I would also like to thank Mr. Sanat Kumar Sharma, Co-executive Director, BPKMPS, Ministry of Science and Technology, for his generous assistance during preparation of manuscript.

All my friends and staffs of Central Department of Botany as well as other people are also thankful for their direct or indirect help during research period.

Finally, I am indebted to my family members for their continuous support and encouragement for the completion of my masters.

May, 2010.

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ABSTRACT

Regeneration behavior of tree species is characterized by their population structure which depends upon the presence of adequate number of seedlings and saplings. *Quercus semecarpifolia* is a main forest forming evergreen tree species from upper temperate to lower sub alpine regions of the Himalaya. Vegetation structure and regeneration of *Quercus semecarpifolia* were studied in two forests of midhills of Central Nepal with different disturbance levels; one was distrubed forest at Simbhanjyang, Makawanpur, and another was undisturbed forest in Shivapuri National Park, Kathmandu. A systematic random sampling method, using square quadrats, was used for vegetation and soil sampling. Soil was collected from each quadrat and their physicochemical characteristics (soil pH, organic carbon and total nitrogen) were analysed. In each quadrat, presence/absence of herbs and shrubs; and the total number of individuals of tree species, sapling and seedling were recorded. Community attributes such as importance value index, species richness and species diversity were determined for both forests and compared. Density-diameter relations for trees, and the spatial pattern of distribution of seedlings and saplings were analyzed to understand regeneration pattern.

Altogether 86 and 57 species of flowering plants were found in disturbed and undisturbed forests, respectively. Tree species diversity was higher in undisturbed forest while herb and shrub diversity was higher in disturbed forest. There was significant ($p<0.05$) difference in soil pH, soil nitrogen, soil organic carbon, litter coverage, total tree density, density of *Quercus semecarpifolia* tree, sapling and seedling of *Quercus semecarpifolia*, density of seedlings of all tree species, and total species richness between two forests. Sapling density of *Quercus semecarpifolia* declined with increasing tree basal area in both forests and seedling density was also decreased with increasing basal area in undisturbed forest whereas no relation was found in disturbed forest. Significant increase in regeneration of *Quercus semecarpifolia* along with other tree species in disturbed forest might be due to disturbances in the canopy of trees.

Keywords: Canopy cover, Disturbances, Species diversity, Soil characters

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LIST OF ABBREVIATION AND ACRONYMS

°C	degree celcius
asl	above sea level
BA	Basal Area
C	Simpson's index of dominance
C/N	Carbon versus Nitrogen
CABI	Centre for Agriculture and Biosciences International
D	Density
DBH	Diameter at Breast Height
DF	Disturbed forest
DNPWC	Department of National Park and Wildlife Conservation
DPR	Department of Plant Resources
Gov/N	Government of Nepal
H'	Shannon- wiener index
ha	hectare
IS_J	Jaccard's Similarity Index
IS_S	Sorenson's Similarity Index
IVI	Important Value Index
KATH	National Herbarium and Plant Laboratories, Godawari
MPFS	Master Plan for the Forestry Sector
N	Nitrogen
OC	organic carbon
pH	negative logatherium of Hydrogen ion
pl/ha	plants per hectare
RBA	Relative Basal Area
RD	Relative Density
RF	Relative Frequency
S	Total number of species
SD	Standard Deviation
SPSS	Statistical Package for Social Science
TUCH	Tribhuwan University Central Hurbarium
UDF	Undisturbed forest
VDC	Village Development Committee

1. INTRODUCTION

1.1 Background

Regeneration is the process of regrowing or reproducing the plant species. Young plants produced from natural seed fall, or from stump or root sprouting in openings formed after existing plants are cut, burned or blown over is known as natural regeneration whereas the growth of new trees through seeding and planting is called as artificial regeneration (Ramakrisnan *et al.* 1982). Regeneration depends mainly upon the average seed output, viability of seeds, seed dormancy, reproductive capacity, seed dispersal, seedling growth, vegetative propagation, vegetative growth and reproductive growth (Sharma 1975). Regeneration behavior of tree species is characterized by their population structure which depends upon the presence of adequate number of seedlings and saplings.

Oaks are found in the northern temperate zone, subtropical and tropical Asia, and the Andes of South America (Shrestha 2003). *Quercus* is a widely distributed genus in the northern hemisphere with 500 recorded species. They are in general late successional dominants in drier forests and occur as mid successional species on the more mesic sites (Spurr and Barnes 1973). There are more than 35 species of *Quercus* reported from Himalayan region (Negi and Naithani 1995). *Quercus semecarpifolia* is commonly known as brown oak which is the main forest forming evergreen tree species from upper temperate to lower sub alpine regions of the Himalaya (Singh and Singh 1992). Comprehensive studies on *Quercus* forests in the Himalaya have been undertaken by Stainton (1972), Ohsawa *et al*. (1986), Acharya *et al*. (1991), Singh and Singh (1992), Singh *et al.* (1997), Vetaas (2000), Bhuyan *et al*. (2003), Sagar *et al*. (2003), Ram *et al.* (2004) and Kumar and Ram (2005). Regenerative capability of this important forest element, after human-induced or natural disturbances, is poor in North America (Carvell and Tryon 1961, Crow 1988, Abrams and Downs 1990, Lorimer *et al*. 1994, Vetaas 2000), Eurasia (Vetaas 2000), Europe (Watt 1919, Mellanby 1968, Shaw 1968, Andersson 1991) and Asia (Saxena *et al*. 1984, Singh and Singh 1987, Masaki *et al*. 1992).

According to DPR (1997), eight species of oaks including *Q. semecarpifolia* are found in Nepal. *Q. semecarpifolia* is one of the highly useful species of oak having considerable social impact, facing threat from environmental degradation and it plays vital role in water and soil conservation (Singh and Singh 1986). Due to the lack of proper and extensive scientific studies, a management practice of this forest element is very poor.

The influence of biotic and abiotic factors affects the survival and growth of saplings. Lack of regeneration in oak is sometimes attributed to the effect of climate change (Upreti *et al*. 1985), but according to Shrestha (2003), there is no long term data on population dynamics to support this. Abundance of established seedlings and saplings under the adult trees affect the future composition of the forest. Seed germination and seedling establishment are related to the availability of space created through perturbation and to adaptation to particular light regimes (Ramakrisnan *et al.* 1982). Regeneration of canopy tree is commonly assessed by the distribution of size classes measured as diameter at breast height (DBH) at 1.37 m above ground level. This is based on survivorship curve and density diameter relationship. The reverse ‘J’ shaped size class distribution indicates sustainable regeneration and a bell shaped size class distribution indicates the lack of sustainable regeneration (Vetaas 2000).

The absence of natural regeneration of *Q. semecarpifolia* forest has been attributed to lopping of branches, agricultural expansion, litter collection, grazing, charcoal making, using as firewood in the cheese factory, felling of trees for construction works, and harvest of important ground flora (Subedi 2006). Natural regeneration of *Q. semecarpfiolia* is often prevented from establishing itself by a dense growth of weeds and heavy undergrowth (Troup 1921). Thick litter generally reduces the rates of germination of seedling of *Q. semecarpfiolia* however, herbaceous cover, has an even more adverse effect on seedling emergence, survival and growth (Tripathi and Khan 1990, Dzwonko and Gawronski 2002). Due to lack of detailed information on seedling establishment and growth behavior of *Q. semecarpifolia*, the problems of poor survival of planted seedlings have remained unsolved (Jackson 1994, Shrestha and Paudel 1996).

1.2 Justification of the Study

Forest plays a dynamic role in protecting the fragile mountain ecosystems and maintaining diverse and complex ecosystems. Oaks promote the recharge of mountain springs (Valdia 1998). Human beings have always had a strong connection with oak. Throughout history, the oak has been a symbol of permanence, strength and courage (Keator and Bazel 1998). It is a home for many plants and animals as tree trunks and branches are usually densely covered with epiphytic plants, including ferns and orchids. Besides it harbours a rich faunal diversity and is important for watershed protection and biodiversity conservation in general (Tashi 2004). The bark of *Q. semecarpifolia* is an important source of tannin (Pandey and Makkar 1991).

Lopping of *Quercus* tree is a common practice among the mid hill farmers for fodder. Heavy lopping results pole like appearance of the trees with scanty leaves (Jackson 1994, Zobel *et al*. 1995, Shrestha and Paudel 1996). This practice, on the other hand, removes biomass and causes disturbance (Grime 1979). Grazing and litter collection are other disturbance factors in oak forest. Continuous regeneration of species is necessary for the sustainability of forest. For the sustainable management of oak forest, a thorough understanding of the ecology of the species is very important. The study is no doubt very complex, as many factors are involved in determining the regeneration of *Q. semecarpifolia*. Canopy openness (Crow 1992), grazing (Putman 1986), erratic seed production, defoliation, forest fire, and acorn predation (Singh and Singh 1987, Andersson 1991, Lorimer *et al*. 1994, Thandani and Ashton 1995) have been confirmed as a main reason for poor natural regeneration of oaks.

The lack of natural regeneration of this important forest flora and its frequent degradation become a serious issue in many areas of the world including Nepal (Vetaas 2000, Shrestha 2003) and it can lead to the degradation of the species from the forests of Nepal. In this context, the findings of this type of study will help to determine the causes of poor regeneration and follow best forest management practices. Though oaks are the important and dominant forest vegetation of temperate region of Nepal, the detail study is very sparse; hence detailed study about the regeneration of this species is essential.

1.3 Hypotheses and Objectives

The following working hypotheses are proposed here.

- Plant diversity is higher in undisturbed forest than in disturbed.
- Forest regeneration is continuous in undisturbed forest and erratic in disturbed forest.

In order to accomplish mentioned hypothesis, following objectives were identified:

- To measure species diversity of flowering plant in *Quercus semecarpifolia* forests under different disturbance level.
- To assess regeneration status of forest and dominant tree species of *Quercus semecarpifolia* forests.
- To understand spatial variation in recruitment of seedling and saplings of *Quercus semecarpifolia.*

2. LITERATURE REVIEW

2.1 Oak (*Quercus* species) Forest

Forest trees are an integral part of rural livelihoods in the Himalaya.They dominate not only the landscape but also the way people live. Forests provide 75% of the total energy consumed in Nepal (fuelwood) and more than 40% of fodder for livestock is extracted from forests (MPFS 1988). About 500 species of oaks (*Quercus* species, Fagaceae) are distributed in the sub- tropical, temperate and sub- arctic zones all over the world (Spurr and Barnes 1973). Oaks are found in the northern temperate zone, subtropical and tropical Asia, and the Andes of South America (Shrestha 2003). The oaks are broad leaved monoecious trees with unisexual flowers. However both male and female sexes present in same tree. The fruit is nut (acorn) which is globose or turbinate, partly or wholly encircles by a woody cup of involucre.

The oak is a light demanding species and fails to establish itself under shade. The oaks of Himalayas are mainly evergreen in contrast to those of northern latitudes in Europe and America (Gopal and Meher- Homji 1983). They are mostly gregarious, medium to large-sized tree, distributed at elevations of 800 to 3800 m asl throughout the Himalayan region. The species ranges across the Himalayas from Bhutan, Nepal, India and is also found in Afghanistan, Pakistan, China and Myanmar as a component of mixed forests, reaching upto 30 m in height. They are naturally found in moist temperate forests of the western Himalayas within the elevation range of 2400 to 4000 m (Baduni and Sharma 1996, CABI 2002, Viswanath *et al.* 2002). They are among the dominant vascular plants of the Himalayas, ranging from the subtropical to the sub-alpine zones (Shrestha 2003) and distributed in the almost entire length of the temperate region of Nepal (Subedi 1998). In Nepal, it is predominantly found in the dry western part of the country, whereas in eastern Nepal it is found on dry south- facing slopes (Ohsawa *et al*. 1986). Eight species of oaks (*Quercus floribunda, Q. glauca, Q. lanata, Q. leucotrichophora, Q. lamellosa, Q. mespilifolioides, Q. oxyodon* and *Q. semecarpifolia*) are found in Nepal (DPR 1997).

2.2 *Quercus semecarpifolia* Forest

Q. semecarpifolia is an element of central Himalayan vegetation, which has occurred in this region for millions of years. Steppe formed after the final uplift of the Himalayas was invaded by this species and oak became the dominant element of then sub-alpine and alpine forest (Singh and Singh 1992). At present it is a dominant species in the Himalayas, from southwest China to Afghanistan, at elevations of 2100 to 3800 m asl (Negi and Naithani 1995). It is often found as dominant species on north-facing slopes in the Himalayas, from 2400-3600 m (Gamble 1972). It usually found on the moister southern slopes, which are influenced by the monsoon (Puri *et al.* 1989) and also occurs in moist temperate and sub-alpine regions with heavy snowfall and moderate rainfall, however it is absent from the dry regions of the inner Himalayas (Negi and Naithani 1995). In Nepal, *Q. semecarpifolia* forest lies between 2438 to 3048 m both on north and south faces in west midlands, however it is restricted to south facing slopes or the sides of big river valleys in the central midlands and in east midlands, it is absent because it is replaced there by other east Himalayan forest type (Stainton 1972).

Q. semecarpifolia can be found as pure stands especially along the tops and upper slopes of ridges (Troup 1921), but can also be found with conifer species as a component of the cool temperate forest (Norbu 2000). It is frequently mixed with *Picea* sp., *Abies alba*, *Taxus baccata* and in some localities with *Pinus wallichiana*. Among broad-leaved species, occasionally associated with it are *Pyrus* sp., *Prunus* sp., *Acer* sp. *Juglans regia* and *Betula* sp. (Troup 1921). There is often luxuriant herbaceous and shrubby undergrowth in the *Q. semecarpifolia* forest. The common associated shrubs are species of *Rosa*, *Rubus*, *Viburnum*, *Lonicera* and dwarf bamboo (Troup1921). Some other species associated with *Q. semecarpifolia* forest are *Rhododendron* sp., *Pieris* sp., *Myrsine* sp., *Berberis* sp. and *Daphne bholua* (Viswanath *et al.* 2002).

Seedlings of *Q. semecarpifolia* are normally leafless in the first year with buds on the axil of the scale leaf, which enables them to withstand autumn drought and winter cold. Food stored in the large seed is sufficient to allow the early growth of the seedling before green leaves are produced, however, under favorable conditions new leaves are produced in the first season (Shrestha 2003). Rates of survivorship increases as seedling become larger and older (Liebermann *et al.* 1996). It has been observed that seeds of *Q. semecarpifolia* start to germinate as soon as seed ripens and falls to the ground. In some instances, it starts to germinate even when they are still on the tree. The radical develops rapidly after germination. However, the epicotyl usually does not develop until the next spring (Troup 1921).The seeds have high water content and large amount of stored food which enable an extensive and deep root development (Rao and Singh 1989). They are thus largely insensitive to moisture variation for germination (Singh and Singh 1992).

The mass of litter and herbaceous cover can suppress emergence, survival and growth of oak seedlings, but since it is a viviparous species, according to Singh and Singh (1992), it has an added advantage in establishing seeds on over- stocked ground. The seeds lack dormancy and thus are not found in the soil seed- bank. Major leaf drop and leaf emergence of *Q. semecarpifolia* were observed simultaneously during May- June, indicates that the species do not take a risk of withholding both the sets of foliage together during high evapo- transpiration rate (Siluwal 1999). The noticeable growth of acorn was observed only during the following spring as soon as the new shoots started to appear and ripened and fruit fall was recorded during June (Siluwal 1999).

Q. semecarpifolia prefers a good deep fertile loamy soil and free soil drainage (CABI 2002). There were no significant relationship between saplings and soil variables in oak forests (Vetaas 2000, Maren *et al*. 2007). Seedlings of *Q. semecarpifolia* seem to prefer a pH of around 6, and total nitrogen between 2 to 3% (Vetaas 2000). Isichei *et al.* (1992) pointed the effect of tree canopy cover on soil fertility in Nigerian savanna. They reported that soil under tree canopies were found to have significantly higher levels of organic matter, calcium, magnesium, potassium, pH, total exchangeable base and cation exchange capacity than those in grassland. Amount of litter fall and subsequent decomposition greatly influence soil characteristics (Baral 1983). Similarly, Heikkinen (1991) analyzed the relationship between forest vegetation and major environmental factors and concluded that nitrogen and phosphorus were slightly higher in soils under tree canopies than those in grasslands. The soil in broad-leaved forests is usually dark black and deep due to the decomposition of a large amount of organic matter.

The density of *Quercus semecarpifolia* dominated forest of Kumaun Himalaya ranged from 370 to 580 pl/ha and 400 to 650 pl/ha in north east and north-west aspect respectively (Kharkwal 2009). The density of *Q. semecarpifolia* was found to be 410 and 70 pl/ha in Juphal and Amaldapani community forests of Dolpa district of mid west Nepal (Kunwar and Sharma 2004). The density of *Q. semecarpifolia* was found to be 480 pl/ha in a high altitude of Central Himalaya (Adhikari 1995).

Basal area of *Q. semecarpifolia* was found to be 0.38 and 0.69% in Juphal and Amaldapani community forests of Dolpa district of mid west Nepal (Kunwar and Sharma 2004). Tree basal area of semi- evergreen forest of eastern ghat India ranged from 0.26 to 0.42% (Kadavul *et al*.1999). The total basal cover of *Q. semecarpifolia* in a high altitude region of Central Himalaya was 0.73% (Adhikari 1995). Important Value Index of *Q. semecarpifolia* dominated forest of Kumaun Himalaya ranging from 1500- 2600 m asl of India was 200 (Kharkwal 2009). IVI of *Q. semecarpifolia* in Garhwal region of west Himalaya was found to be 166.91 and 70.80 at the altitude of <3000 and >3200 m respectively (Gairola *et al*. 2008). IVI of *Q. semecarpifolia* was 57.31 and 16.84 Juphal and Amaldapani community forests of Dolpa district of mid-west Nepal (Kunwar and Sharma 2004). IVI of *Q semecarpifolia* at higher altitudes of Shivapuri National park was 108.37 (Sigdel 2008).

2.3 Biotic Pressure on *Quercus semecarpifolia*

Even though human settlements have existed in the Himalaya for thousands of years, it is only in the last hundred years or so that human intervention in the middle hills has taken place on a large scale (Moench and Bandyopadhyay 1986, Singh 1998, Khera *et al*. 2001, Saberwal and Rangarajan 2003, Carpenter 2005, Subedi 2006). Anthropogenic disturbances to forests are lopping for fuelwood and fodder, burning, livestock grazing, browsing, deforestation, surface burning, collection of various products such as forest floor biomass, fruits, fiber, medicinal plants and conversion of forest to cropland (Singh 1998). Depletion of oak forests in Himalayas has been a matter of serious concern, attributed not only by over exploitation for fodder, fuelwood and timber, due to fire and shifting cultivation practice as well (Singh and Singh 1987, Negi and Naithani 1995, Thadani and Ashton 1995, Shrestha and Paudel 1996). On average, 40% of Nepal's livestock is fed with leaf fodder from approximately 100 tree species (Moench and Bandyopadhyay 1986). Cattle, Goats and sheep eat the seedling and leaves of *Q. semecarpifolia* especially during the lean months (Singh *et al*. 1998) or during dry season from February to April when other green fodder is not available (Shrestha 2003), especially at high altitudes (above 2000 m) where the species is most abundant (Jackson 1994). Herbivore mammals may eat the whole seedling before it becomes woody therefore, exclusion of mammals from the forest significantly reduces seedlings mortality rates (Turner 2001).

The degradation of *Q. semecarpifolia* forest has occurred or is ongoing due to heavy lopping by cow herders and high grazing pressure and its inherently low regeneration and slow growth (Troup 1921). Predation of oak seeds by wild animals, thick litter layer preventing contact of seeds with soil, destruction of seed due to forest fire, collection of litter and seeds by local people for compost and pig fodder respectively, thick seed coat and recalcitrant nature of the seeds are some of the major factors hampering the regeneration process of *Q. semecarpifolia* (Siluwal 1999). There is a high likelihood that the catching activities of the squirrels, mice and birds are the primary dispersers of the seeds (CABI 2002). Acorn herbivory considerably reduces the healthy seed fall. Common herbivores are the Himalayan languor (*Presbytis entellus*), acorn worm (*Calandura sculpturata*), Himalayan black bear (*Solenarctos thibetanus*), other birds and rodents (Rawat and Singh 1989). Bears, wild boar, monkeys, squirrels and birds devour the acorns (Troup 1921). According to Shrestha and Paudel (1996) in oak forest of Nepal, beside cattle, browsers such as goats and sheep graze the small saplings of oak tree. Fodder lopping and free livestock grazing in the western hills of Nepal have hampered seedling and natural regeneration of oak (Shrestha and Paudel 1996).

Forest grazing has negative impacts on forest ecosystems, such as soil erosion, depletion of nutrients, soil compaction and acidification (Belsky and Blumenthal 1997, Barnes *et al.* 1998). However, many authors argue that forest grazing can be sustainable if grazing intensity is controlled (Krzic *et al.* 2001, Pollock *et al.* 2005, Mayer and Huovinen 2007). Forest grazing can enhance tree growth by reducing the biomass of grasses and sedges (Belsky and Blumenthal 1997, Gratzer *et al.* 1999, Darabant *et al.* 2007). Grazing has also been reported to promote biodiversity (Mitchell and Kirby 1990, Mountford and Peterken 2003) but when the seedling is young, it is likely to be eaten by herbivore where forest grazing is still in practice. Forest grazing has been reported to cause tree damage through trampling and browsing (Palmer *et al.* 2004, Mayer *et al.* 2006, Vandenberghe *et al.* 2007) and loss of species richness and diversity (Fleischner 1994). Natural regeneration of *Q. semecarpifolia* is often prevented from establishing itself by a dense growth of weeds and heavy undergrowth (Troup 1921). According to Troup (1921), heavy growth of *Strobilanthes wallichii* in oak forest hinders the regeneration process. Loss of photosynthetic surface due to repeated lopping not only leads to early senescence but also impairs the ability to coppice (Singh and Singh 1992). Heavy lopping is a casual factor of poor root regeneration, poor health of the oak trees and the ecosystem degradation (Moench and Bandyopadhyaya 1986).

2.4 Regeneration of *Quercus semecarpifolia*

The problem of inadequate natural regeneration of *Q. semecarpifolia* has long been reported (Singh and Singh 1992, Negi and Naithani 1995, Metz 1997, Vetaas 2000) . Poor natural regeneration of *Q. semecarpifolia* has been reported from both disturbed and undisturbed forests (Shrestha 2003) as a result this important forest element became threatened. Among the twenty five tree species that was listed as a threatened and vanishing species of Nepal by a seminar of the International Board for Plants Genetic Resources (currently IPGRI), held during 23-25 September 1981 in Kathmandu, *Q. semecarpifolia* was one (Tamrakar 2003). It is a bitter truth that lack of sufficient regeneration is a major problem of mountain forests (Krauchi *et al.* 2000). The status of oak forests is highly threatened due to over exploitation and poor regeneration (Siluwal *et al.* 2001).

In many undisturbed and little disturbed *Q. semecarpifolia* forests, there are presence of large old trees and seedlings, but saplings and recruits are absent (Metz 1997, Shrestha and Lekhak 2002); absence of individuals between these two size classes denotes a clear indication of large-scale death of saplings and small trees before they reach the canopy. Regeneration is more sustainable in the mildly degraded *Quercus-Rhododendron* forest than in mature and relatively non-degraded forest, where sapling counts indicate that *Symplocos* and *Quercus* are replacing *Rhododendron* (Koirala 2004). In the absence of scientific management of wildlife as well as forest disturbance regimes, oak stands usually have poor natural regeneration and may begin to be replaced by shade tolerant species (Li and Ma 2003). This does not only affect the ecosystem but also arrest the succession of the communities. As a result, the structure and composition of major forest-types of the Himalayan region are changing (Ghildiyal *et al*. 1998, Singh 1998, Khera *et al*. 2001, Kumar and Ram 2005).

When tree size is analysed, the undisturbed old-growth forests have a reversed J-shaped size class distribution indicating continuous regeneration (West *et al*. 1981, Parker and Peet 1984, Bernadzki *et al*. 1988). The number of seedlings in the oak stands correlated with factors indicating increasing disturbance, i.e. increasing light intensity and decreasing canopy cover (Maren *et al*. 2007). Oak species are the most heavily exploited, showing low regeneration above 2400 m (Saxena *et al.* 1984, Mahat *et al.* 1986, Thadani and Ashton 1995). Though the oak species are slow growing ones, its natural regeneration seems highly encouraging; especially in trial plantation, therefore, the management of the natural forests seems desirable with the development of conservation strategies based on ecological principles (Subedi and Shakya 1999).

For successful regeneration, canopy gap formation, control form of lopping and grazing and a favorable composition of herb layer species seems highly responsible (Subedi 1999). The dense canopy of the forest did not promote the satisfactory establishment of oak in the understory however the moderate disturbance appeared to benefit the regeneration (Thadani and Asthon 1995). Besides browsing, growth rate and species composition of the natural regeneration are mainly determined by the light conditions (Ammer 1996). Lopping of trees every year and at the interval of two years did not produce seeds and hampered natural regeneration of oak and resulted gradual disappearance of *Q. Semecarpifolia*, while trees lopped at the interval of three years or more do produce seeds (Shrestha and Paudel 1996). Human impact has been used to explain low regeneration of evergreen oaks and indicated the best regeneration in the least disturbed sites (Maren *et al.* 2007). Thick litter generally reduces the rates of germination and of seedling establishment. However, herbaceous cover, rather than litter, has an even more adverse effect on seedling emergence, survival and growth (Tripathi and Khan 1990, Dzwonko and Gawronski 2002).

Some findings showed that the presence of seedlings and saplings of *Q. semecarpifolia* in plots of high canopy cover was higher than low canopy cover (Vetaas 2000, Tashi 2004). According to Tashi (2004) *Q. semecarpifolia* germination is not dependent upon the canopy openness, but survives better with more canopy cover for initial years of the seedling stage. He recommended that for the oak seedling, there seems to be a need for shade in the initial years for it to survive as young plants can tolerate reasonable levels of shade. But during later stages need more light to grow and develop into the next phase because older trees do not tolerate shade (Gamble 1972).

The vital characteristics in forest tree regeneration strategies include seed production, seed size, dispersal mechanisms, shade tolerance, growth rate and longevity, resistance to insects and pathogens, biomass production, allocation of photosynthate and nutrient requirement (Barnes *et al*. 1998). *Q. semecarpifolia* respond well to coppicing (Gamble 1972). It coppices and pollards well. However, coppice and pollard shoots are liable to be bent or broken by snow (Troup 1921). Under natural conditions, germination takes place in profusion as soon as seed falls on exposed ground (CABI 2002). Germination takes place early in the rainy season. The seedling continues to derive nourishment from the fleshy cotyledons for sometimes and the remains of the cotyledons can be found even during the second season (Tashi 2004). Germinating seedlings depend initially on seed reserves for all its energy and nutrient requirements. The rapid development of the root allows the seedling to become anchored and to start taking up water and nutrients. Foliaceous cotyledons begin to start photosynthesizing and reduce the dependence on the seed reserve (Turner 2001).

Some management attempts, including artificial plantation, have been undertaken in order to induce natural regeneration of *Q. semecarpifolia*. The direct sowing of seeds and planting nursery-raised seedlings are both practiced, however the former is widely preferred (Shrestha 2003). Direct sowing has been successfully adopted in various parts of India (Negi and Naithani 1995) though survival of nursery-raised seedlings in plantation is very low, as it was reported less than 4% in Solukhumbu, Nepal (Stewart 1984). Metz (1997) hypothesized that *Q. semecarpifolia* is not able to reproduce in individual tree fall gaps, but needs more severe disturbance. Management practices in natural forest, involving thinning of old trees, so as to open the canopy and allow more light to reach the ground, have produced promising results in India (Negi and Naithani

1995). However, even the community forestry programmes in Nepal have not developed any management strategies that might induce natural regeneration of *Q. semecarpifolia* and other species of oaks (Shrestha and Paudel 1996). Protection of a few mother trees without lopping (Shrestha and Paudel 1996) or rotational lopping (Shrestha 2003) was recommended to ensure seed production and natural regeneration.

The seed size of *Q. semecarpifolia* is among the largest for trees in the Himalaya and in the oak family, weighing 5.0 to 6.5 g (Jackson 1994), approximately 2.4 g dry weights per seed (Singh and Singh 1992). Late successional species produce large seeds, but few in numbers to provide sufficient reserves for the seedling to survive for a period of time under the energy poor understory (Foster 1986). Seed germination depends strongly on the quality and thickness of litter and on the quality of light. There was a significant positive correlation between the numbers of seedlings in the litter-removal (Dzwonko and Gawronski 2002). Various experiments have shown that seedling emergence of large seeded tree species is inhibited by litter to a much lesser extent than that of small seeded species (Peterson and Facelli 1992, Myster 1994, Seiwa and Kikuzawa 1996). It is generally believed that seedlings of large seeded species are better able to survive environmental hazards, including burial under soil or litter, deep shade during the cotyledon stage and drought (Westoby *et al*. 1996).

3. STUDY AREA

The study was carried out in two *Quercus semecarpifolia* forests of central Nepal; one located at Simbhanjyang of Makawanpur district, and other at Shivapuri of Kathmandu district. Both areas lie in temperate region and almost have similar physiographic and edapho-climatic conditions. The forest of Simbhanjyang is highly disturbed, due to high grazing pressure, litter collection and lopping for fodder. The forest at Shivapuri is virtually undisturbed and it has been protected nearly for 40 years under different management systems.

3.1 *Quercus semecarpifolia* Forest in Simbhanjyang (Disturbed Forest)

The study area of the forest of Simbhanjyang (27º35’ N, 85º05’E, altitude range: 2380 to 2540 m asl) lies in Daman V.D.C. of Makawanpur district. Based on the data of the nearest weather station (Figure 1) the rain fall was highest in July (482.2 mm) and lowest in November (15 mm). The highest average maximum temperature was recorded in August (23.04°C) and the lowest average minimum temperature in January (1.93°C). The forest of study area is dominated by *Q. semecarpifolia* with the major associated species such as *Rhododendron arboreum, Lindera pulcherrima* etc. The study area is a part of three community forests; Karunabhumi, Risheshwor and Jhirghari community forests. The forest was extremely disturbed in the past. The forest was handed over to user group as community forest only in 1996; before that, the forest was open access resource and thus anthropogenic pressure was high. Still the forest is disturbed. The demand for fodder is highest during the dry season just before the monsoon and demand for fuelwood is fairly continuous throughout the year. Though cutting of live trees has been prohibited, people cut them to fulfill the demand of fuelwood. In addition local inhabitants has been collecting litter to maintain the soil fertility of their farmland and mulching for cattles and pigs, using broom. About 250 livestock grazed the forest everyday in the study area. The forest has been refered, hereafter, as ‘disturbed forest’.

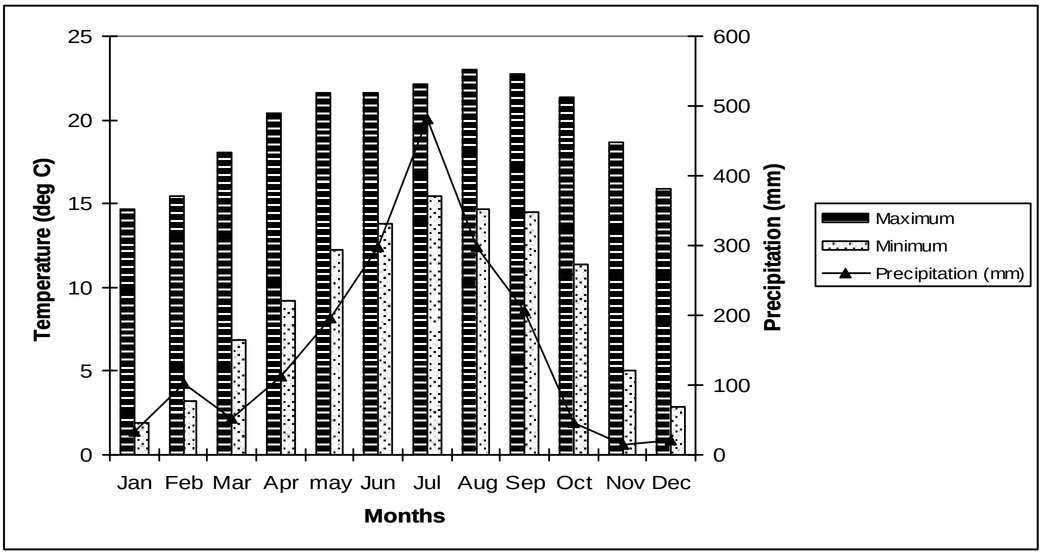

Figure 1: Five year (2003-2007) average of minimum and maximum temperature and precipitation recorded at Daman weather station (2736 m asl), Makawanpur (Source: Department of Hydrology and Meteorology, Government of Nepal)

3.2 *Quercus semecarpifolia* Forest at Shivapuri (Undisturbed Forest)

Shivapuri national park (27º48' N, 85º23'E, altitude range: 1366 to 2732 m asl and area 144 sq. km) lies at the distance of 12 km to the north of Kathmandu valley. It lies in a transition zone between subtropical and temperate zone. Due to its strategic location and convenience, Shivapuri was proclaimed as a watershed area supplying about one million cubic liter spring water per day to the city (DNPWC 2003). After Shivapuri experienced several problems concerning soil erosion as a result of deforestation, over-grazing, cultivation on steep slopes etc., reducing the quality and quantity of the water supplied, Government of Nepal initiated a program to protect Shivapuri and its adjoining areas as a watershed and wildlife reserve in 1975. In 2002, Shivapuri area was accredited to National Park (http://www.shivapuri.com.np/nationalpark.php).

Many species of wildlife like Rhesus monkey, Himalayan black bear, Leopard, Jungle cat etc. has been recorded in the park. The Park is also home to 177 species of birds, including 9 threatened species, over 100 species of butterflies with a number of rare and endangered species, and 129 species of mushroom (http://www.nepalnature.com/nepalnature.asp?natureid=snpark).

Shivapuri National Park has subtropical to temperate type of vegetation. The subtropical zone is dominated by *Schima wallichii, Castanopsis indica, C. tribuloides* and *Pinus roxburghii.* The common associates are *Alnus nepalensis, Prunus cerasoides, Engelhardia spicata* and *Q. glauca*. The shrubs include *Mussaenda frondosa, Osbekia stellata, Hypericum cordifolium* and *Phyllanthus parvifolius.* At higher elevations, mixed temperate forest of oak (*Q. lanata, Q. semecarpifolia*) and *Rhododendron* (*R. arboreum*) are prominent. The common associates are *Lyonia ovalifolia, Myrica esculenta, Q. lamellosa, Symplocus* sp., *Rhus* sp., *Gaultheria fragrantissima, Potentilla fulgens, Hedyotis scandens, Rubia manjith* (Chaudhary 1998).

Based on the data of the nearest weather station (Figure 2) the rain fall was highest in July (738.4 mm) and lowest in November (6.2 mm). The highest average maximum temperature was recorded in June (23.46°C) and the lowest average minimum temperature in January (4.78°C). The study area of the present research lies at the upper part of Shivapuri hill between 2180 and 2700 m asl. The area has mature forest of *Q. semecarpifolia*. By park regulation, felling of trees and collection of firewood and litter have been prohibited. Grazing has also been banned, but a few number of livestock from the nearby bufferzone area grazed sometimes in the area.

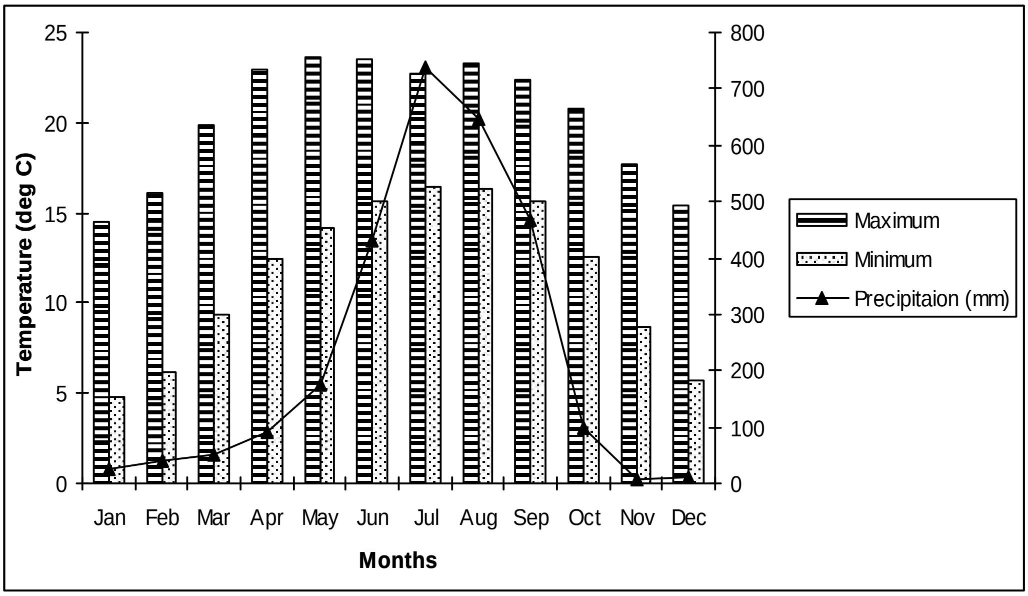

Figure 2: Five year (2003-2007) average of minimum and maximum temperature and precipitation recorded at Kakani weather station (2064 m asl), Nuwakot (Source: Department of Hydrology and Meteorology, Government of Nepal)

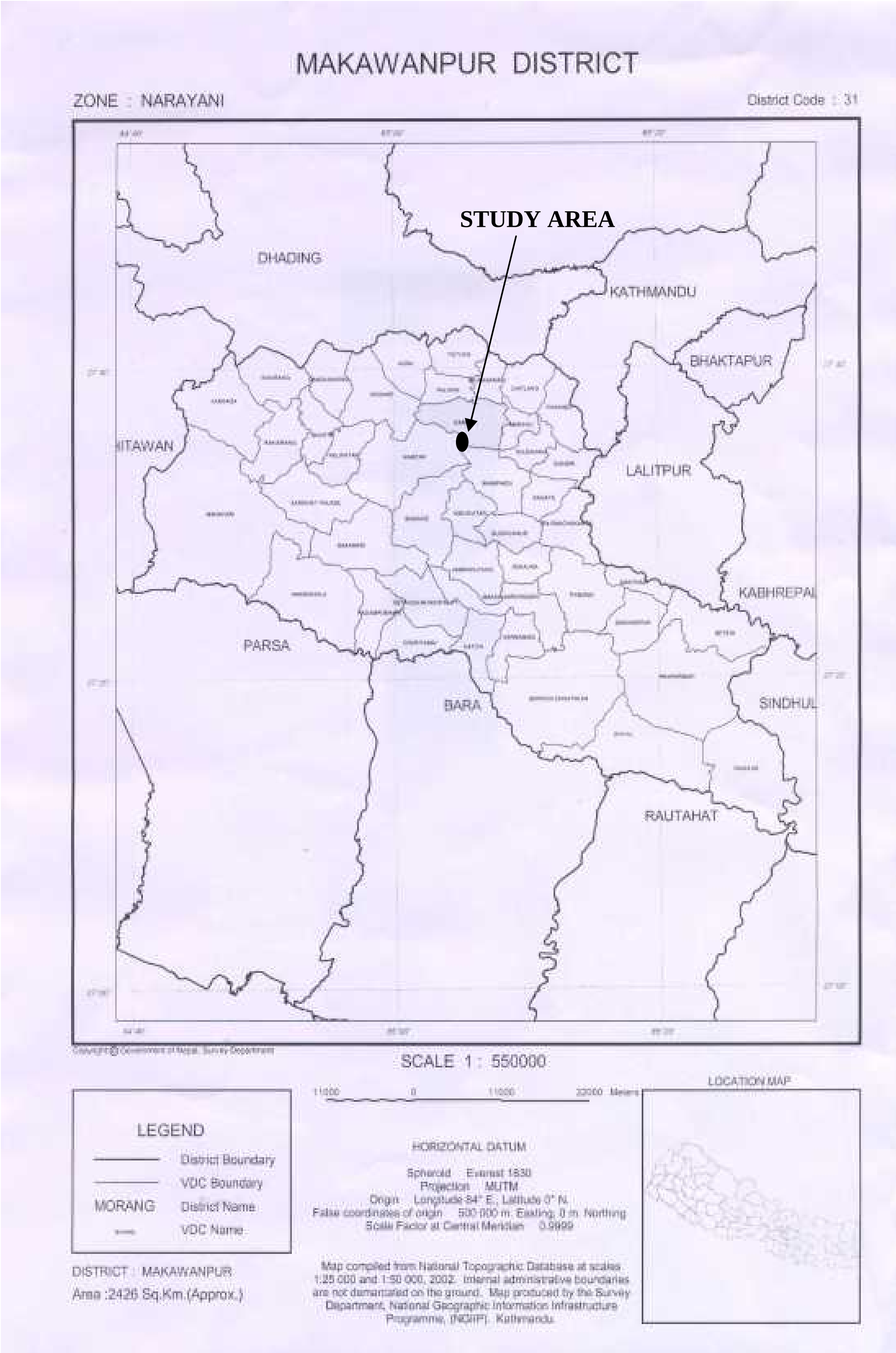

Figure 3: Map showing study area in Simbhanjyang, Makwanpur district (Disturbed forest)

Figure 4: Map showing study area in Shivapuri National Park, Kathmandu (Undisturbed forest).

4. MATERIALS AND METHODS

4.1 Field Data Collection

4.1.1 Vegetation Sampling

Vegetation sampling was conducted from September 21^{st} to October 17^{th}, 2007. A systematic random sampling method was used (Martin 1995, Cunningham 2001). In disturbed forest site, two vertical transects were visually located from the altitude of 2380 to 2540 m asl. The distance between the two vertical transects was 100-150 m. In each transect, twenty five quadrats (10 m × 10 m) were sampled at an interval of surface distance of 100-150 m. The vertical transects crossed Tribhuvan Highway, along with the residential area, as a result the interval between the quadrats nearby the highway was about 700 m.

Undisturbed forest site was divided into four vertical transects. Two transects run along each side of the trekking route towards the top of the hill. The first transect was at the horizontal distance of 100 m on each side from the route. Similarly the second transect in each side was again at 100 m horizontal distance from the first transect. In each transect, twelve quadrats (10 m × 10 m) were sampled at the interval of 150-250 m surface distance between 2180 and 2700 m asl. Two additional quadrats, one in each side were sampled at the distance of 100 m from the last quadrat of each second vertical transect.

In total hundred quadrats, 50 in each, were laid in the disturbed and undisturbed *Q. semecarpifolia* forests. In each sampling plot, the number of trees [diameter at breast height (DBH i.e. at 137 cm) ≥10 cm] and DBH of each tree were measured. Tree, shrub and herb species (only flowering plants) rooted in each of sampling plot were noted. Each quadrat was divided into four equal parts so that each sub-quadrat sized 5 m × 5 m. The number of saplings (DBH≥10 cm, height|Ψ137 cm), and seedlings (height|Φ137 cm) were counted for each tree species from the two diagonally located sub-quadrats (5 m × 5 m). Dead but erect trees were also recorded. Forest type, physical location (latitutde, longitude and altitude), topography (aspect and slope), disturbance and other environmental factors were recorded for each sampling plot. The field data sheet used for vegetation sampling has been attached in appendix (Appendix 4).

4.1.2 Plant Collection, Herbarium Preparation and Identification

Specimens of all herb, shrub and tree species encountered in sampling areas were collected, tagged and pressed using a herbarium press. Field notes documented the colour of the flower (if available), fruit, fragrance or any special features of the plants collected. When the plant specimens were completely dry, they were mounted on herbarium sheet of 16.5” × 11” using glue or tape, and labeled in accordance to Press *et al.* (2000). The herbarium specimens were identified using references such as Polunin and Stainton (1984) and Stainton (1988). These were also compared with specimens at Tribhuvan University Central Herbarium (TUCH), National Herbarium and Plant Laboratories, Godawari (KATH) and some of them were identified by experts of Taxonomy. Herbarium specimens were deposited in Tribhuvan University Central Herbarium (TUCH) existed in Central Department of Botany, Tribhuvan University, Kathmandu.

4.1.3 Soil sampling

Soil samples were collected from the four corners and middle of each quadrat in both study sites at a depth of 10-15 cm using a soil digger. These sub samples were mixed thoroughly to get single sample for each quadrat. The soil samples were air dried in shade in field as well as in laboratory and debris of plants, stone and objects other than soil were removed. About 200 g fine dry soil (passed through sieve of mesh size 0.5 mm) was stored in air tight polythene bag until laboratory analysis. There were 100 soil samples, in total, with 50 from each sampling site.

4.2 Soil Analysis

Soil samples stored in air tight polythene bags were analyzed at the Ecology laboratory in the Central Department of Botany, Tribhuvan University. For each soil sample pH, organic carbon (OC), and total nitrogen (N) were estimated using procedure described by Gupta (2000) and Zobel *et al.* (1987).

4.2.1 Soil pH

Soil pH of each soil sample was determined by using Fischer's Digital pH meter in 1:2 ratio of soil and distilled water. Before measurement, the pH meter was calibrated using buffer solutions made by buffer tablets of known pH (pH 4 and pH 7) in 100 ml distilled water. During the pH measurements, 25 g of soil sample was poured into 50 ml of distilled water in clean beaker. The mixture was stirred at least 30 minute using a magnetic stirrer and then allowed to settle down for few minutes. The calibrated electrode was dipped into the mixture and reading of pH was noted.

4.2.2 Organic Carbon

Walkey and Black's rapid titration method (1934) was followed to determine the organic carbon content in the soil. Soil sample (0.2 g) was taken in a 500 ml conical flask and added 10 ml of 1N potassium dichromate ($K_2Cr_2O_7$) and 20 ml of concentrated sulphuric acid (H_2SO_4) with gentle swirling for digestion. The digestion reaction being exothermic, the flask was left for about 30 minutes to cool down to room temperature. After 30 minutes, 200 ml distilled water, 10 ml orthophosphoric acid, and 0.5 ml diphenylamine indicator solution were added successively to the conical flask and shaken.

To that mixture in conical flask, ferrous ammonium sulphate solution ($Fe(NH_4)_2(SO_4)_2$ $6H_2O$) of 0.5 N was run from burette, with constant stirring until the color changed from violet to bright green through blue. The volume of ferrous ammonium sulphate solution consumed for titration was noted on burette. A blank titration (without soil) was run for every lot of 13 samples in a similar manner.

Volume of 0.5N $Fe(NH_4)_2(SO_4)_2$ $6H_2O$solution used for blank titration: X

Volume of 0.5N $Fe(NH_4)_2(SO_4)_2$ $6H_2O$consumed with soil: Y

Volume of 1N $K_2Cr_2O_7$ used for oxidation of organic carbon in soil: $\frac{X-Y}{2}$

$$\text{Organic carbon in soil (\%)} = \frac{X - Y}{2} \times 0.003 \times \frac{100}{2}$$

4.2.3 Total Nitrogen

Micro-Kjeldahl method involves the conversion of organic nitrogen into ammonia by boiling with concentrated sulphuric acid (H_2SO_4), the ammonia was subsequently liberated from its sulphate by distillation in presence of an alkali, which is titrated against hydrochloric acid (HCl).

Digestion

Air dried and sieved soil (1 g), 0.4 g copper sulphate ($CuSO_4.5H_2O$) and 3.5 g potassium sulphate (K_2SO_4) were taken in a 300 ml clean and dry Kjeldahl digestion flask. To the soil mixture, 6 ml of concentrated sulphuric acid (H_2SO_4) was added with gentle shaking. The mixture was heated on the preheated heating mantle at low heat until bubbles disappeared from the black mixture. When there was no frothing and then the heat was raised until the content of the flask would change to grey or greenish in color with complete digestion. The digest was cooled to room temperature and about 50 ml distilled water was added to the mixture with gentle shaking.

Distillation

The Kjeldahl distillation flask with digested materials was assembled and warmed up for 15 minutes. In the Kjeldahl distillation flask 30 ml sodium hydroxide (40% NaOH) was added through the funnel connected to tube of distillation flask and the cork was set. In clean and dry (50 ml) beaker, 10 ml boric acid indicator was pipetted and placed below the nozzle of the condenser in such a way that the tips of nozzle dip in to the indicator. Temperature was raised so as to boil the mixture in the distillation flask. When the distillate began to condense, the color of boric acid indicator changed from pink to green. Distillation was continued until the volume of distillate in beaker reached about 40 ml.

Titration

Beaker containing about 40 ml distillate was removed and titrated it with hydrochloric acid (0.1 N) in burette. The volume of HCl (Hydrochloric acid) consumed by distillate to change the green colour into pink was recorded. The same procedure was followed for other samples. For each batch of 10 samples, single blank (without soil) sample was included.

The following formula was used to calculate soil N.

$$\text{Soil N (\%) X}\frac{14 \,|\, \text{N} \,|\, (\text{S} - \text{B}) \,|\, 100}{\text{M}}$$

Where, N = normality of HCl

S = volume of HCl consumed with sample (ml)

B = volume of HCl consumed with blank (ml)

M = mass of soil taken (mg)

4.2 Data Analysis

From the field data, density, frequency, basal area and the importance value index (IVI) of trees were calculated following Zobel *et al.* (1987). The density of seedlings and saplings of each tree species were also calculated. To access regeneration status of *Q. semecarpifolia* density-diameter curves were developed for each site.

Plot wise data of vegetation and soil attributes were used in statistical analysis. Mean and standard deviation of the value of each attributes (community and soil) measured were determined separately for two forests. The mean values of these attributes were compared by Students’t-test. Spearman's correlation coefficients were determined among the plant community attributes and soil variables for the two forests separately. Scattered diagrams were constructed for the following pairs of characters: seedling and sapling density of *Q. semecarpifolia* with total tree basal area and seedling density of *Q. semecarpifolia* with litter coverage. All statistical analyses were done using Statistical Package for Social Sciences (SPSS 2001) version 11.5.

Community Structure

The field data was used to calculate frequency, density, basal area and importance value index following the method described by Zobel *et al.* (1987). The formulae used for the calculation of these attributes are given below:

$$\text{Frequency (\%)} = \frac{\text{Number of sampling units in which individual species occurred}}{\text{Total number of quadrats studied}} \mid 100$$

$$\text{Density (pl/ha)} = \frac{\text{Total number of individual species in all quadrat}}{\text{Total number of quadrats studied} \times \text{Area of a quadrat (m)}} \mid 10000$$

Basal area (BA) of a tree was obtained by following formula:

$$\text{Basal area (m}^2\text{)} = \frac{\pi\,(\text{DBH})^2}{4}$$

Basal area of a species in each sampling plot was obtained by the summation of BA of all individuals of a species. BA was expressed in percentage using the following formula,

BA of a species (%) = Total BA of a species × 100 /total area sampled

Importance value index (IVI) gives the overall importance of each species in the community. It was calculated as the sum of relative values of density, frequency and basal area for trees. Relative values were obtained by the following relations:

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

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

$$\text{Relative basal area (\%)} = \frac{\text{Basal area of individual species}}{\text{Total basal area of all trees}} \mid 100$$

Importance value index = Relative frequency Γ Relative density Γ Relative basal area

Species Diversity

Species diversity is the combination of species richness and species evenness. Species richness is the number of species per sampling unit. Species evenness is the distribution of individuals among the species. Evenness is the maximum when all the species have same or nearly equal number of individuals. Species diversity can be expressed in single index number. Among the several indices most commonly used two indices are Simpson's index (Simpson 1949) and Shannon-Wiener's index (Shannon and Weaver 1949). Simpson's index (C) reflects the dominance because it is more sensitive to the most abundant species than the rare species. Following relations were used to calculate Simpson's and Shannon-Weiner indices following Barbour *et al*. (1999).

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

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

Where, s = total number of species

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

Beta (β) Diversity and Similarity Index

The calculation of Beta (β) diversity helps to know the extent of species turn over between the sampling plots. The Whittaker's β diversity (β_w) was calculated using the following formula (Magurran 2004).

$$\beta_w = s/\bar{a}$$

Where, s = Total number of species recorded in a site.

ā = mean of total number of species recorded in each sampling plot.

Degree of similarity between any two stands or sites can be determined through the use of community coefficient (similarity index) which depends on the quantitative phytosociological characters of species common to both stands. Higher the index value more similar will be the stands to each other. Following are the formula for calculating similarity index.

$$\text{Jaccard's similarity index } (IS_J) = \frac{C}{A+B-C} \; |100$$

$$\text{Sorensen's similarity index } (IS_S) = \frac{2C}{A+B} \; |100$$

Where, IS = Index of similarity

A = Total number of species in one community

B = Total number of species in another community

C = Number of species which occur in both community

The similarity index ranges from 0 to 100 to quantify the range from no similarity to complete similarity.

Regeneration

With the objective of assessing regeneration patterns and population structure in the study areas, density - diameter (d-d) curves were developed for trees (individuals with DBH 10 cm and more) of each study forest. For developing the d-d curves total individuals of all sampling plots were counted, and placed in 10 cm DBH classes (10-20 cm, 20-30 cm, 30-40 cm, ….., 150-160 cm). The tree density in each diameter class was then computed. Density - diameter (d-d) curve was obtained by plotting diameter class (cm) on x-axis and density (pl/ha) on y-axis. This diagram was constructed for entire forest as well as for the dominant species *Q. semecarpifolia*. Percentage of seedling, sapling and tree of all tree species and of *Q. semecarpifolia* were calculated separately and represented in a bar diagram. The ratio of seedling and sapling to tree was calculated using the following formula:

For each plot,

$$\text{Seedling to tree ratio} = \frac{\text{Estimated number of seedlings}}{\text{Number of trees}}$$

$$\text{Sapling to tree ratio} = \frac{\text{Estimated number of saplings}}{\text{Number of trees}}$$

Then mean and standard deviation (±SD) for each site was calculated.

5. RESULTS

5.1 Soil

The two sites differ (P=0.002) in soil pH, total nitrogen and organic carbon (Table 1). The undisturbed forest had higher total nitrogen and organic carbon than in disturbed forest.

Table 1: Mean value (±SD) of soil attributes measured in two forests. The mean values of two forests were compared by Student's t-test. The sample size for each attribute was 50 from each forest.

Attributes	**Mean value (±SD)**		**T value**	**P value**
	Disturbed forest	**Undisturbed forest**		
Soil pH	4.9±0.34	4.74±0.28	3.327	0.002
Soil Nitrogen (%)	0.47±0.12	0.66±0.18	-5.568	0.000
Soil organic carbon (%)	4.8±1.5	6.4±2.3	-4.764	0.000
Carbon nitrogen ratio	10.7±3.3	10.3±4.7	0.495	0.623

Some of the soil variables showed significant correlations with vegetation structure. Herb species richness in disturbed forest declined with increasing soil nitrogen (r = Z 0.420, p= 0.002). In the same forest, total sapling density declined with increasing soil organic carbon (r = Z0.314, p= 0.026). These relationships were not significant for the forest in undisturbed forest.

Table 2: Correlation coefficients among various plant community attributes and soil characters in disturbed forest

Attributes		Correlation coefficients	Significance level
Total tree density	*Quercus semecarpifolia* sapling density	0.508**	0.000
	Total seedling density	0.286*	0.044
Herb species richness	Soil nitrogen	-0.420**	0.002
Soil organic carbon	Total sapling density	-0.314*	0.026

*Correlation significant at p<0.05, **significant at p<0.01

Table 3: Correlation coefficients among various plant community attributes and soil characters in undisturbed forest

Attributes		Correlation coefficients	Significance level
Total tree density	Tree species richness	0.525**	0.000
BA of *Quercus semecarpifolia*	Litter coverage	-0.289*	0.042
	C/N ratio	0.340*	0.061
Litter coverage	Shrub species richness	-0.384**	0.006
	Organic carbon	-0.331*	0.019
	Canopy coverage	0.478**	0.000

**Correlation significant at p<0.01, *significant at p<0.05

5.2 Vegetation Analysis

Community Structure

In disturbed forest, twelve species were recorded at tree stage. Tree density ranged from 2 to 1202 pl/ha, and basal area from less than 0.001 to 0.697%. The total basal area of all tree species was 0.776%. *Q. semecarpifolia* was the dominant tree species with the highest importance value index (218.31). Since the study area was pure oak forest, other tree species were rarely found. *Lindera pulcherrima* with importance value index 24.29 was found more frequently in comparison to other tree species. Out of twelve species, eight species had IVI less than ten (Table 4).

Table 4: Frequency (F, %), Relative Frequency (RF, %), Density (D, Pl/ha), Relative Density (RD, %), Basal Area (BA, %), Basal Area (RBA, %) and Importance value index (IVI) of tree species at disturbed forest (DF)

SN	Plant Species	F	RF (%)	D	RD (%)	BA (%)	RBA (%)	IVI
1	*Quercus semecarpifolia* Sm.	100	44.643	1202	83.82	0.697	89.75	218.31
2	*Lindera pulcherrima* (Nees) Benth. ex Hook. f.	16	7.143	32	2.23	0.028	3.62	24.29
3	*Rhododendron arboreum* Sm.	36	16.071	66	4.60	0.013	1.73	16.41
4	*Lyonia ovalifolia* (Wall.) Drude	26	11.607	44	3.06	0.007	0.93	10.31
5	*Mahonia napaulensis* DC.	10	4.464	20	1.59	0.006	0.80	7.08
6	*Quercus lamellosa* Sm.	10	4.464	10	0.69	0.011	1.46	6.62
7	*Viburnum erubescens* Wall. ex DC.	2	0.893	2	0.14	0.006	0.72	6.58
8	*Ilex dipyrena* Wall.	4	1.786	6	0.48	0.002	0.29	3.05
9	*Myrsine semiserrata* Wall.	2	0.893	2	0.14	0.003	0.44	2.65
10	*Quercus leucotrichophora* A. Camus	4	1.786	4	0.28	0.001	0.18	2.24
11	*Quercus lanata* Sm.	10	4.464	26	1.813	0.001	0.07	1.10
12	*Eurya acuminata* DC.	4	1.786	14	0.97	0.000	0.02	1.05
	Total	224	100	1428	99.813	0.776	100	299.69

In undisturbed forest, fifteen species were recorded at tree stage. Tree density ranged from 2 to 274 pl/ha, and basal area from 0.0006 to 1.09% (Table 5). The total basal area of all tree species was 1.282%. *Q. semecarpifolia* was the dominant tree species with the highest IVI (151.21) while the IVI of the second dominant species, *Eurya acuminata*, was 37.41. Out of fifteen species nine species had IVI less than ten.

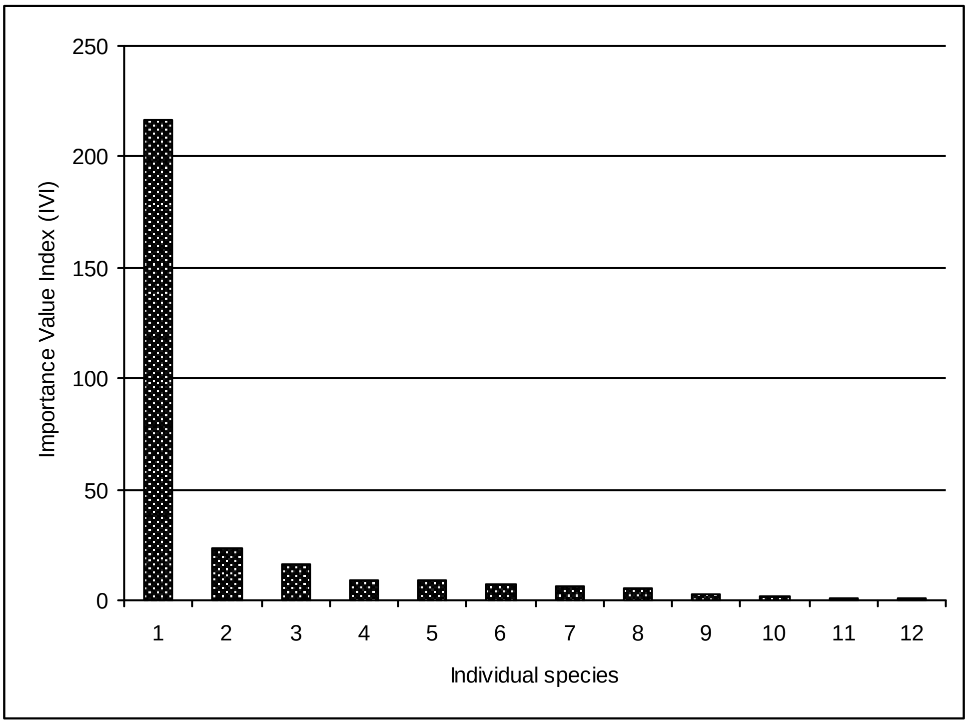

Figure 5: Importance Value Index (IVI) of tree species at disturbed forest. The individual species corresponds to the serial number in the table 4.

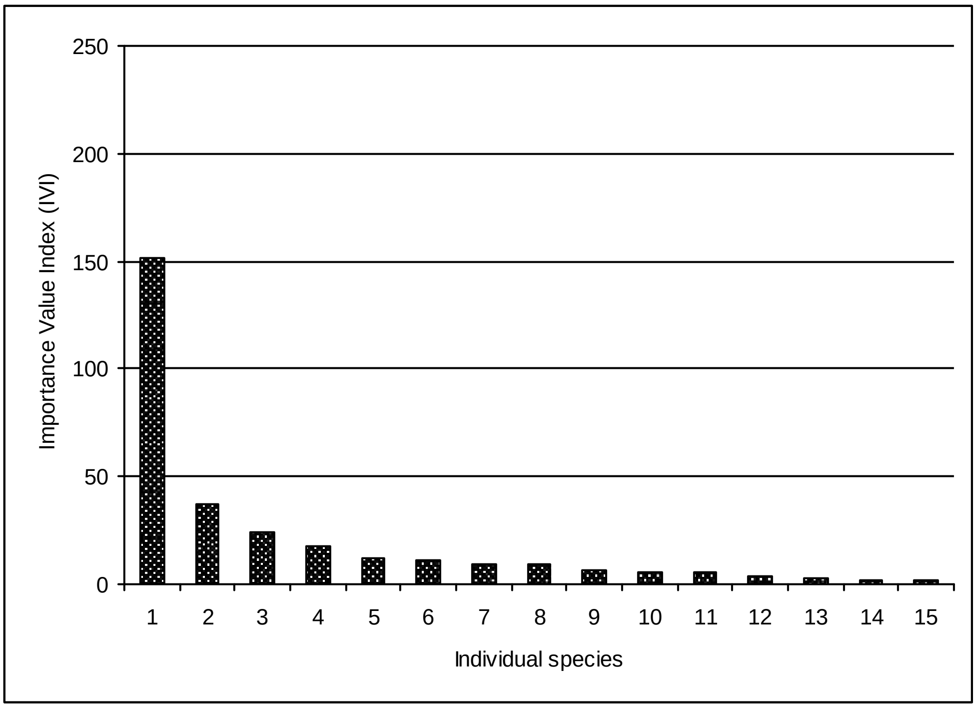

Figure 6: Importance Value Index (IVI) of trees at undisturbed forest. The individual species corresponds to the serial number in the table 5.

Table 5: Frequency (F, %), Relative Frequency (RF, %), Density (D, pl/ha), Relative Density (RD, %), Basal Area (BA, %), Basal Area (RBA, %) and Importance value index (IVI) of tree species at Undisturbed forest (UDF)

SN	Plant Species	F	RF (%)	D	RD (%)	BA (%)	RBA (%)	IVI
1	*Quercus semecarpifolia* Sm.	96	27.746	274	38.375	1.0909	85.097	151.218
2	*Eurya acuminata* DC.	58	16.763	132	18.487	0.0277	2.164	37.414
3	*Ilex dipyrena* Wall.	46	13.295	92	12.885	0.0709	5.529	31.709
4	*Litsea oblonga* (Wall. ex Nees) Hook. F.	24	6.936	50	7.003	0.0509	3.969	17.908
5	*Rhododendron arboreum* Sm.	24	6.936	34	4.762	0.0059	0.462	12.160
6	*Lindera pulcherrima* (Nees) Benth. ex Hook. f.	24	6.936	28	3.922	0.0067	0.525	11.383
7	*Myrsine semiserrata* Wall.	18	5.202	26	3.641	0.0049	0.380	9.223
8	*Lyonia ovalifolia* (Wall.) Drude	12	3.468	20	2.801	0.0061	0.477	6.746
9	*Photinia integrifolia* Lindl.	12	3.468	16	2.241	0.0016	0.124	5.833
10	*Quercus lamellosa* Sm.	12	3.468	14	1.961	0.0036	0.278	5.707
11	*Skimmia arborescens* T. Anderson ex Gamble	10	2.890	12	1.681	0.0081	0.629	5.200
12	*Stranvaesia nussia* (D. Don) Decne.	2	0.578	4	0.560	0.0006	0.048	1.187
13	*Polygala arillata* Buch.-Ham. ex D. Don	4	1.156	4	0.560	0.0022	0.169	1.885
14	*Mahonia napaulensis* DC.	2	0.578	6	0.840	0.0007	0.056	1.475
15	*Viburnum erubescens* Wall. ex DC.	2	0.578	2	0.280	0.0008	0.065	0.923
	Total	346	100	714	100	1.282	99.971	299.971

Species Richness and Diversity

Eighty six flowering plant species in total were recorded in the disturbed and fifty seven species in the undisturbed forest. Tree species richness (α diversity) was significantly higher in undisturbed than in disturbed forest while the herb and shrub species richness was higher in disturbed than in undisturbed forest (Table 6). In undisturbed forest, the shrub species richness was negatively correlated with litter cover on the forest floor (r = Z 0.384, p= 0.006) (Table 3). Simpson’s index of dominance (C) for trees was higher in disturbed (0.71) than in undisturbed forest (0.21) whereas Shannon-Wiener's index (H') was higher at undisturbed (1.96) than at disturbed forest (0.75). The calculated t-test value (9.2) was higher than tabulated value. Hence, there was significant variation in species diversity between two forests.

Beta (β) Diversity and Similarity Indices

The β diversity of trees was higher (5.35) in disturbed forest while β diversity of herbs and shrubs were higher in undisturbed forest (Table 6). Jaccard's and Sorenson's similarity indices for trees, shrubs and herbaceous layer were greater than 50%. Trees had the highest Jaccard's and Sorensen's similarity indices (58.8 % and 74.07 %) between the two forests whereas herbs had the least similarity index.

Table 6: Total number of species (S), species richness (α diversity), β- diversity, Simpson's index (C) of dominance, Shannon-Wiener index (H') of species diversity and Jaccard's and Sorenson's similarity index for *Quercus semecarpifolia* in disturbed forest (DF) and undisturbed forest (UDF)

Plant habit	**S**		**Alpha (π) diversity**		**Beta (β) diversity**		**C**		**H'**		**Similarity indices**	
	DF	**UDF**	**DF**	**UDF**	**DF**	**UDF**	**DF**	**UDF**	**DF**	**UDF**	**IS_J (%)**	**IS_S (%)**
Tree	12	15	2.2	3.5	5.35	4.23	0.71	0.21	0.75	1.96	58.82	74.07
Shrub	17	13	3.4	2.4	4.94	5.5	-	-	-	-	57.89	73.33
Herb	57	29	16	5.5	3.44	5.31	-	-	-	-	50.87	67.44

Population Structure and Regeneration

In disturbed forest, population structure of *Quercus semecarpifolia* includes 51.57% seedling, 20.25% sapling and 28.17% trees (Figure 7). Contribution of saplings and seedlings in the population of *Q. semecarpifolia* was much higher in disturbed than in undisturbed forest (Figure 7). Population structure of all the species includes 53.36% seedling, 29.49% sapling and 17.14% trees in UDF. Size class distribution diagrams of *Q. semecarpifolia* alone and of all tree species combined were similar and resembled inverse J- shape. There were greater numbers of individuals in lower size classes. The diagrams showed that *Q. semecarpifolia* as well as other species in the forest were regenerating currently. However, regeneration was not continuous as indicated by absence of individuals in some diameter classes.

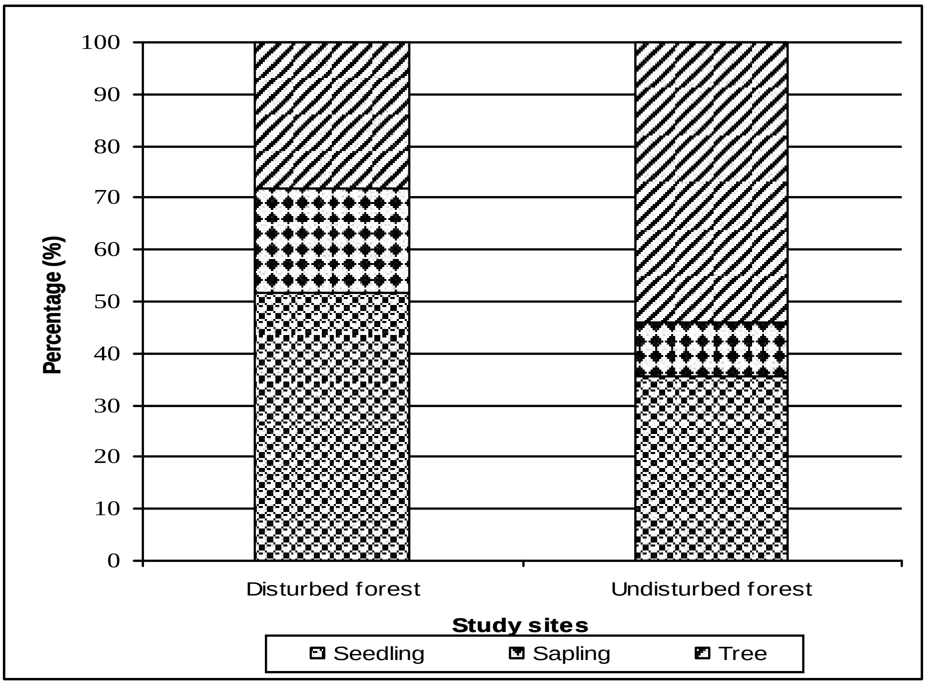

Figure 7: Percentage of seedlings, saplings and trees of *Q.semecarpifolia* in disturbed and undisturbed forest.

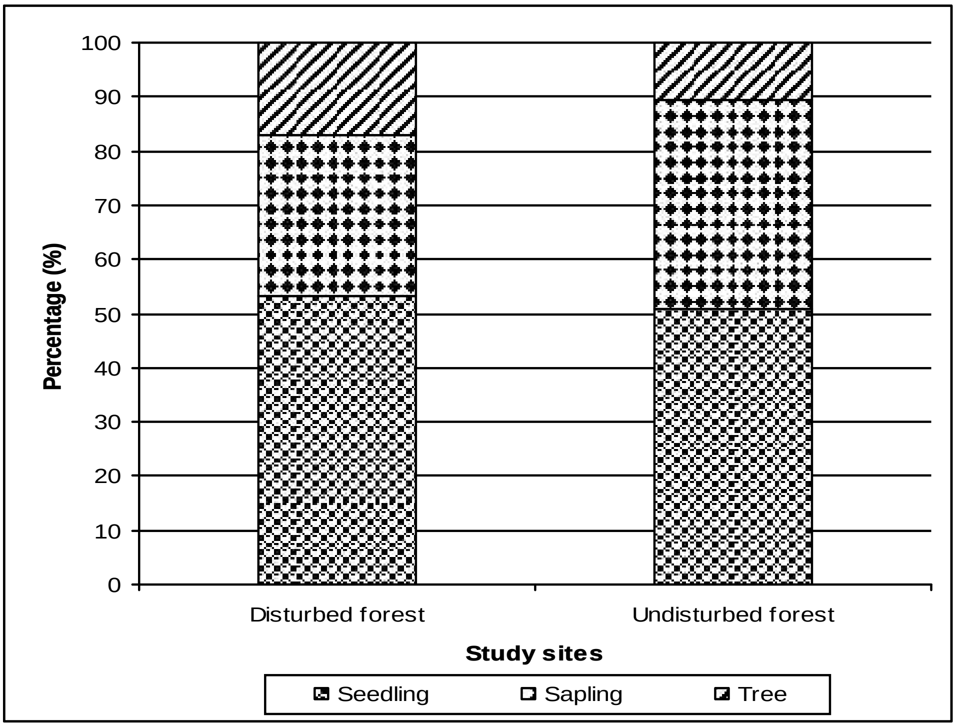

Figure 8: Percentage of seedlings, saplings and trees of all tree species in disturbed and undisturbed study sites

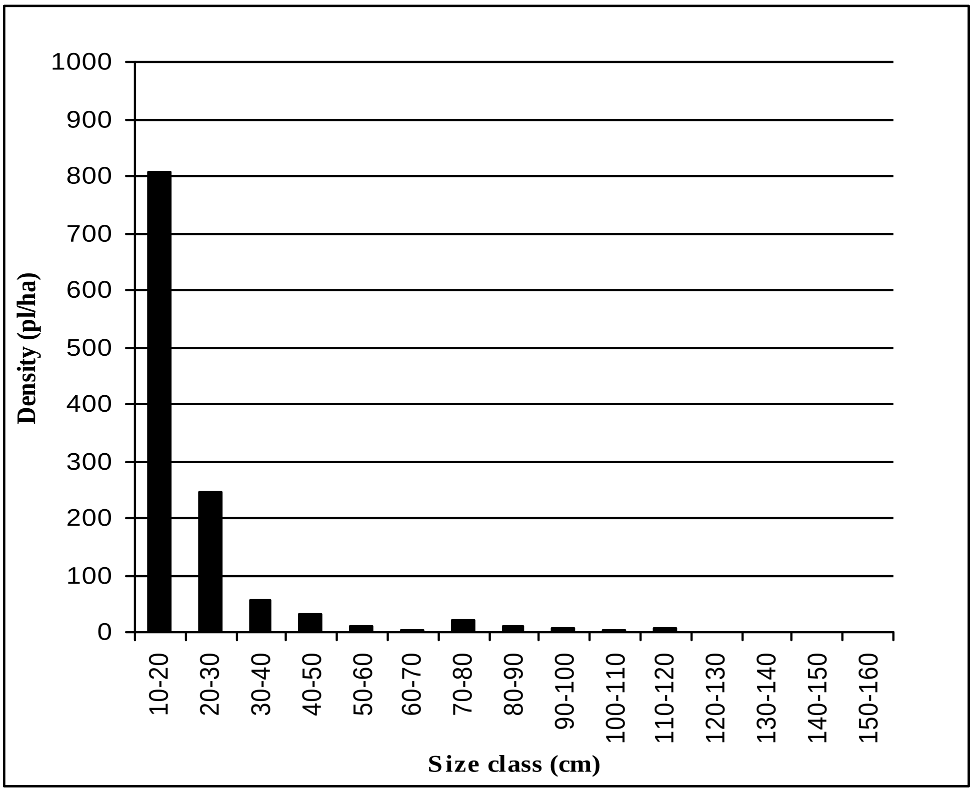

Figure 9: Density of different diameter classes of trees of *Q. semecarpifolia* in disturbed forest

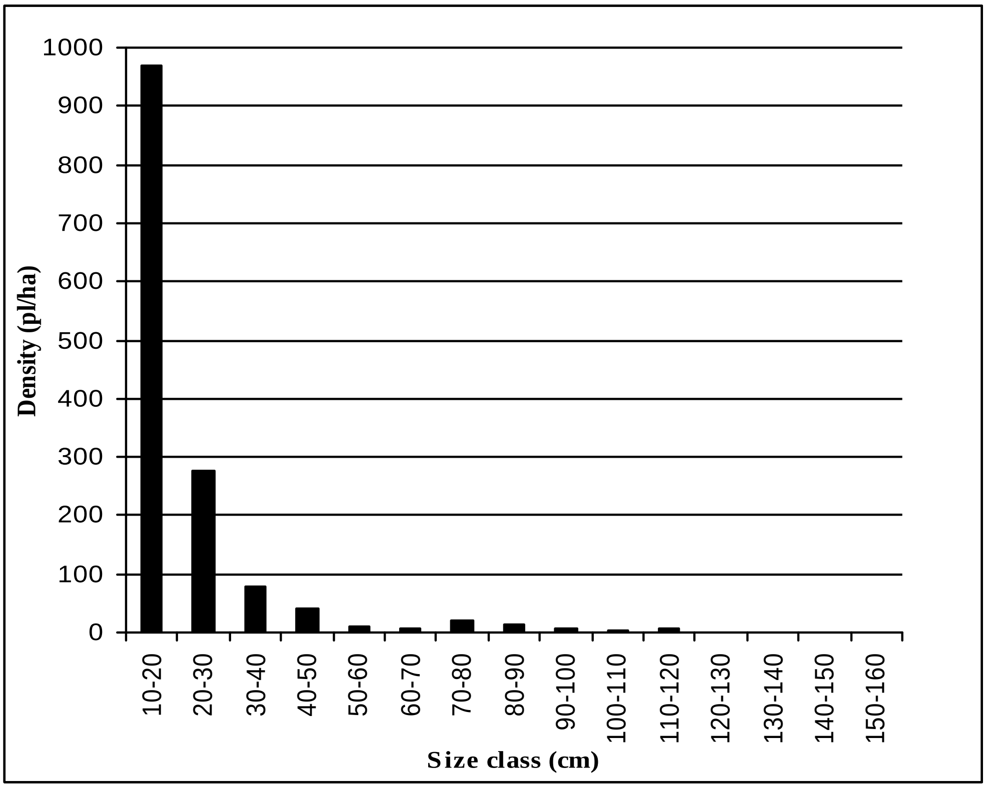

Figure 10: Density of different diameter classes of trees of all species in disturbed forest

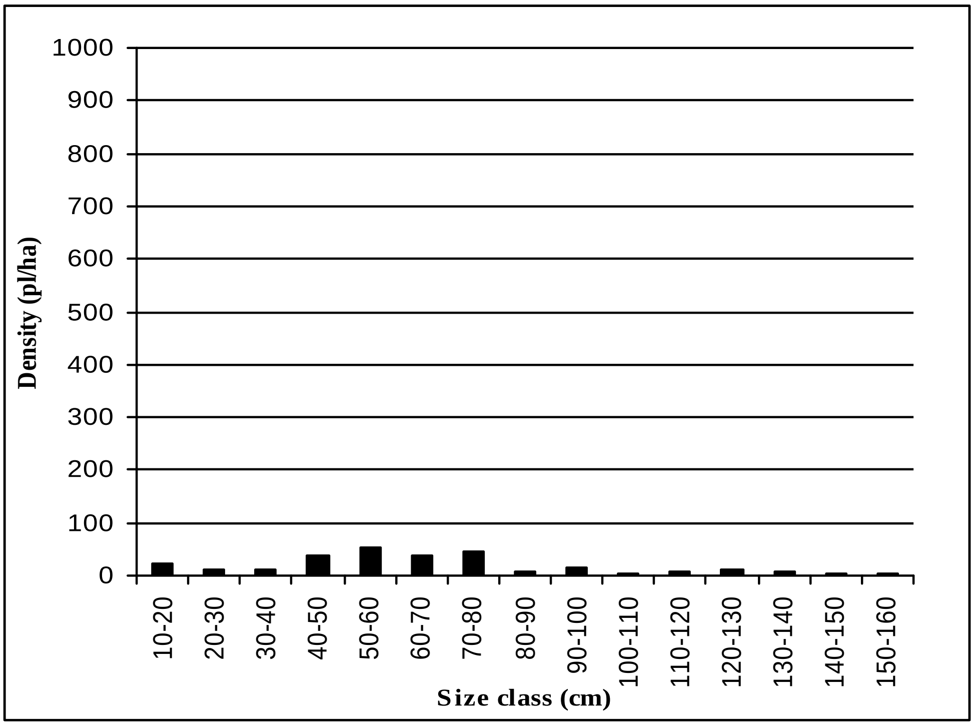

Figure 11: Density of different diameter classes of trees of *Q. semecarpifolia* in undisturbed forest

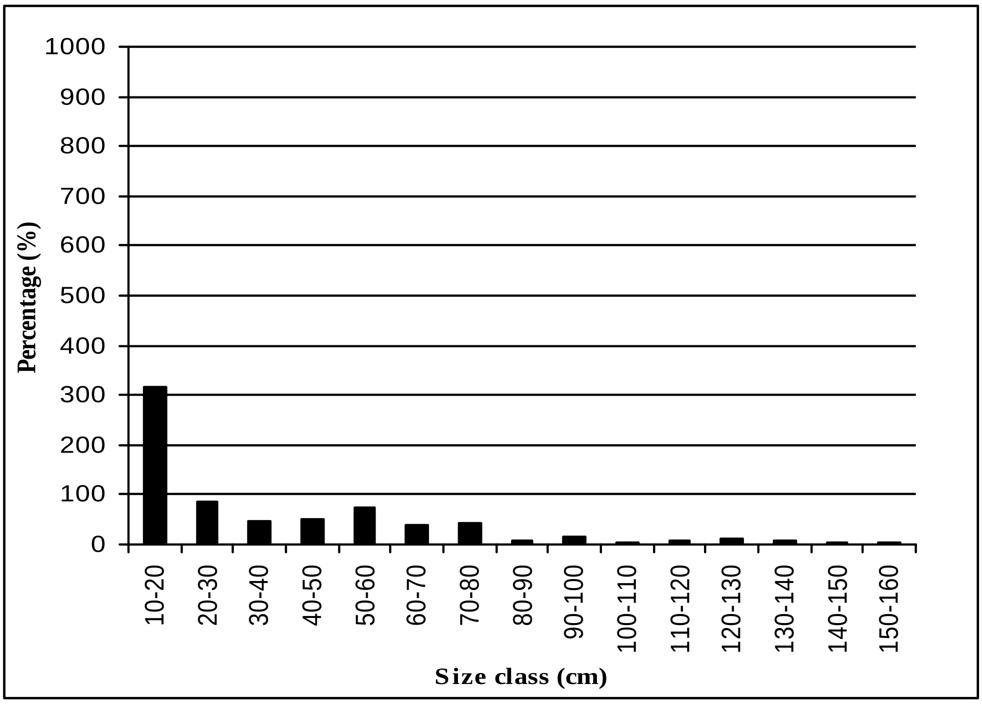

Figure 12: Density of different diameter classes of trees of all species in undisturbed forest

In undisturbed forest, the percentage of seedlings, saplings and trees in the population of *Quercus semecarpifolia* were 35.57 %, 10.28 % and 54.15 %, respectively (Figure 8). Density diameter curve of *Q. semecarpifolia* was different from the curve of all tree species in undisturbed forest. Curve was bell shaped when only *Q. semecarpifolia* was considered however, nearly inverse J- shaped when all tree species was considered. It indicates less regeneration of *Q. semecarpifolia* though there was frequent regeneration of other species in recent time. The percentage of seedlings, saplings and trees of all the species combined were 50.80 %, 38.49 % and 10.6 %, respectively. In disturbed forest, seedling density of *Q. semecarpifolia* was almost half in comparison to the seedling density of total tree species (Table 7). However, in undisturbed forest, it was still lesser than the total density of all tree species.

Table 7: Mean value (±SD) various community attributes measured in two forests. The mean values of two forests were compared by Student's t-test. The sample size for each attribute was 50 from each forest

Attributes	**Mean value**		**T-value**	**P-value**
	Disturbed forest	**Undisturbed forest**		
Total tree density (pl/ha)	1428±756	714±270	6.287	0.000
Density of *Quercus semecarpifolia* trees (pl/ha)	1202±833	274±141	7.761	0.000
Density of saplings of all tree species (pl/ha)	2456±1966	2580±1968	-0.315	0.753
Density of *Quercus semecarpifolia* sapling (pl/ha)	864±1095	52±180	5.174	0.000
Density of seedlings of all tree species(pl/ha)	4444±2671	3408±2464	2.015	0.047
Density of *Quercus semecarpifolia* seedling (pl/ha)	2200±1323	180±465	10.187	0.000
Basal area of *Quercus semecapifolia* (%)	0.69±0.4	1.09±0.7	-3.35	0.001
Basal area of all tree species (%)	0.77±0.38	1.28±0.69	-4.416	0.000
Herb species richness (species/100m²)	16±4	5.5±2.7	15.909	0.000
Shrub species richness (species/100m²)	3.4±1.4	2.4±1.5	3.607	0.001
Tree species richness (species/100m²)	2.2±1.5	3.5±1.3	-4.649	0.000
Total species richness (species/100m²)	22.2±4.4	9.6±3.5	15.882	0.000
Litter coverage (%)	54±22	78±19	-5.845	0.000

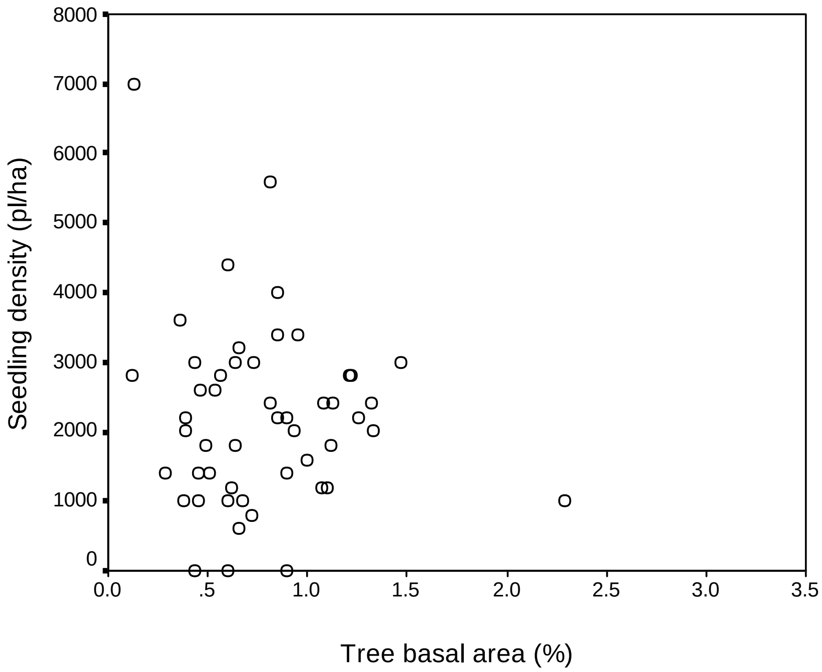

Figure 13: Scatter diagram showing variation of seedling density of *Q. semecarpifolia* with total basal area of all tree species in disturbed forest

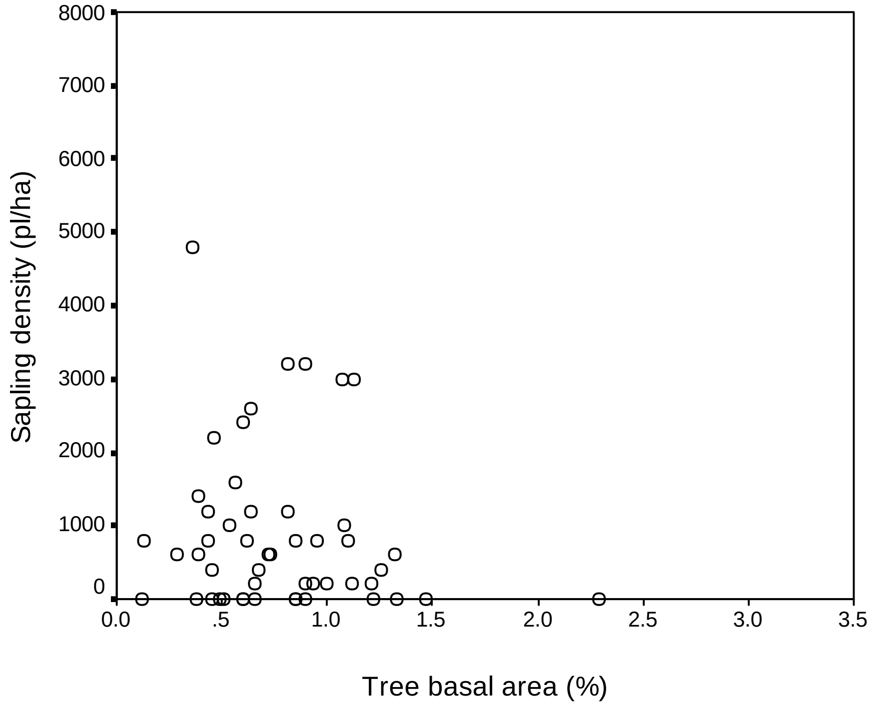

Figure 14: Scatter diagram showing variation of sapling density of *Q. semecarpifolia* with total basal area of all tree species in disturbed forest

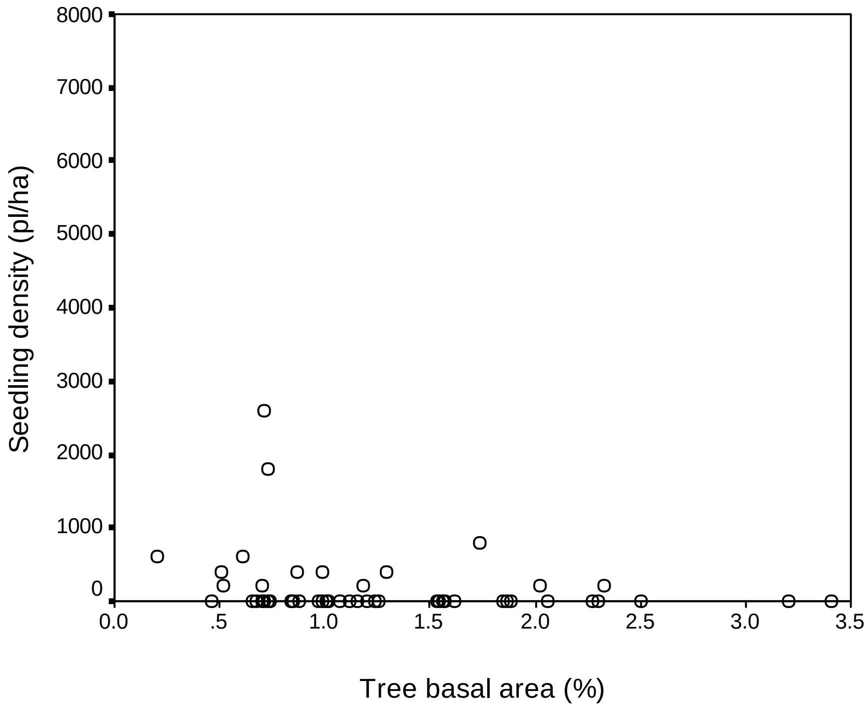

Figure 15: Scatter diagram showing variation of seedling density of *Q. semecarpifolia* with total basal area of all tree species in undisturbed forest

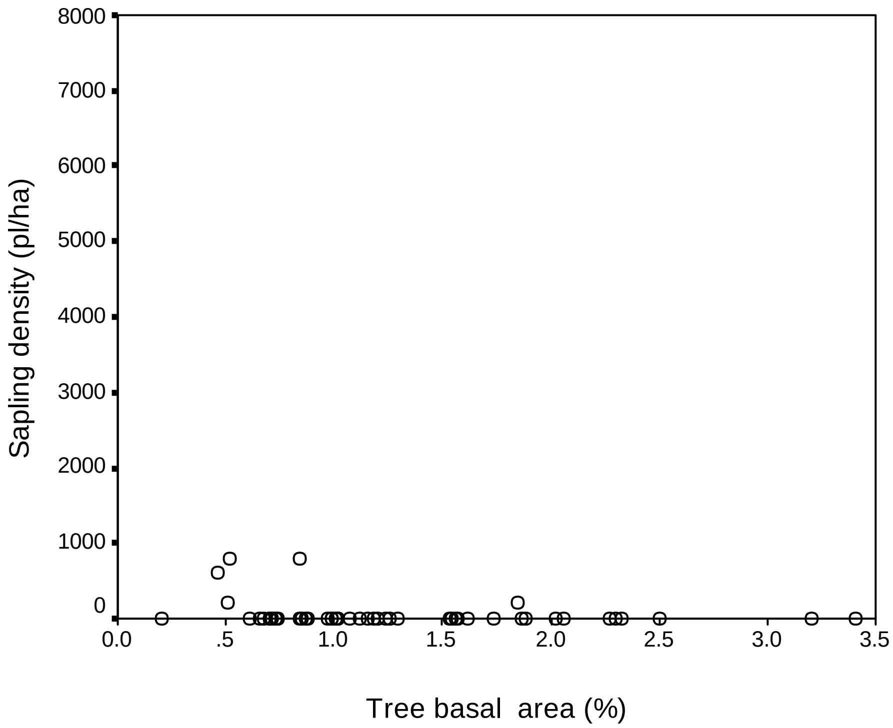

Figure 16: Scatter diagram showing variation of sapling density of *Q. semecarpifolia* with total basal area of all tree species in undisturbed forest

The seedling and sapling density of *Q. semecarpifolia* was high on those plots where basal area of all tree species was low (Figures 13-16). On plots with BA> 0.3%, seedlings and saplings had very low density in both forest.

Out of 50 plots in disturbed forest, seedlings of *Q. semecarpifolia* were absent only in three plots and saplings absent in fifteen plots. However, in undisturbed forest, the seedlings were absent in thirty six plots and saplings in forty five plots. The number of seedlings and saplings of *Q. semecarpifolia* is much lower in undisturbed forest. In both forests, seedling density did not show any pattern of variation with litter cover.

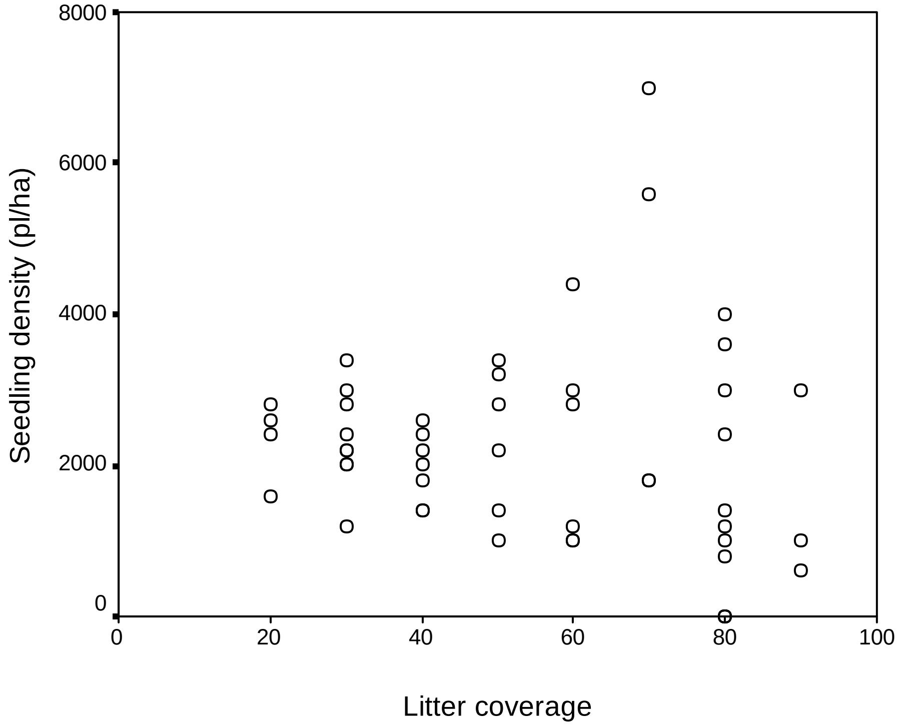

Figure 17: Scatter diagram showing variation of seeding density *Q. semecarpifolia* with litter coverage in disturbed forest

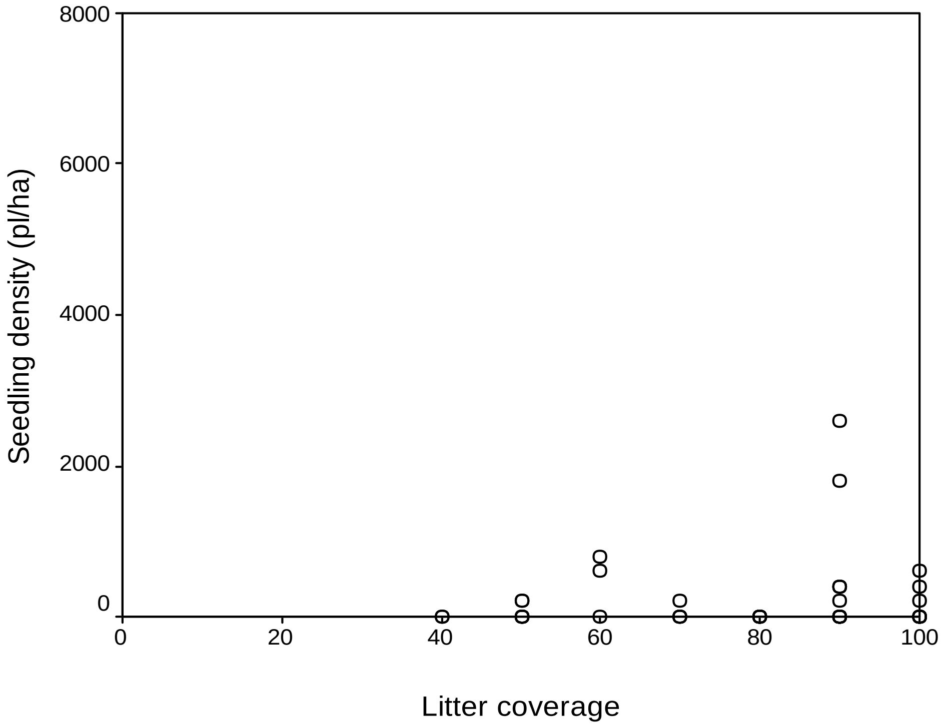

Figure 18: Scatter diagram showing variation of seeding density *Q.semecarpifolia* with litter coverage in undisturbed forest

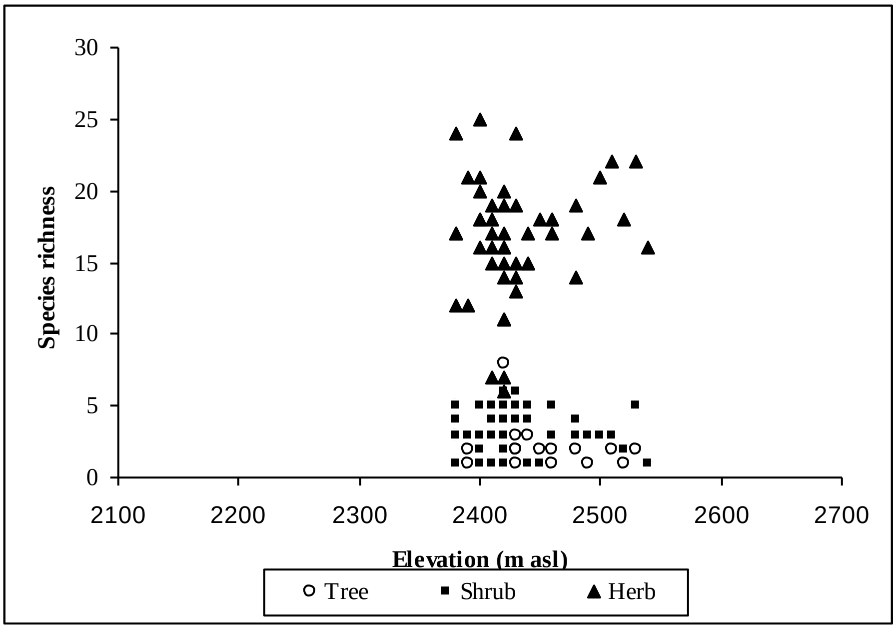

Figure 19: Scatter diagram showing variation of species richness (number of species/100 m^2) with elevation in disturbed forest

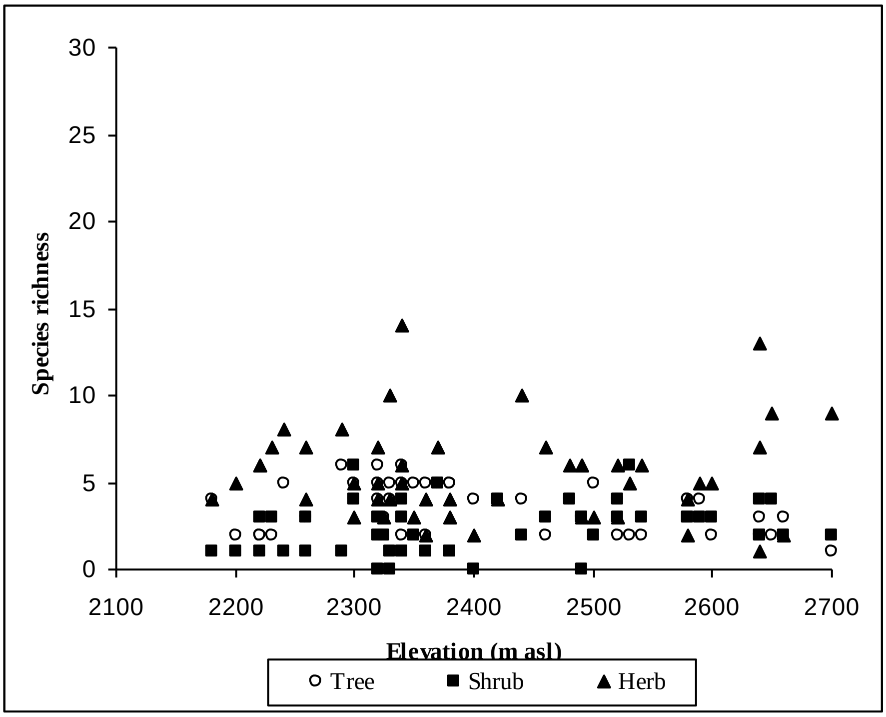

Figure 20: Scatter diagram showing variation of species richness (number of species/100 m^2) with elevation in undisturbed forest

Table 8: Seedling and sapling to tree ratio of *Quercus semecarpifolia* and all tree species combined in the two study sites

Attributes	Seedling tree ratio		Sapling to tree ratio	
	Disturbed forest	Undisturbed forest	Disturbed forest	Undisturbed forest
Quercus semecarpifolia	3.4±5.2	0.89±2.51	0.72±0.95	0.16±0.64
All tree species combined	4.05±3.5	5.16±4.60	1.94±1.92	3.8±3.27

6. DISCUSSION

6.1 Soil Attributes

6.1.1 Soil pH

Although the soil pH of both the forests was acidic, it differs significantly between two forests (Table 1). Since litter had not collected from undisturbed forest, there was thick accumulation of litter. High litter accumulation and soil organic matter decrease soil pH (Biswas and Mukherjee 1994). This might be the reason for low pH of soil in undisturbed forest than in disturbed, where litter collection by locals near the village was very common. In addition, the acidic nature of soil of the study area could be attributed to the high rainfall (Figures 1 and 2) which is sufficient to remove basic cations out of the surface horizons of the soils. According to Vetaas (2000) and Tashi (2004), *Quercus semecarpifolia* seedlings seem to prefer a soil pH of around 6, which is less acidic than the present finding.

6.1.2 Soil Organic Carbon and Nitrogen

Soil organic carbon (OC) and nitrogen (N) in disturbed forest were lower than in undisturbed. The mean organic carbon was 4.8% in disturbed and 6.4% in undisturbed forest. Due to effect of low temperature and high rainfall on decomposition and mineralization rates, the organic matter content of the soil increases at higher altitudes (Begon *et al.* 1990). Mean nitrogen content in disturbed and undisturbed forest was 0.47% and 0.66%, respectively. Higher value of soil N in undisturbed forest might be due to accumulation of more litter, and the low N content in soil of disturbed forest might be due to extensive litter collection. Soils under dense canopy usually have significantly higher organic matter and nitrogen (Isichei *et al*. 1992). Increase in total nitrogen is due to the increase in organic matter content of the soil (Hatton and Smart 1984). In addition, high accumulation of nitrogen beneath tree canopy might be due to less favorable condition for denitrification and ammonia volatilization (Barth and Klemmedson 1978). Litter is the main source of organic matter and other plant nutrients. In the present study, soil did not seem to be an influencing factor for the variation in seedling density of *Quercus semecarpifolia*. Similarly, Vetaas (2000) and

Tashi (2004) reported no clear relationship between the seedlings of *Q. semecarpifolia* and the soil variables, and they added that survival of seedlings may be determined by external factors.

6.2 Vegetation Structure

Tree canopy of both disturbed and undisturbed forest was mainly formed by *Quercus semecarpifolia* as it is a pure oak forest with a small contribution from codominant trees. *Q. semecarpifolia* was the dominant tree species both in disturbed and undisturbed forest with highest IVI (Tables 4 and 5). IVI of *Q. semecarpifolia* was higher in disturbed forest (218) than in undisturbed (151). This might be due to less number of tree species in the disturbed forest, and relatively low representation of associated species in the community. Total number of tree species was slightly higher in undisturbed forest (15 species) than in disturbed (12 species). Uniyal *et al.* (2010) also reported higher number of tree species (16 species) in undisturbed than in disturbed *Q. leucotrichophora* forest (14 species). These observations indicate that tree species richness remained high in undisturbed forest. A low number of tree species in disturbed forest might reflect the high pressure of resource utilizations in the form of timber, firewood, fodder, etc.

In understory vegetation, the total number of species and the plant species richness (α diversity) of herb and shrub layer were both higher in disturbed forest than in undisturbed (Table 6). The disturbed forest had relatively open canopy as compared to undisturbed forest. High canopy openness allows more light to reach the forest floor and creates a favourable niche for the growth of ground vegetation, which is otherwise limited by low light in forest with closed canopy. Uniyal *et al.* (2010) also reported the higher number of shrub species in disturbed *Q. leucotrichophora* forest than in undisturbed. Shrestha (2005) reported higher density and the number of shrub species in mid hill *Shorea robusta* forest with open canopy than in similar forest with closed canopy. The result implies that a small-scale lopping regime, thereby increasing canopy openness, will enhance species richness of vascular plants (Vetaas 1997).

Total basal area of tree species was higher (1.28%) in undisturbed forest than in disturbed (0.776%). Decline in basal area with increasing disturbance was also reported for eastern Himalayan (Bhuyan *et al.* 2003) and Mexican montane rain forests (Ramirez *et al.* 2001). The low basal area observed in disturbed forest might be resulted from the high stocking among the small size classes (10-15 cm DBH), and the absence of large trees due to human activities such as timber harvesting and fuelwood collection. The undisturbed forest of the present study lies inside the Shivapuri National Park, where tree logging had been banned for more than three decades. The higher tree basal area in that forest was due to the large stocking of mid size classes along with the presence of large trees (size 150-155 cm DBH).

The patterns of tree density were just reverse to basal area. Total tree density was higher in disturbed forest (1428 pl/ha) than in undisturbed forest (714 pl/ha). This might be due to presence of larger number of small sized trees in disturbed forest and large sized but fewer trees in undisturbed. However, Uniyal *et al.* (2010) reported lower density in disturbed forest (804 pl/ha) than in undisturbed forest (2144 pl/ha) of Garhwal Himalaya. The contrasting pattern observed between present study area and the forest of Garhwal Himalaya could be due to higher intensity of disturbance in the 'disturbed' forest studied by Uniyal *et al*. (2010).

6.3 Species Similarity and Species Diversity

Similarity indices for tree (74.07%) and shrub (73.33%) species between two forests were relatively high (Table 6). It might be due to similar climatic and topographic conditions. The similarity index for herb species was slightly low (67.44%). It might be due to differences in canopy cover and disturbances between two forests.

Alpha diversity of tree was higher in undisturbed forest whereas alpha diversity of shrub and herb layer was higher in disturbed forest. Lower alpha diversity of tree in disturbed forest might be due to chopping and logging of trees for fuelwood and timber purpose. Due to low number of large sized trees in disturbed area, the canopy was open. The open canopy might favour the growth of herb and shrub species. This might be the reason of higher alpha diversity of shrub and herb species in disturbed forest. However, the ground vegetation was sparse in undisturbed forest due to closed canopy.

The Shannon-Wiener diversity index of tree species was more than twice in undisturbed forest (1.96) than the value in disturbed (0.75) This might be due to higher alpha diversity of tree layer, and the total number of tree species in undisturbed forest than in disturbed. The present values are closely comparable to those reported by Uniyal *et al.* (2010) from Garhwal Himalaya, where it was 1.4 for undisturbed forest and 0.7 for disturbed. However, Shannon-Wiener indices were nearly equal for disturbed (3.5) and undisturbed (3.4) evergreen forests of Andaman Island (Rasingam and Parathasarathy 2009). In protected (undisturbed) forest of the same island, Tripathi *et al*. (2004) reported ShannonWiener index from 2.63 to 3.58.

Simpson's index for trees of disturbed forest (0.71) was higher than of undisturbed (0.21). This might be due to higher concentration of dominance to single dominant tree species (*Quercus semecarpifolia*) in disturbed forest. However, Uniyal *et al.* (2010) reported Simpson's to be 0.24 and 0.35 for disturbed and undisturbed forest, respectively, in Garhwal Himalaya. Similarly, Rasingam and Parathasarathy (2009) reported Simpson's index of trees as 0.05 and 0.06 for disturbed and undisturbed evergreen forest of Andaman Island, respectively. Tripathi *et al*. (2004) found Simpsons index of undisturbed forest from 0.041 to 0.126.

Beta diversity of tree was higher in disturbed forest whereas beta diversity of shrub and herb layer was higher in undisturbed forest. In undisturbed forest, individual plot had 1 to 6 tree species whereas it was 1 to 8 species in disturbed forest. It showed that local patchiness and discontinuity of tree species was higher in disturbed forest than in undisturbed, which might increase beta diversity of trees. Higher beta diversity of shrub and herb layer was found in undisturbed forest than in disturbed. This might be due to large elevation range of undisturbed forest. Wider altitude range in undisturbed forest might have included a diversity of microhabitats for shrub and herb species, thereby increasing species turnover across the sampling plots.

The total plant diversity was found higher in disturbed forest than in undisturbed. Tree species diversity was found higher in undisturbed forest while herb and shrub diversity was higher in disturbed forest. Hence, the first hypothesis was rejected. Since, disturbance influences the biodiversity, higher diversity was found in disturbed forest.

6.4 Regeneration

Due to a greater proportion of individuals of *Quercus semecarpifolia* in lower size classes, compared to larger size classes in disturbed forest, the size class distribution diagram resembled inverse 'J' shape (Figure 9). In comparison to undisturbed forest, the larger trees (DBH Ψ120 cm) were absent in disturbed forest. This absence of larger trees could be due to excessive felling of large trees in the past to meet the demand of firewood and timber. Similarly inverse 'J' shaped size class distribution diagram was observed in disturbed forest when all tree species was considered together. Presence of 2200 seedlings and 864 saplings of *Q. semecarpifolia* per hectare in disturbed forest indicate frequent reproduction in present time. In the present research, seedling survival and recruitment in the open site was significantly better than the shade site which agreeds with the findings of Thadani and Asthon (1995). They reported that the dense canopy of the forest in central Himalaya did not promote the satisfactory establishment of oak in the understory however the moderate disturbance appeared to benefit the regeneration. It has also been reported that regeneration is more sustainable in the mildly degraded *Quercus-Rhododendron* forest than in mature and relatively non-degraded forest in midhills of eastern Nepal (Koirala 2004). An open canopy in disturbed forest allows the growth of seedlings and saplings of *Q. semecarpifolia*, which ensures sustainable regeneration.

A lower proportion of individuals of *Quercus semecarpifolia* in smaller size classes as compared to middle size classes gave a bell shape to size class distribution diagram in undisturbed forest. Presence of 180 seedlings and 52 saplings of *Q. semecarpifolia* per hectare in undisturbed forest indicate rare reproduction in recent time. Metz (1997) also reported only large old trees and seedling in temperate forest of east central Nepal, without sapling. Shrestha (2003) reported the death of saplings and small trees before they reach the canopy in the Himalayan region. Lack of sufficient regeneration is a major problem of mountain forests (Krauchi *et al.* 2000). Oak stands usually have poor natural regeneration and begin to be replaced by shade tolerant species (Li and Ma 2003), which does not only affect the ecosystem but also arrest the succession of the communities. If such trend continues, the population of light demanding species such as *Q. semecarpifolia* is on the way to extinction. However, the density diameter curve was nearly inverse J - shaped when all tree species was considered in undisturbed forest, indicating frequent regeneration of other tree species.

Seedlings and saplings together constituted about 72% of the total population of *Q. semecarpifolia* in disturbed forest but only about 46% in undisturbed forest (Figure 7). Seedling density and seedling - to - tree ratios as well as sapling density and sapling - to - tree ratios of *Q. semecarpifolia* were lower in undisturbed forest than in the disturbed (Table 8). Thus, regeneration potential of *Q. semecarpifolia* was good in disturbed forest but very poor in undisturbed. More seedlings in the disturbed forest than in the undisturbed forest showed that canopy gaps caused by lopping in a limited area may not inhibit regeneration but rather facilitate it (Troup 1921, Thadani and Ashton 1995, Metz 1997, Singh *et al.* 1997). However, patterns was reversed when seedlings and saplings of all tree species was considered. It indicates that regeneration potential of the forest, combining all species together, was still good in undisturbed forest.

The higher density of seedling in comparison of sapling in disturbed and undisturbed forest might be due to the seedling establishment problem. To maintain the soil fertility of mountain farmland and mulching for cattles and pigs, a huge amount of litter has been collected by local inhabitants, which might have prevented seedling establishment. Shrestha and Paudel (1996) also reported browsers such as cattle, goats and sheep in oak forest of Nepal which graze the small saplings of oak tree. These factors might have reduced sapling abundance of *Q. semecarpifolia* in disturbed forest.

The damage of oak seedlings by Himalayan languor (*Presbytis entellus*), acorn worm (*Calandura sculpturata*), Himalayan black bear (*Solenarctos thibetanus*), other birds and rodents (Rawat and Singh 1989, Singh *et al*. 1990) is more relevant in undisturbed forest of Shivapuri than in disturbed forest of Simbhanjyang. In a mature undisturbed forest with closed canopy, seedling establishment is prevented by lower light intensity on the ground surface. However, the findings of Welander and Ottosson (1998) showed that one to two year old oak seedlings can grow in very low light as well. This could be attributed to the resources present in large acorn (Grime and Jeffrey 1965). These might be the reason of larger density of seedlings than saplings in undisturbed forest, though the canopy of the forest was high.

The density of sapling and seedling of *Q. semecarpifolia* was low on those plots where basal area of all tree species was high. High basal area indicates presence of large sized trees and closed canopy. Major portion of light is absorbed by tree canopy, and reduces the amount of light that reaches to ground vegetation (Sharma 1975). The number of seedlings in the oak stands increased with increasing light intensity and low canopy cover (Maren *et al*. 2007). Similarly, Schumann *et al*. (2003) reported that low canopy cover was positively correlated with the total density of sapling. Due to presence of large sized trees, the light available on the ground could be low enough to increase seedling mortality of *Q. semecarpifolia*. In both disturbed and undisturbed forests, seedling density did not show any pattern of relation with litter cover (Figuers 17, 18) but Tripathi and Khan 1990, Dzwonko and Gawronski reported a significant positive correlation between the numbers of seedling density and litter cover.

The regeneration was found better in disturbed forest. This might be due to open canopy by lopping, mild grazing and diversity of associated herbs and shrub layer. Subedi (1999) also reported that canopy gap formation, control form of lopping, grazing, and a favorable composition of herb layer seem highly responsible for regeneration of *Q. semecarpifolia* from Phulchoki, Central Nepal. Ammer (1996) also reported that natural regeneration is mainly determined by the light conditions. Regeneration potential of tree species other than *Q. semecarpifolia* was good in both the study forest (Figures 9 to 12). This might be due to presence of both light demanding and shade tolerant species in the disturbed forest and shade tolerant species in undisturbed forest.

Forest regeneration was found continuous in disturbed and erratic in undisturbed forest. Hence, the second hypothesis was rejected. As *Q. semecarpifolia* is a light demanding species, it needs open canopy for continuous regeneration. The chances of canopy gap formation are either due to death and decay of the parent tree or selective cutting.

7. CONCLUSION

Altogether, 86 and 57 flowering plant species were found in disturbed (Simbhanjyang) and undisturbed (Shivapuri) forest, respectively. Higher number of tree species was found in undisturbed forest whereas higher number of shrub and herb species was found in disturbed forest. Higher species richness for herbs and shrubs in disturbed forest indicate that opening of canopies favours herb and shrub growth. Disturbed forest, which is closer to settlement, experienced higher pressure in the form of fuelwood and fodder collection. Total basal area of tree species was high in undisturbed forest however the density was higher in disturbed forest. The basal area of the dominant species *Quercus semecarpifolia* was also higher in undisturbed forest, but the density was higher in disturbed forest. Higher species diversity was found in disturbed forest than in undisturbed. Soil organic carbon and nitrogen were higher in undisturbed forest, and the soil pH was higher in disturbed forest.

Density - diameter curve of *Q. semecarpifolia* in disturbed forest showed greater number of individuals in lower size classes and indicated that regeneration was continuos in disturbed forest than in undisturbed. The two sites differed significantly in density of seedling and sapling of *Quercus semecarpifolia*. The abundance of seedling and sapling of *Q. semecarpifolia* were higher in the disturbed forest. In both forests, seedling density did not show any pattern of variation with litter. Soil attributes also had no significant relations with density of seedlings and saplings.

Both of the hypotheses were rejected, hence it can be concluded that canopy openness due to mild disturbance influences the species diversity as well as enhances the regeneration of *Quercus semecarpfolia*.

8. RECOMMENDATION

Based on the results of the present study the researcher has made the following recommendations:

- The regeneration of *Quercus semecarpifolia* was found better in open canopy than in closed so long term management programs such as sustainable methods of lopping the trees for fodder is essential.
- Old dying trees should remove to make the canopy more open, so that adequate amount of light can reach in the ground to favour the light demanding plants.

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ANNEXES

ANNEX 1

List of Shrubs Found in Disturbed and Undisturbed Forest

SHRUBS				
S.N.	**Name of the species**	**Family**	**Disturbed forest**	**Undisturbed forest**
1	*Berberis* sp.	Berberidaceae	+	-
2	*Sarcococca* sp.	Buxaceae	+	+
3	*Euonymus* sp.	Celastraceae	+	-
4	*Lonicera angustifolia* Wall. ex DC.	Caprifoliaceae	+	-
5	*Gaultheria fragrantissima* Wall.	Ericaceae	+	+
6	*Pieris formosa* (Wall.) D. Don	Ericaceae	+	+
7	*Desmodium elegans* DC.	Fabaceae	+	+
8	*Hypericum oblongifolium* Choisy	Hypericaceae	+	+
9	*Elsholtzia flava* (Benth.) Benth.	Lamiaceae	+	-
10	*Oxyspora paniculata* (D. Don) DC.	Melastomataceae	+	-
11	*Cotoneaster* sp.	Rosaceae	-	+
12	*Rubus splendidissimus* H. Hara	Rosaceae	+	+
13	*Zanthoxylum oxyphyllum* Edgew.	Rutaceae	+	+
14	*Symplocus* sp.	Symplocaceae	+	+
15	*Camellia* sp.	Theaceae	-	+
16	*Daphne* sp.	Thymelaeaceae	+	+
17	*Wikestromia canescens* Meisn.	Thymelaeaceae	+	+
18	*Smilax* sp.	Smilacaceae	+	+
19	*Boehmeria platyphylla* D. Don	Urticaceae	+	-
Total			**17**	**13**

ANNEX 2

List of Herbs Found in Disturbed and Undisturbed Forest

HERBS				
S.N.	**Name of the species**	**Family**	**Disturbed forest**	**Undisturbed forest**
1	*Acaranthus* sp.	Acanthaceae	+	+
2	*Strobilanthus* sp.	Acanthaceae	+	+
3	*Strobilanthus nutans* (Nees) T. Anders	Acanthaceae	+	-
4	*Allium wallichii* Kunth	Amaryllidaceae	+	-
5	*Oenanathe javanica*	Apiaceae	+	-
6	*Pleurospermum* sp.	Apiaceae	+	+
7	*Pleurospermum* sp.	Apiaceae	+	-
8	*Sinocarum* sp.	Apiaceae	+	-
9	*Arasaema* sp.	Araceae	+	+
10	*Eupatorium* sp.	Asteraceae	+	+
11	*Solidago* sp.	Asteraceae	+	-
12	*Elephantopus scaber* L.	Asteraceae	+	-
13	*Impatiens sulcata* Wall.	Balsaminaceae	+	+
14	*Didymocarpus primulifolius* D. Don	Bignoniaceae	+	-
15	*Stellaria monosperma* Buch.-Ham. ex D. Don	Caryophylaaceae	+	
16	*Cyanotis vaga* (Lour.) Schult. & Schult. f.	Commelinaceae	+	+
17	*Campanula pallida* Wall.	Companulaceae	+	-
18	*Anaphalis busua* (Buch.-Ham. ex D. Don) Dc.	Compositae	+	+
19	*Anaphalis triplinervis* (Sims) C.B. Clarke	Compositae	+	+
20	*Sedum* sp.	Crassulaceae	+	-
21	*Cyperus* sp.	Cyperaceae	+	+
22	*Dipsacus inermis* Wall.	Dipsacaceae	+	-
23	*Agapetes* sp.	Ericaceae	+	-
24	*Boenninghausenia albiflora* (Hook.) Rchb. ex Meisn.	Ericaceae	+	-
25	*Unknown*	Euphorbiaceae	+	+
26	*Gentiana capitata* Buch.-Ham. ex D. Don	Gentanaceae	+	-
27	*Swertia nervosa* (G. Don) *C.B.* Clarke	Gentanaceae	+	+
28	*Cautleya* sp.	Gingiberaceae	+	-
29	*Clinopodium umbrosum* (M.	Labiateae	+	-

	Bieb) K. Koch			
30	*Scutellaria* sp.	Labiateae	+	-
31	*Epipactis* sp.	Orchidaceae	+	-
32	*Habenaria* sp.	Orchidaceae	+	-
33	*Corydalis sp.*	Papaveraceae	+	+
34	*Plantago* sp.	Plantaginaceae	+	+
35	*Arundinaria* sp.	Poaceae	+	+
36	*Bistorta amplexicaulis* (D. Don) Greene	Polygonaceae	+	-
37	*Persicaria capitata* (Buch.-Ham. ex D. Don) H. Gross	Polygonaceae	+	-
38	*Persicaria microcephala* (D. Don) Sasaki	Polygonaceae	+	+
39	*Aconitum ferox* Wall. ex Ser.	Ranunculaceae	+	+
40	*Thallictrum foliolosum* DC.	Ranunculaceae	+	+
41	*Potentilla josephiana* H. Ikedda & H. Ohba	Rosaceae	+	+
42	*Rubus nepalensis* (Hook. F.) Kuntze	Rosaceae	+	+
43	*Rubus nigra*	Rosaceae	+	+
44	*Galium elegans* Wall. ex Roxb.	Rubiaceae	+	+
45	*Hymenopogon parasiticus* Wall.	Rubiaceae	+	-
46	*Rubia mazith* Roxb. ex Fleming	Rubiaceae	+	+
47	*Astilbe rivularis* Buch.-Ham. ex D. Don	Saxifragaceae	+	-
48	*Berginia ciliata* (Haw) Sternb.	Saxifragaceae	+	-
49	*Hemiphragma heterophyllum* Wall.	Scrophulariaceae	+	+
50	*Solanum* sp.	Solanaceae	+	-
51	*Elatostema sessile* J.R. Forst. & G. Forst.	Urticaceae	+	-
52	*Girardiana diversifolia* (Link) Friis	Urticaceae	+	-
53	*Pilea scripta* (Buch.-Ham. ex D. Don) Wedd.	Urticaceae	+	+
54	*Pilea umbrosa* Blume	Urticaceae	+	+
55	*Valeriana* sp.	Valerianaceae	+	+
56	*Viola wallichiana* Ging.	Violaceae	+	+
57	*Roscoea capitata* Sm.	Zingiberaceae	+	+
Total			**57**	**29**

ANNEX 3

Annex - 3A. Values of Soil pH, Carbon %, Soil Nitrogen %, C/N Ratio and Species Richness in Disturbed Forest.

Plot no	Soil pH	Carbon %	Soil Nitrogen %	C/N ratio	Species Richness (species/100m²)
1	6.45	3.09	0.196	15.76	14
2	6.66	2.85	0.182	15.67	13
3	6.05	3.68	0.21	17.54	13
4	5.85	3.80	0.252	15.09	13
5	5.98	3.80	0.252	15.09	12
6	6.37	3.21	0.21	15.28	13
7	5.89	3.80	0.252	15.09	14
8	6.11	3.45	0.224	15.38	13
9	5.75	3.92	0.252	15.56	14
10	6.45	2.97	0.196	15.15	15
11	5.42	4.28	0.266	16.08	15
12	5.95	3.56	0.238	14.98	16
13	5.7	4.04	0.266	15.19	15
14	5.12	4.63	0.294	15.76	15
15	5.79	3.80	0.252	15.09	14
16	5.57	4.16	0.266	15.63	16
17	5.25	4.51	0.294	15.36	15
18	6.47	3.09	0.21	14.71	16
19	5.37	4.40	0.28	15.70	14
20	5.32	4.40	0.28	15.70	15
21	6.79	2.61	0.182	14.36	14
22	5.49	4.28	0.28	15.28	15
23	5.65	4.04	0.266	15.19	15
24	6.5	3.09	0.196	15.76	16
25	6.38	3.21	0.21	15.28	15
26	6.52	2.97	0.196	15.15	16
27	5.67	4.04	0.252	16.03	16
28	5.73	3.92	0.252	15.56	16
29	5.28	4.51	0.294	15.36	16
30	5.98	3.68	0.238	15.48	17
31	6.13	3.56	0.224	15.91	18
32	6.67	2.85	0.182	15.67	17
33	6.49	3.09	0.196	15.76	16
34	6.42	3.09	0.196	15.76	16
35	6.56	2.97	0.196	15.15	17
36	5.79	3.92	0.238	16.47	18
37	6.51	3.09	0.196	15.76	17
38	6.14	3.45	0.224	15.38	18
39	6.29	3.33	0.224	14.85	18
40	5.52	4.16	0.266	15.63	18
41	6.79	2.61	0.168	15.56	17
42	5.81	3.80	0.224	16.97	15
43	5.84	3.80	0.252	15.09	14
44	6.52	3.09	0.196	15.76	15
45	6.13	3.45	0.224	15.38	15
46	5.47	4.04	0.266	15.19	16
47	6.31	3.21	0.21	15.28	14
48	5.56	4.16	0.266	15.63	15
49	5.38	4.40	0.28	15.70	15
50	5.77	3.92	0.266	14.74	16

Annex-3B. Values of Soil pH, Carbon %, Soil Nitrogen %, C/N Ratio and Species Richness in Undisturbed Forest.

Plot no	Soil pH	Carbon %	Soil Nitrogen %	C/N ratio	Species Richness (species/100m²)
1	4.76	8.88	0.74	11.97	3
2	4.72	4.85	0.46	10.50	2
3	4.68	9.93	1.02	9.71	3
4	4.98	3.36	0.55	6.15	1
5	5.52	5.90	0.66	8.96	2
6	4.97	3.28	0.38	8.69	2
7	4.51	9.48	0.99	9.53	2
8	4.85	8.88	0.98	9.06	4
9	4.51	8.66	0.67	12.88	4
10	4.21	11.49	0.64	17.85	4
11	4.62	9.70	0.90	10.83	2
12	5.21	9.25	0.71	12.96	2
13	4.85	8.51	0.55	15.58	2
14	4.12	7.99	0.38	21.12	4
15	4.45	8.43	0.87	9.72	3
16	5.41	5.15	0.60	8.55	3
17	4.86	7.76	0.83	9.40	3
18	4.85	8.36	0.74	11.26	5
19	4.59	4.93	0.85	5.77	4
20	4.57	7.61	0.83	9.22	4
21	5.2	8.21	0.59	13.96	5
22	4.78	4.70	0.50	9.33	4
23	4.12	1.79	0.81	2.21	5
24	4.5	1.49	0.55	2.73	5
25	4.6	6.57	0.24	27.59	2
26	4.78	4.93	0.43	11.35	4
27	4.72	6.64	0.84	7.91	2
28	4.61	1.64	0.88	1.86	3
29	4.4	8.13	0.64	12.63	5
30	4.6	5.07	0.64	7.88	5
31	4.53	7.54	0.39	19.23	5
32	4.55	7.76	0.55	14.21	6
33	4.65	6.42	0.62	10.42	4
34	4.84	1.19	0.56	2.13	6
35	5.31	6.79	0.56	12.13	6
36	4.98	5.00	0.64	7.76	2
37	4.88	7.31	0.56	13.06	5
38	4.83	5.90	0.71	8.26	2
39	4.87	6.12	0.97	6.33	4
40	4.47	6.42	0.88	7.28	4
41	4.98	9.10	0.83	11.02	5
42	4.67	5.60	0.73	7.69	3
43	4.75	7.16	0.45	15.99	3
44	4.85	5.60	0.64	8.69	5
45	4.65	5.45	0.70	7.78	3
46	4.67	4.70	0.56	8.40	5
47	4.9	3.73	0.38	9.87	2
48	4.77	3.96	0.90	4.41	2
49	4.82	6.12	0.56	10.93	2
50	4.62	6.34	0.48	13.33	4

ANNEX 4

Data Collection Format for Vegetation Sampling

Plot characteristics

Date: District: Locality: Altitude:
Aspect:
Slope: Latitude: Longitude: Lopping:
Forest type: Canopy cover: Disturbance, Grazing (0-3):
Litter collection: Yes/ No Silviculturai Practices: Yes/ No Litter cover (%):
Litter type: leaves and small twigs only, with large branches or with logs Soil type: Colour:
Texture:

For trees, plot no: Quadrat no: Quadrat size:

SN	Name of species	DBH

SN	Name of species	DBH

List of shrub and herb species

SN	Name of species	Life form

SN	Name of species	Life form

Tree saplings, Quadrat size: 5m × 5m

QN	SN	Name of species	No.

QN	SN	Name of species	No.

Tree Seedlings, Quadrat Size: 5m × 5m

QN	SN	Name of species	No.

QN	SN	Name of species	No.

PHOTO PLATE I

Photo 1: Seedling of *Quercus semecarpifolia* in litter removal area

Photo 2: Seedling of *Quercus semecarpifolia* in litter covered area

Photo 3: Use of litter for mulching purpose in Simbhanjyang

Photo 4: Grazing of cattle in Simbhanjyang (Disturbed forest)

PHOTO PLATE II

Photo 5: An overview of disturbed forest of *Quercus semecarpifolia*

Photo 6: A large *Quercus semecarpifolia* tree in undisturbed forest

Photo 7: Collection of litter in disturbed forest.

Photo 8: Formation of canopy gap in undisturbed forest