POPULATION STRUCTURE AND REGENERATION OF *QUERCUS SEMECARPIFOLIA* IN LANGTANG NATIONAL PARK AND ITS BUFFER ZONE, CENTRAL NEPAL

A THESIS

SUBMITTED FOR THE PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE MASTER'S DEGREE IN BOTANY

BY

AVINASH PAJIYAR
Symbol No.: 436/073
(T.U. Registration No.: 5-2-37-71-2012)

DEPARTMENT OF BOTANY
AMRIT CAMPUS
TRIBHUVAN UNIVERSITY
KATHMANDU, NEPAL

July, 2022

DECLARATION

I hereby declare that the work presented in this dissertation is a genuine work done originally by me and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

....

Avinash Pajiyar
Department of Botany
Amrit Campus
Thamel, Kathmandu, Nepal
July, 2022

TRIBHUVAN UNIVERSITY
AMRIT CAMPUS
Department of Botany
Thamel, Kathmandu
Tel No.: 4410408
4411637

Institute of Science & Technology
Amrit Campus

Ref. No.:
July, 2022

RECOMMENDATION

This is to recommend that the Master's thesis entitled "**Population Structure and regeneration of *Quercus semecarpifolia* in Langtang National Park and its Buffer Zone, Central Nepal**" is carried out by **Avinash Pajiyar** under my supervision. The entire work is based on original scientific investigations and has not been submitted for any other degree in any institutions. I therefore, recommend this thesis work to be accepted for the partial fulfilment of M.Sc. Degree in Botany.

Prof. Dr. Mohan Devkota
Supervisor
Department of Botany
Amrit Campus
Tribhuvan University
Thamel, Kathmandu, Nepal
July, 2022

Dr. Ramesh Prasad Sapkota
Co-supervisor
CDES, Kirtipur
Tribhuvan University

TRIBHUVAN UNIVERSITY
AMRIT CAMPUS
Department of Botany
Thamel, Kathmandu
Tel No.: 4410408
4411637

Ref. No.:

Institute of Science & Technology
Amrit Campus

LETTER OF APPROVAL

The thesis work submitted by "Avinash Pajiyar" entitled "**Population Structure and regeneration of *Quercus semecarpifolia* in Langtang National Park and its Buffer Zone, Central Nepal**" submitted to Department of Botany, Amrit Campus, Tribhuvan University by "Avinash Pajiyar", "5-2-37-71-2012" has been accepted for the partial fulfilment of the requirement for Master's Degree in Botany.

EXPERT COMMITTEE

External examiner
Lecturer Dr. Achyut Tiwari
Central Department of Botany,
Tribhuvan University, Kirtipur, Nepal

Internal Examiner
Prof. Dr. Mukesh Kumar Chhetri
Department of Botany, Amrit Campus
Tribhuvan University, Kathmandu, Nepal

Supervisor
Prof. Dr. Mohan Prasad Devkota
Department of Botany, Amrit Campus
Tribhuvan University, Kathmandu

Co-Supervisor
Lecturer Dr. Ramesh Prasad Sapkota
CDES, Tribhuvan University,
Kirtipur

Coordinator
Lecturer Dr. Laxmi Joshi Shrestha
Department of Botany, Amrit Campus
Tribhuvan University, Kathmandu, Nepal

Head of Department
Associate Prof. Dr. Shila Singh
Department of Botany, Amrit Campus
Tribhuvan University, Kathmandu, Nepal

Date of oral examination: 2079/02/29

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Avinash Pajiyar

ACRONYMS AND ABBREVIATIONS

DBH	Diameter at Breast Height
kg/ha	Kilogram per Hectare
sq. km	Kilometer Square
LNP	Langtang National Park
DNPWC	Department of National Parks and Wildlife Conservation
IVI	Important Value Index
F	Frequency
RF	Relative Frequency
D	Density
RD	Relative Density
BA	Basal Area
Do	Dominance
RDo	Relative Dominance
TISC	Tree Improvement and Silviculture Component
DPR	Department of Plant Resources
OM	Organic Matter
DI	Disturbance Index
GPS	Global Positioning System
DFRS	Department of Forest Research and Survey
GoN	Government of Nepal
MG	Melamchighyang
TKG	Tarkeghyang

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ABSTRACT

This work was carried out to study the forest composition, population structure, regeneration of *Quercus semecarpifolia* and disturbances at Langtang National Park and its buffer zone. The vegetation data were collected from total of 77 circular plots of radius 10m for tree species of which 40 plots were established at National Park area and 37 plots were established at buffer zone area. Importance Value Index (IVI) of tree species, distribution pattern of seedlings and saplings, and soil attributes were analyzed. Regeneration was assessed by density-diameter curve. Seventy seven soil samples were taken for laboratory analysis. A total of 9 species of trees belonging to 8 families were recorded from National Park and 17 species of tree belonging to 14 families were recorded from its buffer zone. The most frequent and dense tree species in the forest was *Quercus semecarpifolia* with important value index of about 30.23% (IVI= 90.69) inside National Park and the value was about 28.82% (IVI= 86.46) in buffer zone. The tree density of *Quercus semecarpifolia* in the National Park forest area was 158 stem/ha and in buffer zone was 248 stem/ha. Seedling and sapling density of *Quercus semecarpifolia* in the National Park forest was 166 stem/ha and 21 stem/ha and inside buffer zone, the values were 59 stem/ha and 53 stem/ha respectively. The density of tree at (30-49.9cm) DBH class was maximum and the highest DBH class had no individuals inside National Park while the density of tree of DBH class (10-24.9cm) was maximum and that of DBH class (160-174.9cm) was minimum in buffer zone. The density of tree at (5-9.9m) height class was maximum and the height class (<5m) had minimum density inside National Park while the value were maximum at (10-14.9m) and minimum at <5m in buffer zone. *Q. semecarpifolia* inside National Park showed a positively skewed distribution pattern and fluctuating distribution pattern in buffer zone. Disturbance was the main factor for unequal distribution and regeneration of species in study sites. Canopy cover, litter depth, soil nutrients and pH of soil showed positive correlation but insignificant relationship with seedlings and saplings growth. The disturbance index of buffer zone was higher (2.028%) compared to National Park (0.738%). The regeneration was found to be higher in the National park than the buffer zone and canopy cover was found to be most important factor for regeneration.

Keywords*:* Forest composition, forest structure, disturbance index, importance value index

CHAPTER - 1: INTRODUCTION

1.1 Background

Population structure of trees are the direct results of comprehensive interactions among species characteristics, environmental factors, and intraspecific and interspecific plant–plant interactions over a long period (Guo and Wang, 2012). Plant population structure shows whether or not the population has a stable distribution that allows continuous regeneration to take place (Gabeyehu *et al.,* 2019). Knowledge on the population density of seedlings, saplings, and adults is important as it determines the population structure and status of regeneration of any forest community (Paul *et al.,* 2019). The future composition of forests depends on potential reproduction and recruitment as regeneration status of tree species within a forest stand in space and time (Eilu and Obua, 2005; Siraj and Zhang, 2018). The population structure of plant communities can be evaluated in terms of age, size, and form of the individuals that constitute it. As the reproductive capacity and survival of plants depends more on size rather than the age it is a better way to classify the life history of a plant by stages (size) rather than the age (Shaukat *et al.,* 2012). The structure of a plant population is governed both by abiotic and biotic factors that also have a substantial bearing on the spatial pattern, age grouping and genetic structure of plant populations (Shaukat *et al*., 2012). According to Segawa and Nkuutu (2006), the knowledge of the population structure of woody plant species and their natural regeneration status analysis of the given forest becomes prerequisite for forest conservation and management and conservation strategies of biodiversity and its ecosystem services (Segawa and Nkuutu, 2006; Dutta and Devi, 2013). Knowledge of population structure of woody species and their natural regeneration status analysis of the forest resources is also useful in identifying important elements of plant diversity, protecting threatened and economic species, and monitoring the status of forest (Segawa and Nkuutu, 2006; Maua *et al.,* 2020).

Plant regeneration is a complex and dynamic process. This process includes many factors (e.g. flowers, pollination, seed maturity stage, emergence and establishment, planting practices, vegetation management and silvicultural system etc.) that depend upon abiotic environment (Bhatt *et al.,* 2015). The vital characteristics in forest tree regeneration strategies include seed production, seed size, dispersal mechanisms, understory tolerance or shade tolerance, growth rate and longevity, tree crow architecture, resistance to insects and pathogens, biomass production, allocation of photosynthate and nutrient requirement (Barnes *et al.,* 1998). The density value of seedlings and saplings are considered as an indicator of regeneration potential of the species (Arya and Ram, 2011) in which the presence of good regeneration indicates the suitability of a species to the environment, which is in turn affected by climatic factors and biotic interference influence (Dhaulkhandi *et al.,* 2008). The successful regeneration of woody tree species is mainly dependent on a function of three major components: (i) their ability to initiate new seedlings, (ii) the survival ability of seedlings and saplings, and (iii) the growth ability of seedlings and saplings (Good and Good, 1972).

It is also been documented that Himalayan ecosystems are degrading and the consequences of degradation will be more precarious since they are considered as ecologically fragile (Mani, 1974). The regeneration of such degraded ecosystems is extremely difficult due to the physical instability and environmental characteristics of the area (Silori, 2001). In Nepal, *Q. semecarpifolia*, the main component of the Oak forest, is highly exploited because of its high quality wood and leaves (for fodder). It plays a dominant role in the subsistence farming system for growing crops, raising livestock and communities are depending on it for a number of products. *Q. semecarpifolia* has been reported to occur all over Nepal between 1700 and 3800m in 17 various forest types as described by TISC (2002). It is one of the highly useful species of oak having considerable social impact and plays vital role in water and soil conservation facing threat from environmental degradation. But this important component of temperate forests of Nepal is depleting rapidly due to over exploitation and unsustainable utilization (Singh and Singh, 1987). Ever increasing human population of globe has influenced on the forest resources which leads to disturbance in the forest ecosystem.

The structure of plant as well as animal communities in many natural ecosystems is largely influenced by the disturbances, frequently occurring in the system naturally or due to anthropogenic activities (Lalfakawma *et al.,* 2009). In many of these systems, disturbances change overall community structure (Shaforth *et al.,* 2002) which in turn can ultimately affect community and population dynamics. Both diversity and post disturbance regeneration and dominance of tree species are influenced (Borah *et al.,* 2014). Species richness has been related to the occurrence of natural disturbance by several authors (Grubb, 1977; Huston, 1979; Picket, 1980). Past studies indicate that due to disturbance in the forests; conditions become unfavorable for existing species and fail to re-establish themselves (Borah *et al.,* 2014). The natural regeneration of *Q. semecarpifolia* is poor both in disturbed and undisturbed forests. It is failing to regenerate under its own canopy (Upreti *et al.,* 1985). Lack of regeneration is sometimes attributed to the effect of climate change (Upreti *et al.,* 1985). Seed germination depends strongly on the quality and thickness of litter and quality of light. However, herbaceous cover, rather than litter, has more adverse effect on seedling emergence, survival and growth (Tripathi and Khan, 1990; Dzwonko and Gawronski, 2002).

Eight species occur in Nepal (DPR, 1997): *Q. floribunda, Q. glauca, Q. lamellosa, Q. lanata, Q. leuchotrichophora, Q. mespilifolioides, Q. oxyodon* and *Q. semecarpifolia*. Langtang National Park (LNP) holds a large population of various *Quercus* species such as *Quercus semecarpifolia, Quercus lamellosa,* etc. spread over a wide altitudinal zones including its buffer zone and is one of the very important tree species in providing subsistence livelihoods to the rural mountain communities.

1.2 Rationale

The possible causes of regeneration failure include poor seed production of trees (may be limited by various factors such as resource availability, pollination failure, predation on flowers, fruits and leaves), unfavorable micro-sites and anthropogenic pressure and climatic irregularities (Vetaas, 2000). Annual lopping, acorn herbivory, seedling and sapling browsing, litter collection and forest fire are important factors preventing recruitment of *Q. semecarpifolia* in disturbed forests. In a nearly undisturbed forest of central Nepal (Langtang National Park), the regeneration of *Q. semecarpifolia* is continuous (Vetaas, 2000) but the preliminary observation (Siluwal *et al.,* 2001; Shrestha, 2003) of the other forest in the same region (Shivapuri National Park, central Nepal) revealed that the regeneration was not continuous in the protected forest, too. Previously, Gaire *et al*., 2010, had worked in the treeline ecotone of LNP at two different sites i.e. Chaurikharka and Lauribina but the study was not been carried out in its buffer zone where many anthropogenic activities takes place. So, the present study was carried out to study the population structure and regeneration pattern of *Q. semecarpifolia* in the different land management practices inside and outside LNP. The study was also designed to study the status of existing *Q. semecarpifolia* and causes of disturbances.

1.3 Hypothesis

The following hypothesis was set for the research:

"The vegetation composition of LNP and its buffer zone area was significantly different due to disturbances by the local communities".

1.4 Objectives of the Study

The general objective was to study the phytosociology of existing vegetation of LNP and its buffer zone area. Following were the specific objectives of the study:

- To study and compare the population structure of *Quercus semecarpifolia* inside the national park and its buffer zone,
- To find out the anthropogenic disturbances and their effects on the regeneration of *Quercus semecarpifolia*,
- To study the regeneration pattern of *Quercus semecarpifolia* inside NP and its BZ,
- To recommend the appropriate measures for the sustainable management of *Q. semecarpifolia*.

1.5 Limitations

The major limitations of the study were:

- Time restriction to field visit due to (COVID-19) pandemic.
- Inaccessibility of wider study area due to extremely difficult mountain terrain.
- Canopy cover was measured just by visual estimation.

CHAPTER 2: LITERATURE REVIEW

2.1 Vegetation Types of Nepal

In Nepal, forest occupies a total of 40.36% of the total area of the country out of which 82.68% lies outside Protected Areas and 17.32% inside Protected Areas. Within the Protected Areas, Core areas and Buffer Zone contain 0.79 and 0.24 million ha of forest respectively (DFRS, 2015). In Nepal, 13,067 plant species have been described that includes 1,001 species of algae, 2,467 species of fungi, 792 species of lichens, 1,213 species of bryophytes, 580 species of pteridophytes, 41 species of gymnosperms and 6,973 species of angiosperms (Rajbhandary *et al.,* 2020).In this life zone, *Q. semecarpifolia* is found in the Fir-Oak-Rhododendron and Fir-Hemlock-Oak Forests vegetation types, accompanying silver fir on southern aspects. It can also form pure oak stands mainly on southern aspects creating its own vegetation type called Subalpine Mountain Oak Forest (DFRS, 2015).

The temperate zone is located between 3,000 to 2,000 m in elevation. It is very diverse, containing over 40 % of the vegetation types of Nepal (TISC, 2002). The precipitation distribution varies widely in this zone, ranging from semi-arid in the inner valleys and trans-Himalayan regions to humid conditions on the south of the Himalayan mountain range. On drier southern aspects in western Nepal, *Q. semecarpifolia* is associated with the west Himalayan fir (*Abies pindrow*) forming the West Himalayan Fir-Hemlock-Oak Forest. Also in western dry parts of Nepal it forms a distinctive forest with an abundance of *Rhododendron arboreum* called Mountain Oak-Rhododendron Forest. It also occurs forming pure stands in this zone forming the vegetation type Temperate Mountain Oak forest. Its distribution ends at around 2,500 m being replaced by *Q. lanata* and *Q. incana* (Shrestha *et al.,* 2002).

Common accompanying tree species are spruce (*Picea smithiana*), Silver fir (*Abies pindrow*), east Himalayan fir (*A. spectabilis*), Himalayan yew (*Taxus wallichiana*), blue pine *(Pinus wallichiana*), Himalayan hemlock (*Tsuga dumosa*), *Pyrus spp*, *Prunus padus*, *Acer caesium*, *Juglans regia*, *Rhododendron arboreum* and *Betula alnoides* among others. It forms the climax community and in parts of the Western Himalaya also represents the tree line (Jackson, 1994; Singh *et al*., 2011).

2.1.1 Distribution of *Quercus semecarpifolia*

In Nepal, eight species of oak occurs from temperate to sub-alpine region (DPR, 1997). *Q. semecarpifolia* grows up to subalpine forests: *Q. floribunda*, *Q. glauca*, *Q. lamellosa*, *Q. lanata*, *Q. leuchotrichophora*, *Q. mespilifolioides*, *Q. oxyodon* and *Q. semecarpifolia* (Bisht *et al*., 2013). *Q. semecarpifolia*, also called Khasru oak is an evergreen, broadleaved, late successional tree, widespread along the Himalayan region. Dense *Q. semecarpifolia* forests were recorded up to 3,500 m in Darchula's Chamilaya Valley, Nepal (Elliott, 2012). It extends from the wettest monsoonal slopes of the south-east Hindu Kush (Afghanistan), to the rain shadowed areas of the Inner Valleys in Bhutan (Miehe *et al.*, 2015) and to south-west China (Polunin and Stainton, 1997). It commonly grows between 2,400 and 3,000 meters above sea level, but depending on the amount of rainfall and humidity in the area it can also be found between 1,700 and 3,800 m (Jackson, 1994).

2.1.2 Community Structure of *Quercus* Forests

Quercus semecarpifolia Sm. is one of the ecological dominant tree species of upper temperate and sub alpine forest of Himalayas (Shrestha *et al.*, 2017). Major species associated with *Q. semecarpifolia* in mixed forests are *Q. floribunda, Q. lanata, Q. leucotrichophora, Abies pindrow, Rhododendron aeboreum, Pecea smithiana, Cotoneaster acuminate*, *Viburnum mullaha, Betula utilis,* etc. (Shrestha, 2003). With increasing altitude the dominant plant cover changes from a deciduous broad-leaved forest to coniferous forest (forming climax tree line) and to a woody shrub community and ultimately alpine meadows. Ground surface of the subalpine forests received low intensity light under the canopy since the forest had high density and crown closure which tended to decrease in the higher elevations. This led a poor ground vegetation of herbs and shrubs (Dolezal and Srutek, 2002).

Species diversity is an important index in characterizing a community. It is also important in reflecting the type of community, the stage of community development and community stability (Liyun *et al*., 2006). Species richness usually reduces along the vertical gradient and it is largely caused by decline in temperature (Qi-Jing, 1997).

In sub-alpine broad leaved coniferous forest, reported an increase in species richness in secondary forests during the period from 30 to 40 years but tended to decrease significantly in the old-growth coniferous forests (Jiangming *et al*., 2008).

2.1.3 Regeneration

Regeneration behavior of tree species is characterized by their population structure which depends upon the presence of adequate number of seedlings and saplings. Reverse J- shaped size class diagram is the indicative of sustainable regeneration (Vetaas, 2000) where regeneration was most continuous in the nearly disturbed forest. The regeneration of oaks is a multifaceted ecological process. It consists in the flowering, fruiting, and the dispersal of the seeds of mature trees, together with the germination of those seeds, seedling establishment and growth (Johnson *et al.,* 2002). Lack of sufficient regeneration is a major problem of mountain forests. Most studies on subalpine forests have reported poor seedling recruitment in under stories of undisturbed old-growth forests (Mori and Takeda, 2004).

For successful regeneration, canopy gap formation, control form of lopping and grazing and a favorable composition of herb layer species seems highly responsible (Subedi and Shakya, 1999) dense canopy was found to be limiting factor. 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 Ashton, 1995). Besides browsing, growth rate and species composition of the natural regeneration are mainly determined by the light conditions (Ammer, 1996). *Quercus semecarpifolia* requires not only canopy gaps but also exposed to soil for regeneration. In the form of disturbances, gaps formed are too small to enable brown oak to establish seedlings, and in large gaps grazing/browsing does not allow regeneration to progress up to tree size (Singh e*t al.*, 1997). Human impact has been used to explain low regeneration of evergreen oaks and indicated the best regeneration in the least disturbed sites. Thick litter generally reduces the rates of germination and of seedling establishment (Maren and Vetaas, 2007).

Environmental conditions play an important role in establishment and distribution of seedlings (Bonnet *et al*., 2005), regeneration of dominant trees in dry valleys is influenced even by small-scale human impacts. Under such impacts, the typical inverse

J-shaped DBH class distribution observed among forest species, where frequency of individuals in larger size classes falls systematically and progressively, resulting in a non-linear relationship between frequency and size class, generally gives way to a sporadic and/or unimodal distribution (Wangda and Ohsawa, 2006). Inverse J-shaped distribution is indicative of a forest in a state of regeneration. A shift from inverse J-shape to unimodal or multiple-peaked distribution is the result of substantial changes in the state and pattern of forest regeneration, suggesting that the forest is in trouble (Ghimire *et al*., 2010).

The regeneration of oaks is a multifaceted ecological process. It consists in the flowering, fruiting, and the dispersal of the seeds of mature trees, together with the germination of those seeds, seedling establishment and growth (Johnson *et al*., 2002). In the following sections, the known information about the ecology of these oak species (*spp.*) is going to be explained.

2.1.3.1. Reproduction, Seed Germination and Establishment of *Q. semecarpifolia*

Quercus semecarpifolia flowers are monoecious. As is the case with most oaks, it commonly reproduces through its seeds. However, the seeds are frequently damaged by insects and also eaten by birds and wild animals, including bears, squirrels, rats, and monkeys. Poor seed crops and high rates of consumption by animals have significantly impacted on the ability of oaks of this species to regenerate naturally (Buffum *et al.,* 2008). The male catkin and female spikes appear with the new shoots, the former ripening and pollination taking place by the end of May-June. The acorns commence ripening by June and continues ripening during July, and at higher elevation even until August. The acorns may fall green, turning brown on the ground, while others turn dark brown before falling. Under natural conditions, the nut remains on the soil during the dry season and germinate when the conditions become favorable, usually during the rainy or monsoon season (Troup, 1921). This dormancy allows the seed to avoid germination during unfavorable conditions (Singh, 2014). About 80 % of the fresh seeds germinate (Jackson, 1994).

The seed germination of all the Western Himalayan oaks is hypogeal (occurring on or below ground), the radical emerging from the apex of the nut and the plumule extricating itself by the elongation of the cotyledonary petioles. 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. The seedling as a rule produce in the first season nothing more than small leafless stems 5cm to 8cm high, on which mere scales replace normal foliage leaves with buds in their axils, and normal leaves are produced first time only in the second season. However, under very favourable conditions, leaves can also be produced in the first season. The rate of growth of the seedling is very low, averaging only about 5cm to 10cm a year for those growing under natural condition (Troup, 1921) in cold climate.

2.1.3.2. Seed Production and Dispersal of *Q. semecarpifolia*

The seeds are also dispersed by means of zoochory (Troup, 1921). Presumably the same wildlife described for the other species dispersed them, but it is believed that smaller animals such as birds, squirrels and mice are the primary dispersers due to the smaller size of the seeds. There are 1,800 seeds per kilogram (Jackson, 1994).

2.1.3.3. Growth of *Q. semecarpifolia*

The seedling grows slowly, but at the end of the first season it can be between 5 and 12 cm in height. It can be successfully cultivated in a nursery and then transplanted, provided the roots are not excessively exposed during the process. A height growth of 50 cm in 4 years was recorded by Troup (1921) but older trees may grow faster. Direct sowing is also a successful method of artificial reproduction (Troup, 1921). It can reach 15 to 25 m in height and between 0.6 and 0.8 m in DBH. Troup (1921) reported the measurement of an individual with a DBH of 1 m and a height of 21 m.

2.1.3.4 Threats to Regeneration of Q. semecarpifolia

The seeds are prone to be attacked by insects (Jackson, 1994) as well as to suffer a severe predation pressure because of their waiting time on the ground until favorable conditions are met (Singh, 2014). There is an increasing concern about the failure to regenerate of *Q. semecarpifolia,* and several ecological regeneration studies have already taken place (Vetaas, 2000; Shrestha *et al.,* 2004; Tashi, 2004; Thakuri, 2010; Bisht *et al.,* 2013; Shah *et al.,* 2015) which fundamentally indicate that it cannot regenerate when subjected to heavy anthropogenic pressure, mainly lopping and grazing. If we consider its economical, ecological and social importance, the state of knowledge on the regeneration of the species is still not sufficient (Maren and Vetaas, 2007). On the other hand, there is an even bigger lack of knowledge regarding the regeneration of some *Quercus* species (Wangda and Ohsawa, 2006).

Overall, *Q. semecarpifolia* and *Q. lanata* forest types are facing an imminent threat due to the ever-increasing human pressure, their failure to regenerate and the climate change related alterations of climatic patterns, such as changes in the monsoon (Singh, 2014). A change in the timing of the monsoon would impact severely *Q. semecarpifolia* due to the synchronization between the monsoon and the germination of its seeds (Singh, 2014). Increasing temperature is shifting vegetation zones towards higher altitudinal areas, thereby exposing species to harsher conditions such as steeper, more erosive slopes, less fertile soils and pronounced climate fluctuations. These may pose a serious threat to their long-term survival (Shah *et al.,* 2015). Correspondingly, vegetation types from lower altitudes are encroaching into higher altitudinal areas, and could replace the original forest. The potential habitat of *Q. semecarpifolia* is predicted to shrink 40 % and 76 % with 1°C and 2°C increase in temperature, respectively (Saran *et al.,* 2010). A rise in temperature and water stress may advance seed maturation, which might result in the breakdown of the synchrony between the commencement of monsoon rains and seed germination. Moreover, the seedling is a light demander and fails to establish itself under conditions of shade (Singh and Singh, 1987).

Several past researches carried out by Khan *et al.* (1987), Barik *et al.* (1992), Mishra *et al.* (2004) and Tripathi *et al.* (2004) have focused their studies on the population structure and regeneration, but very few studies have considered the role of disturbance on stand structure, species composition and regeneration of tree species. So this study can be very important in providing useful information on the conservation of *Q. semecarpifolia* by using different preventive measures to minimize the disturbances.

CHAPTER 3: MATERIALS AND METHODS

3.1. Study Area

3.1.1. Location and Geomorphology

This study was conducted in the southern part of Langtang National Park and its buffer zone areas in Helambu Gaupalika and Panchpokari Gaupalika, Sindhupalchowk District at Sermathang, Kutumsang, Setighyang, Melamchighyang and Laghang between altitudes of 2500m to 3000m. The national park was gazetted in 1976 and extended by a buffer zone of 420 km^2 (160 sq mi) in 1998 and includes different vegetation types (DNPWC, 2021). Spatially, LNP extends from 28°10′26″N to 85°33′11″E and is a part of the Sacred Himalayan Landscape. In the north and east it is linked with Qomolangma National Nature Preserve in Tibet Autonomous Region. The eastern and western boundaries follow the Bhote Koshi and the Trishuli rivers, respectively. The southern border lies 32 km north of the Kathmandu Valley.

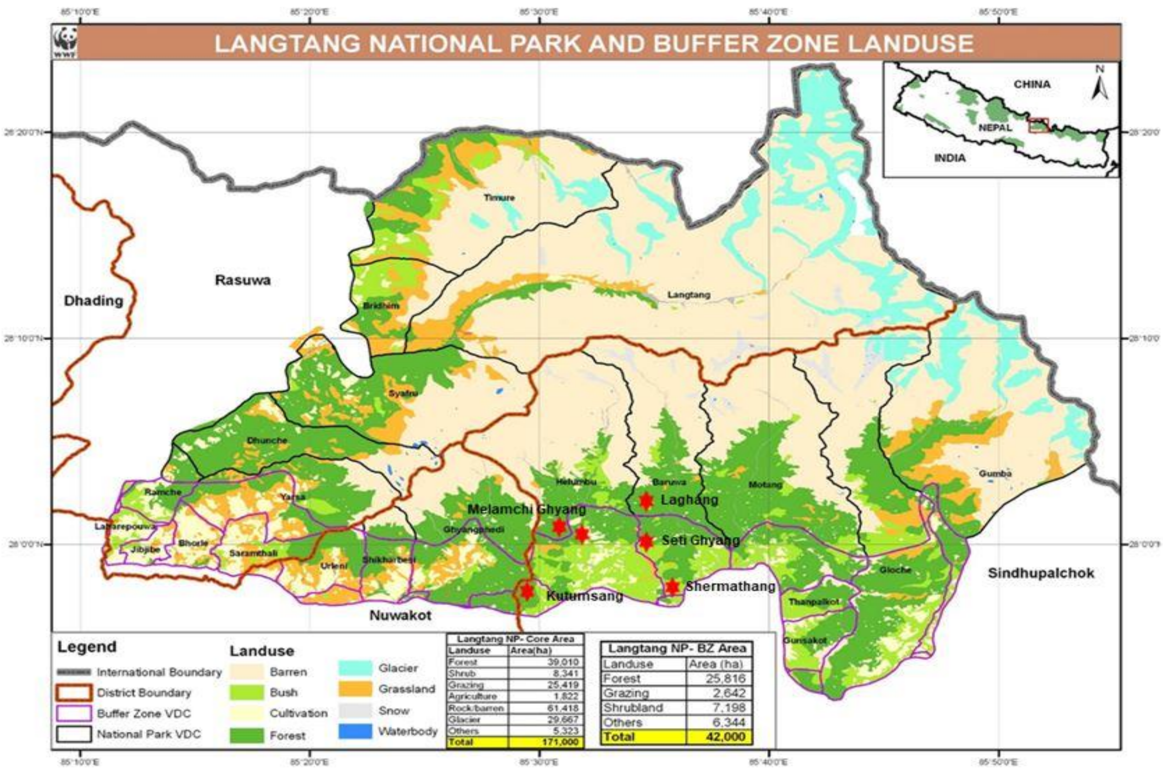

Figure 1: Map of LNP and BZ Showing Study Sites Marked with Red Asterisk. (Source: WWF, Nepal, 2022)

3.1.2 Climate

The climate of the LNP is diverse due to variation in altitude and topography. A thirty-year climatic data (1990-2020) was analyzed, which was taken from meteorological station of Dhunche (Figure 2). Mean annual temperature was 15.29℃. The monthly maximum temperature (24.35℃), the highest, was found in May and minimum temperature (2.89℃), the lowest, was found in December. The average annual precipitation was recorded to be 154.60 mm with highest rainfall in the month August (529.12 mm) and the least in the month November (8.81 mm). Upper range of study site is generally covered by seasonal snowfall. The snowmelt water is the main source of soil moisture for forest in this region. However rainfall and snow feed ground water are the main source of soil moisture for forest in middle and lower range.

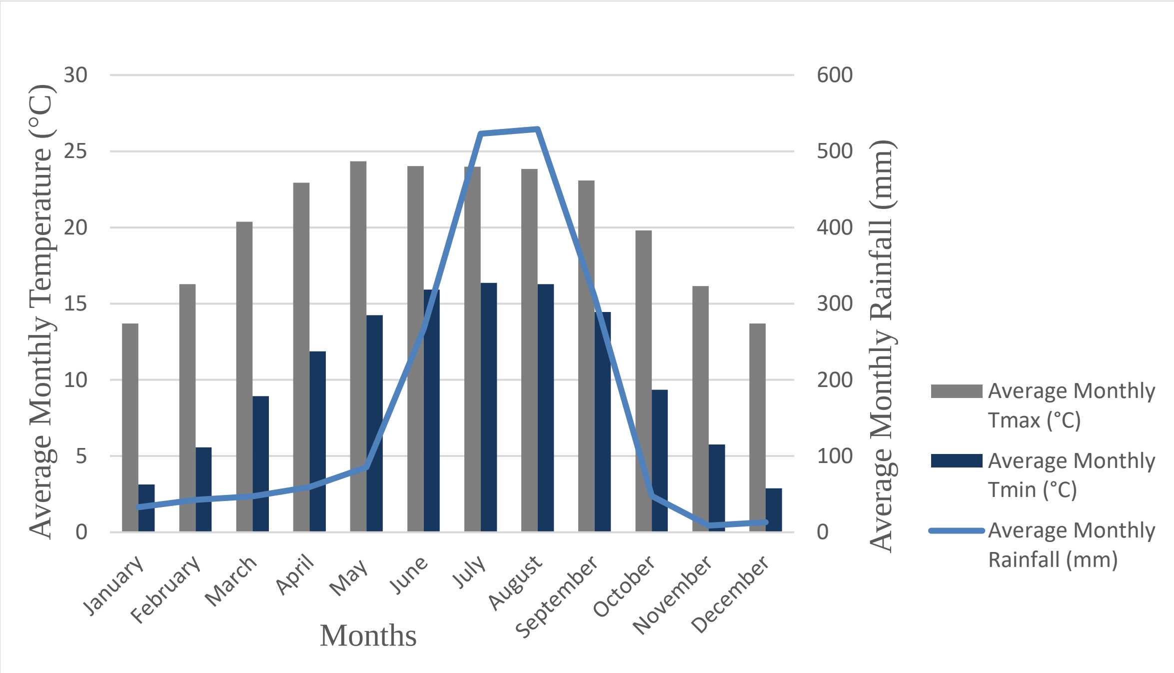

Figure 2. Thirty-Year (1990-2020) Average Monthly Maximum (Tmax) and Minimum (Tmin) Temperature and Precipitation Recorded at Dhunche Weather Station (1097 m a.s.l.), Rasuwa (Source: Department Of Hydrology and Meteorology, Government Of Nepal).

3.1.3 Vegetation

LNP covers the varieties of vegetation as it extends from the sub-tropical region to the alpine region. The prominent features of this area are mountain peaks, high-altitude pastures, forests, springs, rivers, lakes, cultivated lands and settlements area in Buffer zone. The Park's rich vegetation is characterized by Sal (*Shorea robusta*) forest in the southern section of park and it is gradually taken over by hill forest (2000-2600m) consisting of Chirpine (*Pinus roxburghii*), Rhododendrons and Nepalese alder (*Alnus nepalensis*). The temperate zone (2600-3000m) is covered mainly by oak forest fading to old growth forest of silver fir, hemlock, and larch in the lower sub–alpine zone (3000–3600m). The Nepalese larch (*Larix nepalensis*), the only deciduous conifer in the region, is found in the park and few places elsewhere. *R. arboretum*, *R. barbatum*, *R. campanulatum*, scrubs of *R. lepidotum* are some of the different species of Rhododendron found throughout these zones. Tree species such as birch, silver fir, sorbus and twisted *Rhododendron campanlatum* are found near the tree line. All the 4000 m elevation, Juniper and Rhododendron shrubs (*R. anthopogon*) slowly dissolve into the expansive alpine grassland meadows (DNPWC, 2021).

3.2 Study Species

Himalayan oaks are evergreen, mostly gregarious, medium- to large-sized tree, distributed at elevations of 800 to 3800 m throughout the Himalayan region. There are more than 35 species reported from Himalayan region (Negi and Naithani, 1995), most of which are abundant in temperate forest. Eight species occur in Nepal (DPR, 1997): *Q. floribunda*, *Q. glauca*, *Q. lamellosa*, *Q. lanata*, *Q. leuchotrichophora*, *Q. mespilifolioides*, *Q. oxyodon* and *Q. semecarpifolia*.

Quercus semecarpifolia, commonly known as brown oak (locally known as Kharsu Oak), is the main forest-forming evergreen tree species from upper temperate to subalpine regions (2,500–3,300 m). The epithet *semecarpifolia* was given by James Edward Smith when he described the species in 1814 and refers to the resemblance of the leaves of this species to those of *Semecarpus anacardium,* an Indian plant known as “marking nut” by Europeans. It is found throughout the Himalaya from Bhutan westwards into Afghanistan, on the Myanmar-Manipur frontier, Thailand, and into China (Negi and Naithani, 1995). On the southern slopes of the main Himalayan range this species often forms the limit of tree growth (Jackson, 1994).

It is a medium to large sized evergreen tree up to 3.5 m in girth and 30 m high. Trunks and branches are usually densely covered with epiphytic plants, including ferns and orchids. The leaves are coriaceous, elliptical to oblong, with sub-cordate to round base, and veins forked near the margin; they are glossy green above, generally with rust coloured hairs beneath, but old leaves are almost hairless. The leaves of saplings and coppice shoots have spines on the margin but those of older branches of trees have smooth margins. Male spikes are pendulous and occur in fascicles. Involucral scales are free and imbricate, and the acorns are globular, developing in clusters of three. Seeds are among the largest in the oak family, weighing 5.0 to 6.5 gm (Jackson, 1994).

3.3 Methods

3.3.1 Vegetation Sampling

Sampling along environmental and human impact gradients was carried out to study the phytosociology of the forest type and disturbances index in the southern parts of national park and its Buffer zone. Transects across the temperate region of the study area were laid down covering south-north facing slopes of buffer zone and the national park.

Nested Circular plots were established to survey vegetation of different size classes. Trees with <5cm DBH and <1.3m height were measured within the circle of radius 2.5m; trees with 5-10cm DBH and height >1.3m were measured within the circle of radius 5m; and trees >10cm DBH and height >1.3cm were measured within the circle of 10m radius plots, respectively. Other parameters such as height, DBH, base of live crown, crown diameter (only for dominant trees) were measured, whereas canopy cover and lopping intensity were visually observed and recorded for each plot. The cut stumps and lopped trees in each quadrat were counted and the girths were measured at ground height (10cm above the ground).

Study sites were categorized into different disturbance categories, following the disturbance index (Kanzaki and Kyoji, 1986) & other disturbance indicators like lopping intensity, indicators of grazing, trampling, litter raking, fire etc. were also recorded.

3.3.2 Soil and Litter

Litter thickness was measured by a ruler to the nearest millimeter in each sampling plot and average was taken. For a detailed analysis, soil samples were collected from the each quadrat from each plots. In each sampling plot, 5 soil samples (up to 10 cm depth) were collected of which 4 were collected from equal radial distances from center and one from the center which were later mixed and sieved to form a single soil sample, collected in zip locked plastic bags and properly numbered. A total of 77 such samples were collected which were air dried for laboratory analysis.

3.4 Laboratory Works

Soil pH, organic matter (OM) content and 3 macro nutrients (Nitrogen, Phosphorus and Potassium) were estimated at Agricultural Technology Center, Kupondole, Lalitpur, Nepal. Soil pH was determined electronically on a direct pH meter, using a glass electrode with a saturated Potassium Chloride (KCl)- calomel reference electrode at 1:2.5 soil water ratio; OM content by the Walkley and Black method; total N by the Kjeldahl method; available P by Olsen's modified carbonate method; and available Potassium (as K_2O) by aspirating flame photometer method as per the description given by Gupta (2000).

3.5 Data Analysis

3.5.1 Numerical Analysis

3.5.1.1 Community Structure

The field data were used to calculate frequency, density, basal cover and importance percentage of tree species following the method described by Zobel *et al*. (1987) with some modifications. Further analysis was done by R-program.

Frequency (F)

Frequency is the proportion of sampling units containing the species.

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

Relative frequency (RF)

Relative frequency can be obtained by comparing the frequency of occurrences of all the species present.

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

Density (D)

Density is the number of individuals per unit area.

Density (stem/ha) = $\frac{\text{Total number of individuals of a species in all plots} \times 10000}{\text{Total number of plot studied} \times \text{size of the plots}}$

Relative density (RD)

Relative density can be obtained by comparing the density of occurrences of all of the species present.

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

Basal Area (BA)

Basal area is one of the characters which determine dominance. Basal area cover indicates the amount of ground occupied by the stems. The circumference data of tree at 1.3m above the ground level at the base of tree is used for calculating basal area which is given by: Basal area = $\pi d^2/4$

Where,

d = DBH (diameter at the breast height)

$\pi = 3.1416$

Basal area of a species (m^2/ha) = $\frac{\text{Total basal area of a species} \times 10000}{\text{Size of the plot}}$

Relative Basal Area (RBA)

Relative basal area can be obtained by comparing the basal area of occurrences of all of the species present.

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

Importance Value Index (IVI)

Relative frequency, Relative density, and Relative basal area each indicate a different aspect of the importance of a species in a community. Therefore, the sum of these three values should give a good overall estimate of the importance of a species. This sum is called the importance value.

$IVIi = RFi + RDi + RBAi$

Where,

$IVIi$ = Importance Value Index of species i

RFi = Relative Frequency of species i

RDi = Relative Density of species i

$RBAi$ = Relative Basal Area of species i

Species Diversity Index (H')

The Shannon index (Shannon & Weiner, 1949) is one of the most employed variables for the estimation of species diversity; for its determination is employed the formulation:

$H' = -\Sigma\ Pi.\ln(Pi)$

Where,

H' = Species Diversity Index

Pi = proportion of the species

$Pi = ni / N$

N = total importance value of plants

ni = importance value of each species

Simpson's Dominance Index

Simpson's diversity index given by Simpson (1949) is an accepted and often used calculation of plant diversity within a habitat. Within a sample area all plants of all species are counted. The diversity is then calculated using the following equation $D = \Sigma\ (ni/N)^2$

Where,

D = Simpson's Dominance Index

N = total importance value of plants

ni = importance value of each species

5.3.1.2 Disturbance Index

The disturbance index (DI) was calculated as the basal area of cut trees measured at the ground level expressed as fraction of total basal area of all trees (Kanzaki and Kyoji, 1986):

$$\text{DI (\%)} = \frac{\text{Basal area of cut stumps} \times 100}{\text{Total Basal Area (Basal area of cut stumps+Basal area of standing trees)}}$$

CHAPTER 4: RESULTS

4.1 Vegetation Composition and Diversity

A total of 9 tree species belonging to 8 genera and 8 families were recorded inside the national park and 17 tree species belonging to 16 genera and 14 families in the buffer zone area. Family Fagaceae was found to be the dominant family inside the national park while family Fagaceae and Ericaceae were found to be dominant in the buffer zone.

Fagaceae is represented by 2 (22.22%) species and other families were represented by 1 (11.11%) species each in case of national park while Fagaceae and Ericaceae were represented by 2 (12.5%) species each and other families were represented by 1 (6.3%) species each in the buffer zone area. The dominancy of the family both inside the national park and buffer zone along with the number of families and number of species are given in Table 1.

Table 1: Collected Tree Species Along with Number Families and Number of Species.

Categories	Number of Families	Number of Species	Dominant Family
National Park	8	9	Fagaceae
Buffer Zone	14	17	Fagaceae and Ericaceae

Simpson's index of diversity and Shannon-Weiner index of diversity of tree species inside the national park were found to be 0.7934 and 1.832 respectively while those values for buffer zone were found to be 0.7128 and 1.6936 respectively which are given in the table below:

Table 2: Diversity indices of tree species in Buffer zone and National Park.

Categories	Simpson's Index	Simpson's Index of Diversity	Shannon-Weiner Index of Diversity	Evenness
National Park	0.2066	0.7934	1.832	0.834
Buffer Zone	0.2872	0.7128	1.6936	0.598

4.2 Community Structure

The forest inside the national park and buffer zone were found to be of mixed type comprising *Quercus semecarpifolia*, *Quercus lamellosa*, *Abies spectabilis*, *Prunus cerasoides* and other tree species.

The most frequent tree species was found to be *Quercus semecarpifolia* with important value index of 30.23% (IVI=90.69) inside the national park and in case of buffer zone, the same species was most frequent and dense with important value index of 28.82% (IVI=86.46). The frequency percentage of adult, seedling and sapling of *Quercus semecarpifolia* were found to be 100%, 72.97% and 59.46% respectively inside the national park and in case of buffer zone they were found to be 100%, 65% and 35% respectively (Figure 3).

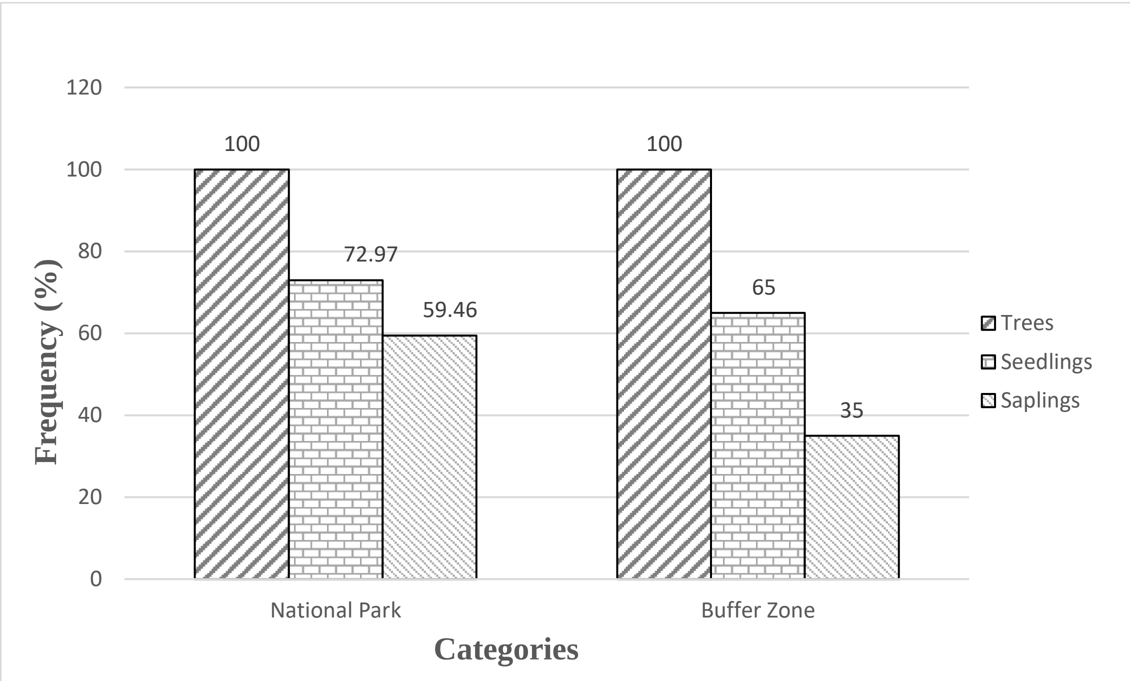

Figure 3: Frequency of all Stages of *Quercus semecarpifolia* inside National Park and Buffer Zone.

The least IVI was found to be of *Prunus cerasoides* (6.56) in the national park and *Citrus* species had the least value of IVI (3.75) in the buffer zone. The IVI value of *Abies spectabilis*, *Rhododendron arboreum*, *Prunus cerasoides*, *Elaeagnus umbellate*, *Elaeocarpus ganitrus* and other species are given below (Table 3):

Table 3: IVI of the Dominant Tree Species.

Name of species	Important Value Indices (IVI)	
	LNP	BZ
Quercus semecarpifolia Sm.	90.69	86.46
Abies spectabilis (D. Don) Spach	62.94	61.28
Rhododendron arboreum Sm.	38.78	38.28
*Elaeagnus umbellate*L.	29.57	21.28
*Elaeocarpus lanceifolia*L.	24.39	8.03
Ilex dipyrena Wall.	20.17	6.2
Quercus lamellosa Sm.	18.85	3.37
Lindera pulcherrima (Nees) Benth. ex Hook.f.	8.06	4.46
Prunus cerasoides (D. Don)	6.56	32.75
Lyonia ovalifolia (Nutt.)	-	9.27
Cinnamomum glaucescens (Nees) Mazz.	-	5.32
Citrus sp. L.	-	3.75
Maesa macrophylla Wall. ex Roxb.	-	3.41
Acer pectinatum Wall. ex Pax.	-	5
Myrica esculenta (Buch.-Ham. Ex D.Don)	-	4.05
Mahonia nepaulensis DC.	-	1.75
Alnus nepalensis (D.Don)	-	5.34

Total tree density, sapling density and seedling density of *Quercus semecarpifolia* inside national park were found to be 158 stem/ha, 166 stem/ha and 21 stem/ha respectively and that of buffer zone were found to be 248 stem/ha, 59 stem/ha and 53 stem/ha respectively (Table 6). This indicates that the seedling density was higher than tree density with least sapling density in the national park and tree density was found to be higher followed by seedling density and sapling density in the buffer zone.

Table 4: Density of Adult, Sapling and Seedling of *Quercus semecarpifolia*.

	Tree Density (stem/ha)	Sapling Density (stem/ha)	Seedling Density (stem/ha)
National Park	158	21	166
Buffer Zone	248	53	59

4.3 Regeneration and Size-Class Distribution

4.3.1 DBH-Class Distribution

In case of national park, the regeneration resembled a positively skewed distribution pattern. The density of tree was maximum at 30-49.9cm class and followed by 50-69.9

cm DBH class (Figure 7). The largest DBH class size (≥250 cm) and class (210-229.9 cm) had fewest individuals and class (190-209.9cm) and (230-249.9cm) had no individuals.

While, in the buffer zone, the regeneration showed fluctuating pattern. The density of trees was found to fluctuating with increase in diameter. The density of tree was maximum at DBH class (10-24.9cm) and was minimum i.e. 0 at DBH class (160-174.9cm).

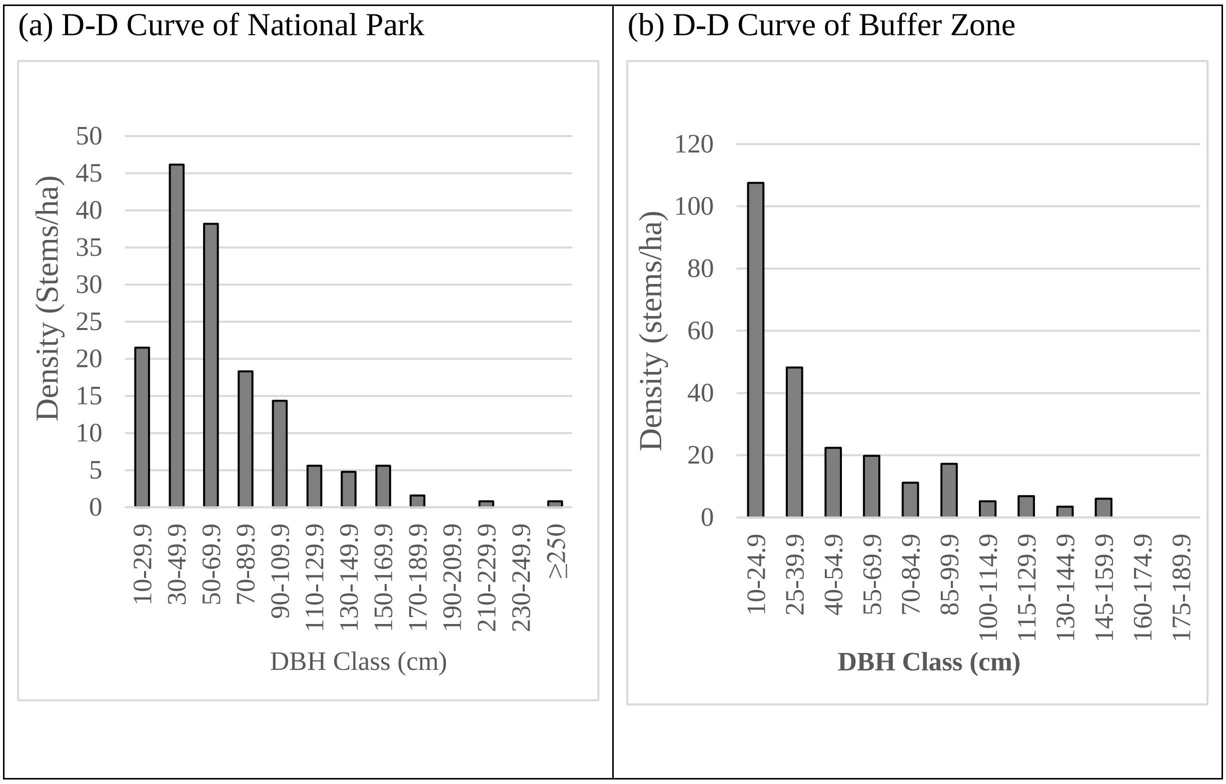

Figure 5: Comparison of D-D curve of *Q. semecarpifolia* in National Park and Buffer Zone.

4.3.2 Height Class Distribution

The bar graph of height of *Quercus semecarpifolia* in the buffer zone showed that the density of trees with height class 5-9.9m was highest (219) and that of trees with height class <5m was found to be lowest (49) whereas inside the national park, the density of trees with height 10-14.9m was highest (132) and that of trees with height class <5m was found to be lowest (14) as shown in the Figure 6 below:

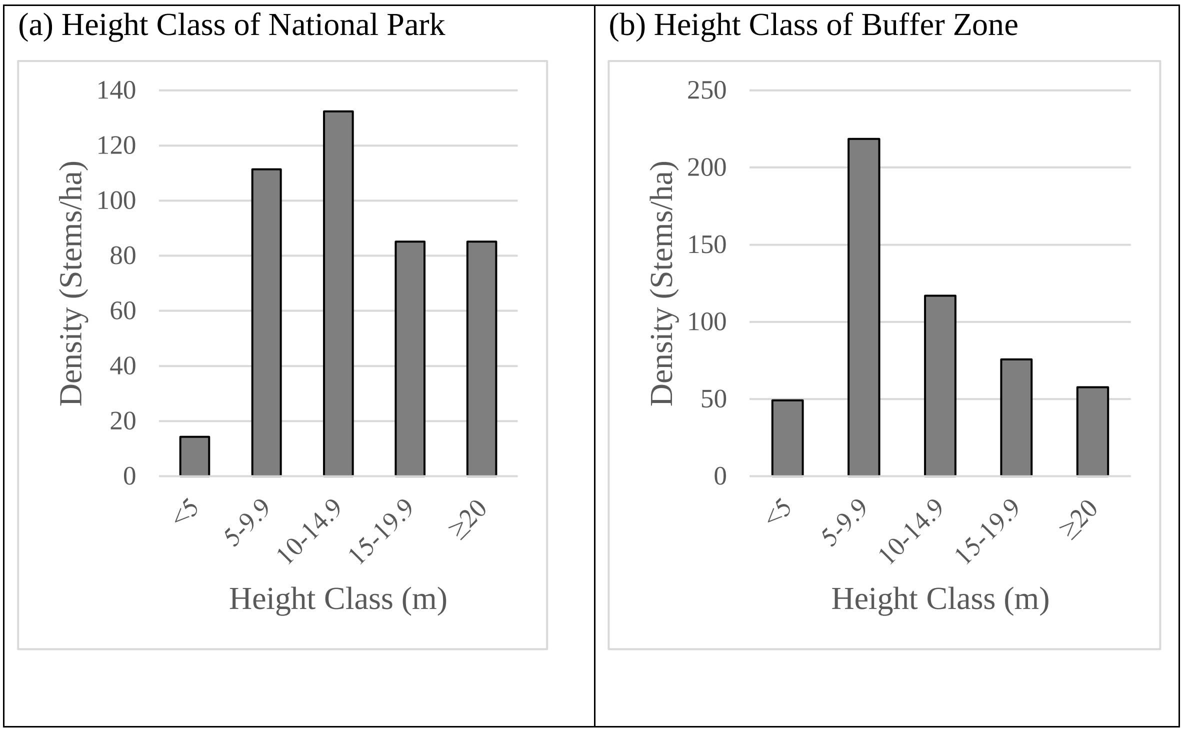

Figure 6: Comparison of Height Class of *Quercus semecarpifolia* in the National Park and its Buffer Zone.

4.4 Regeneration and Soil Parameters

4.4.1 Organic Matter Content in the Soil

The organic matter content in the soil in buffer zone ranged between (6.74%-20.98%) and in national park the value was between (5.87%-25.11%). The p-value for correlation between the organic matter content in the soil and seedling was found to be 0.428 which is greater than 0.05 and r-value was found to be 0.130 growth in the national park and in case of buffer zone, the p-value was found to be 0.207 which is also greater than 0.05 and r-value was found to be 0.213 (figure 7 (a) and (b)).

The p-value for correlation between the organic matter content in the soil and sapling growth was found to be 0.544 which is greater than 0.05 and r-value was found to be -0.099 in the national park and in case of buffer zone, the p-value was found to be 0.107 which is also greater than 0.05 and r-value was found to be 0.269 (figure 7 (c) and (d)). The p-values obtained shows that there was no significant relation between organic matter content in the soil and regeneration.

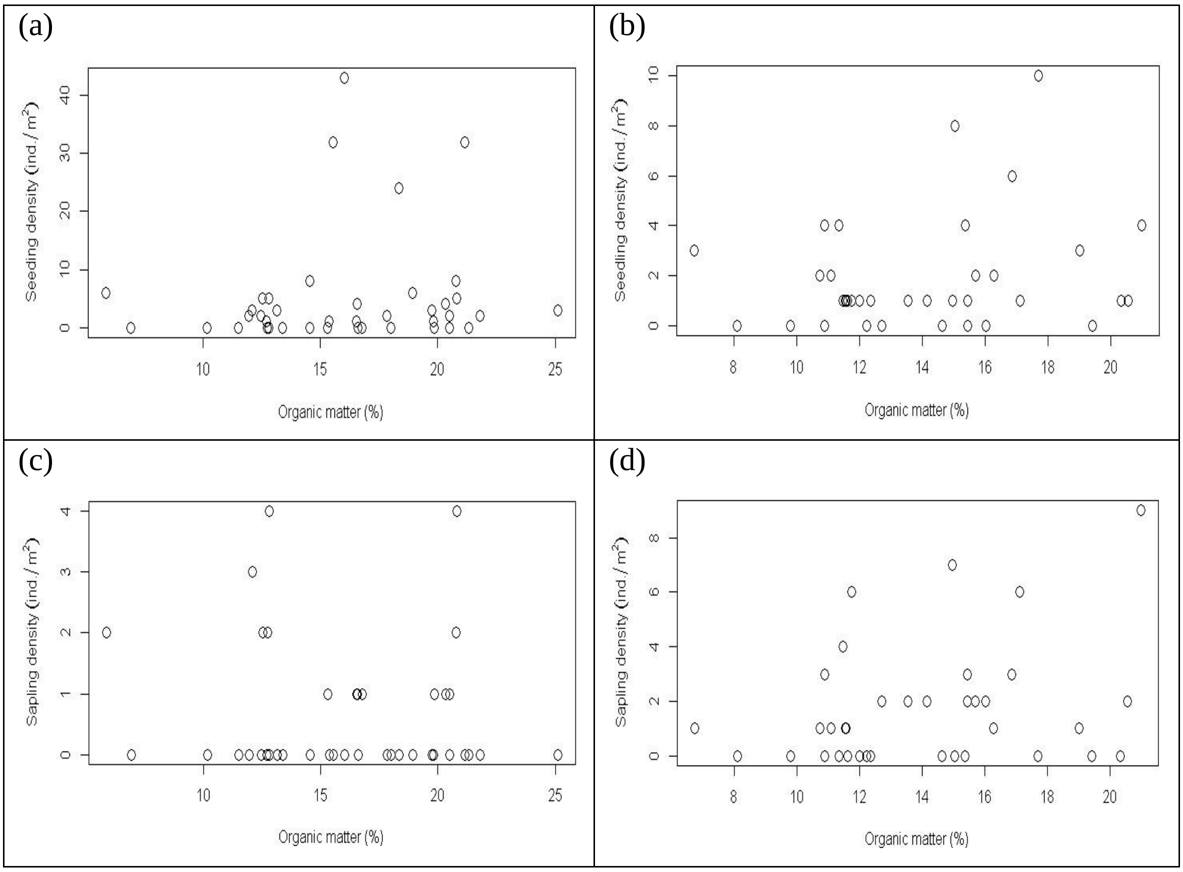

Figure 7: Correlation between Organic Matter Content and Seedling Growth ((a) and (b)) and Sapling Growth ((c) and (d)) in the National Park and Buffer Zone.

4.4.2 pH of Soil

Forest soils were found to be extremely acidic both in the buffer zone (pH: 3.01-4.15) and national park (pH: 3.31-4.51).The p-value for correlation between the pH of soil and seedling growth was found to be 0.094 which is greater than 0.05 and r-value was found to be 0.268 in the national park and in case of buffer zone, the p-value was found to be 0.400 which is also greater than 0.05 and r-value was found to be -0.142 (figure 8 (a) and (b)). The p-value for correlation between the pH of soil and sapling growth was found to be 0.209 which is greater than 0.05 and r-value was found to be 0.203 in the national park and in case of buffer zone, the p-value was found to be 0.229 which is also greater than 0.05 and r-value was found to be -0.203 (figure 8 (c) and (d)). The p-values obtained shows that there was no significant relation between pH of soil and regeneration.

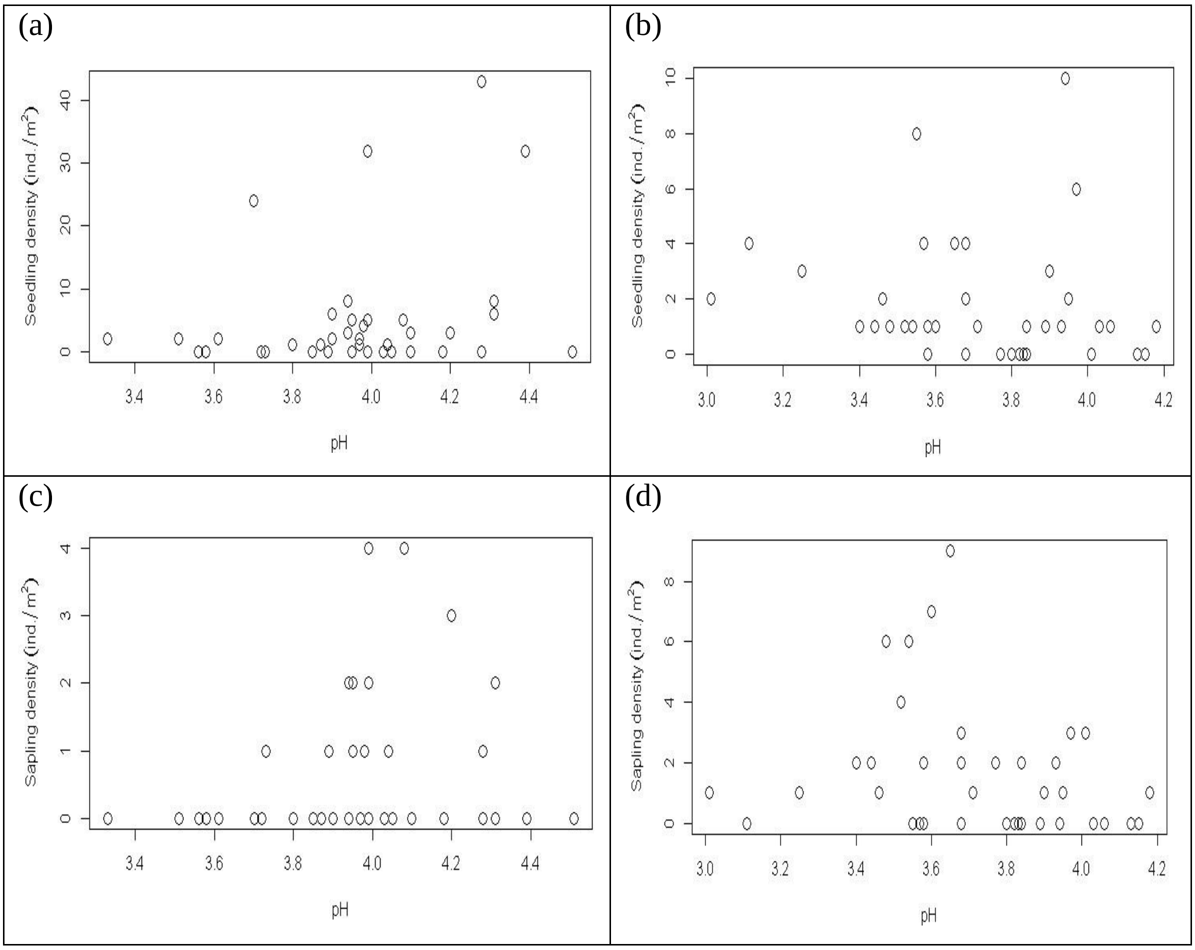

Figure 8: Correlation between Soil pH and Seedling Growth ((a) and (b)) and Sapling Growth ((c) and (d)) in the National Park and Buffer Zone.

4.4.3 Nitrogen Content in Soil

The nitrogen content in the soil in buffer zone ranged between (0.27%-0.84 %) and in national park the value was between (0.24%-1%). The p-value for correlation between the nitrogen content in the soil and seedling growth was found to be 0.427 which is greater than 0.05 and r-value was found to be 0.129 in the national park and in case of buffer zone, the p-value was found to be 0.185 which is also greater than 0.05 and r-value was found to be 0.223 (figure 9 (a) and (b)).

The p-value for correlation between the nitrogen content in the soil and sapling growth was found to be 0.482 which is greater than 0.05 and r-value was found to be 0.115 in the national park and in case of buffer zone, the p-value was found to be 0.084 which is also greater than 0.05 and r-value was found to be 0.288 (figure 9 (c) and (d)). No significant relation between nitrogen content in the soil and regeneration was observed.

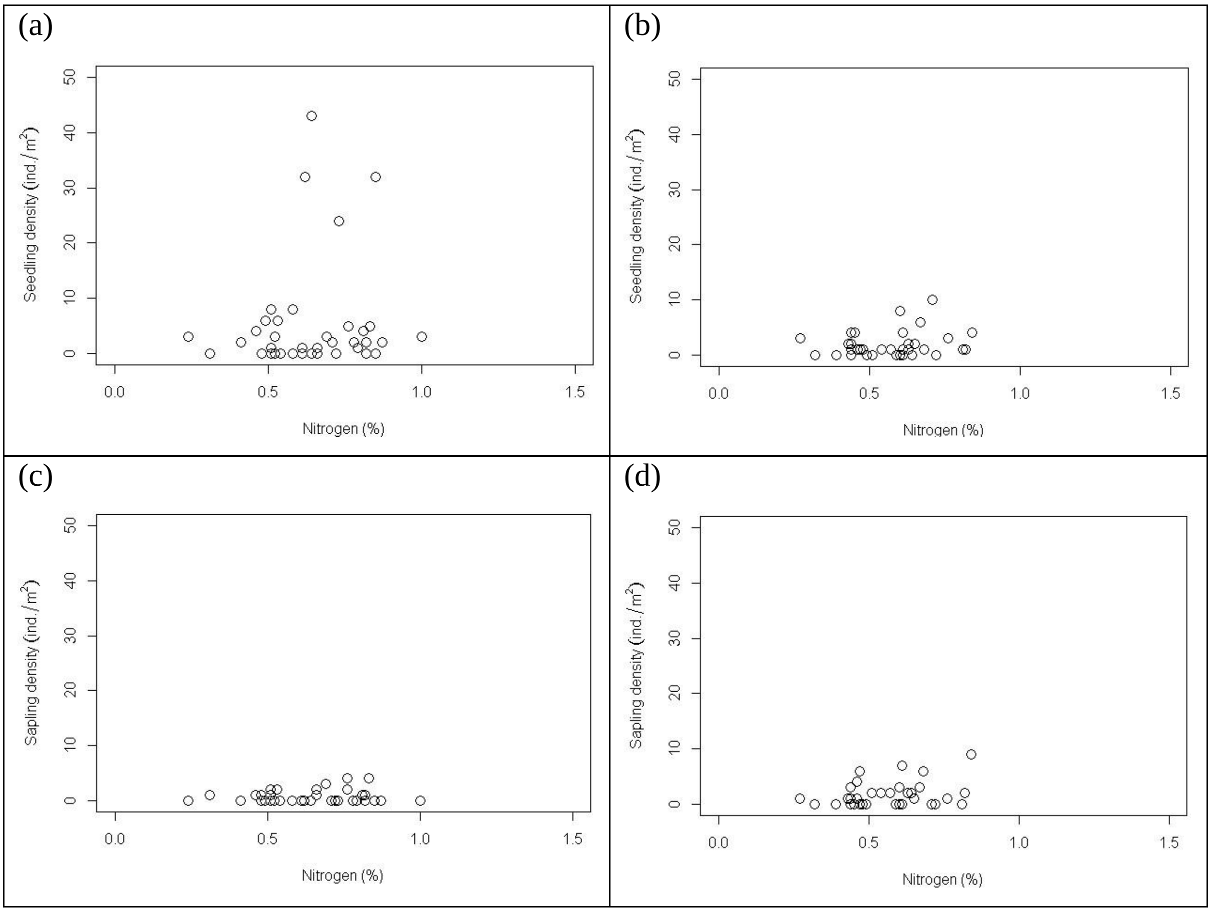

Figure 9: Correlation between Nitrogen Content and Seedling Growth ((a) and (b)) and Sapling Growth ((c) and (d)) in the National Park and Buffer Zone.

4.4.4 Phosphorus Content in Soil

The phosphorus content in the soil in buffer zone ranged between (35-263.5 kg/ha) and in the national park the value was between (35.93-357.48 kg/ha).The p-value for correlation between the phosphorus content in the soil and seedling growth was found to be 0.452 which is greater than 0.05 and r-value was found to be -0.122 in the national park and in case of buffer zone, the p-value was found to be 0.674 which is also greater than 0.05 and r-value was found to be 0.071 (figure 10 (a) and (b)).

The p-value for correlation between the phosphorus content in the soil and sapling growth was found to be 0.217 which is greater than 0.05 and r-value was found to be 0.199 in the national park and in case of buffer zone, the p-value was found to be 0.690 which is also greater than 0.05 and r-value was found to be 0.068 (figure 10 (c) and (d)). It means there was no significant relation between phosphorus content in the soil and regeneration.

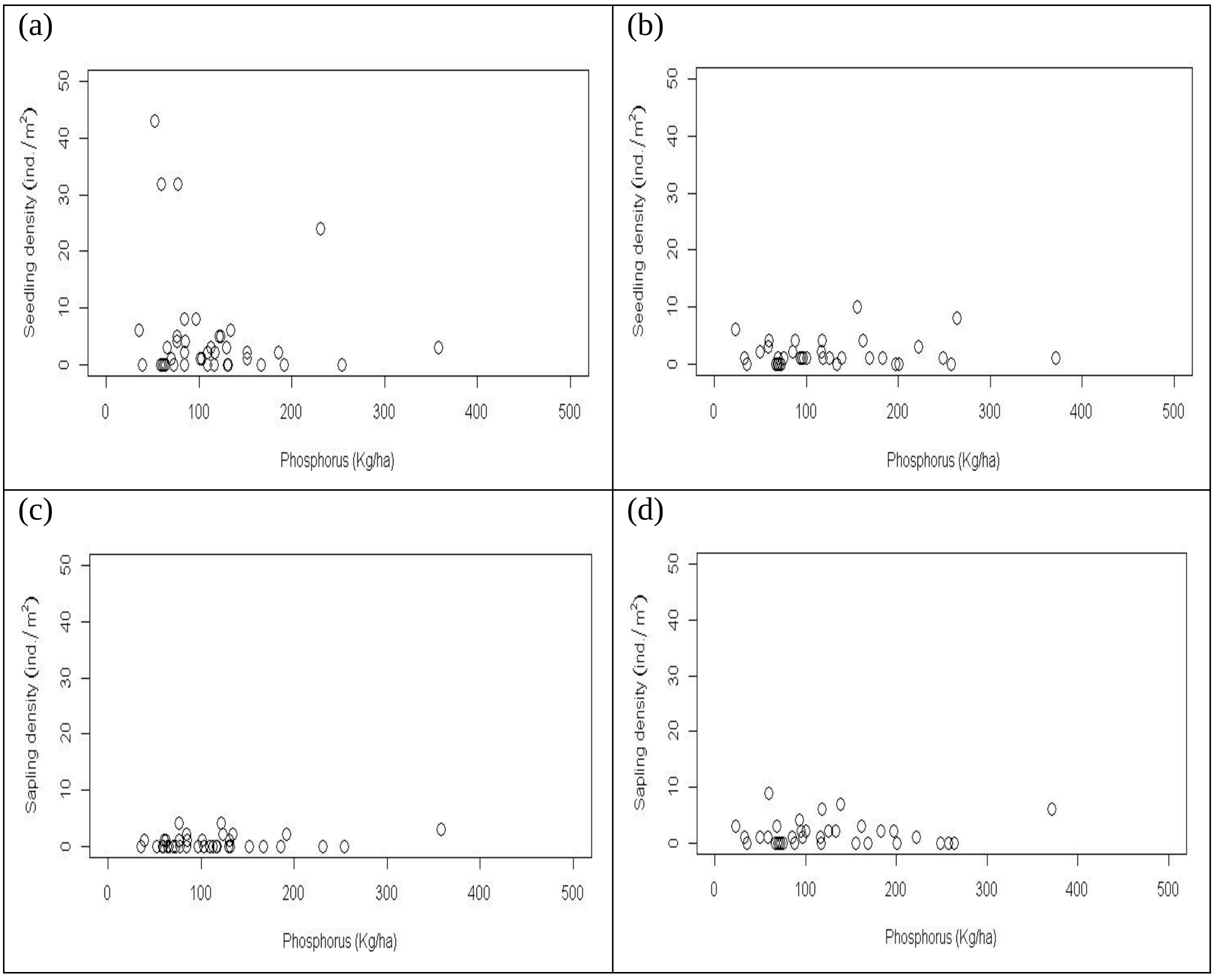

Figure 10: Correlation between Phosphorus Content and Seedling Growth ((a) and (b)) and Sapling Growth ((c) and (d)) in the National Park and Buffer Zone.

4.4.4 Potassium Content in Soil

The potassium content in the soil in buffer zone ranged between (134-683.4 kg/ha) and in national park the value was between (174.2-670 kg/ha).The p-value for correlation between the potassium content in the soil and seedling growth was found to be 0.199 which is greater than 0.05 and r-value was found to be -0.207 in the national park and in case of buffer zone, the p-value was found to be 0.602 which is also greater than 0.05 and r-value was found to be -0.089 (figure 11 (a) and (b)).

The p-value for correlation between the potassium content in the soil and sapling growth was found to be 0.289 which is greater than 0.05 and r-value was found to be 0.171 in the national park and in case of buffer zone, the p-value was found to be 0.504 which is also greater than 0.05 and r-value was found to be 0.113 (figure 11 (c) and (d)). There was no significant relation between potassium content in the soil and regeneration.

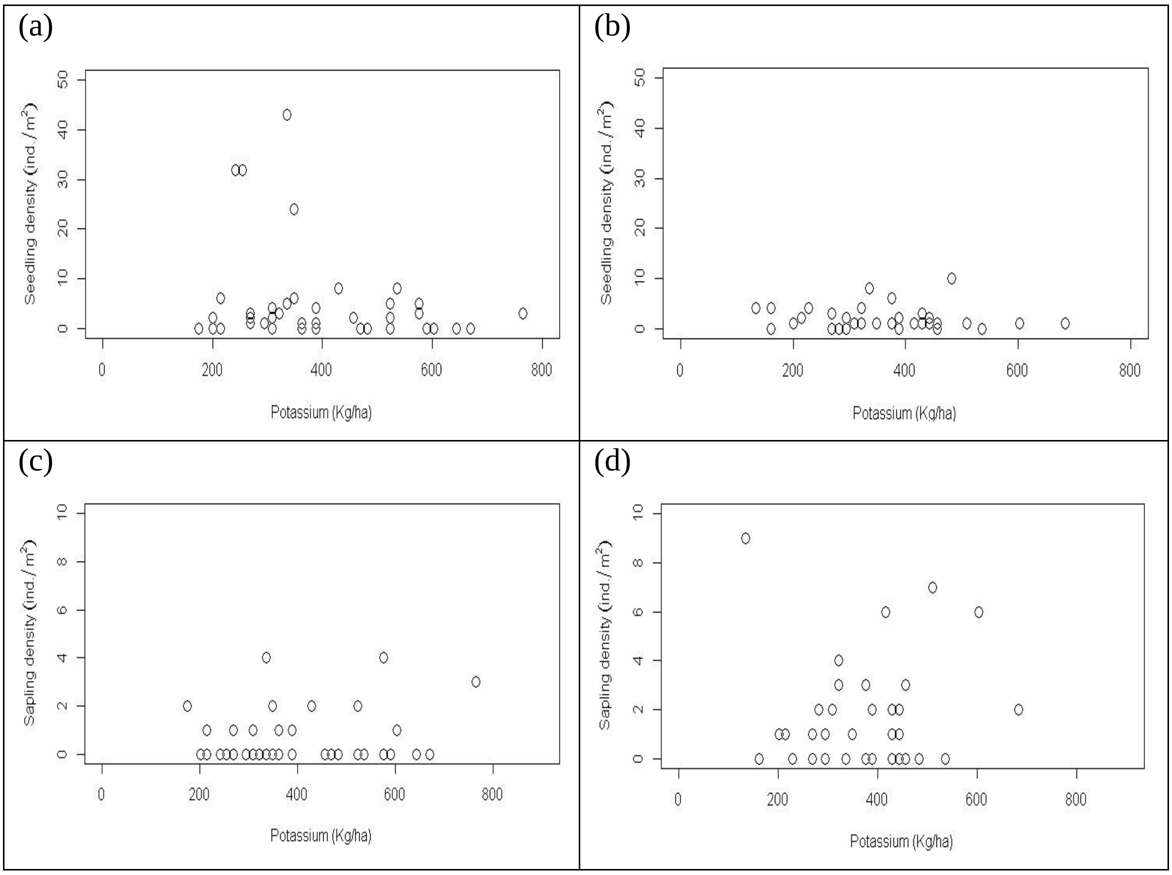

Figure 11: Correlation between Potassium Content and Seedling Growth ((a) and (b)) and Sapling Growth ((c) and (d)) in the National Park and Buffer Zone.

4.4.5 Canopy Cover

The canopy cover in buffer zone ranged between (40%-80%) and in national park the value was between (20%-90%).The p-value for correlation between the canopy cover and seedling growth was found to be 0.580 which is greater than 0.05 and r-value was found to be 0.090 inside national park and in case of buffer zone, the p-value was found to be 0.863 which is also greater than 0.05 and r-value was found to be 0.029 (figure 12 (a) and (b)).

The p-value for correlation between the canopy cover and sapling growth was found to be 0.623 which is greater than 0.05 and r-value was found to be 0.080 inside national park and in case of buffer zone, the p-value was found to be 0.058 which is also greater than 0.05 and r-value was found to be 0.314 (figure 12 (c) and (d)). This shows no significant relation between canopy cover and regeneration.

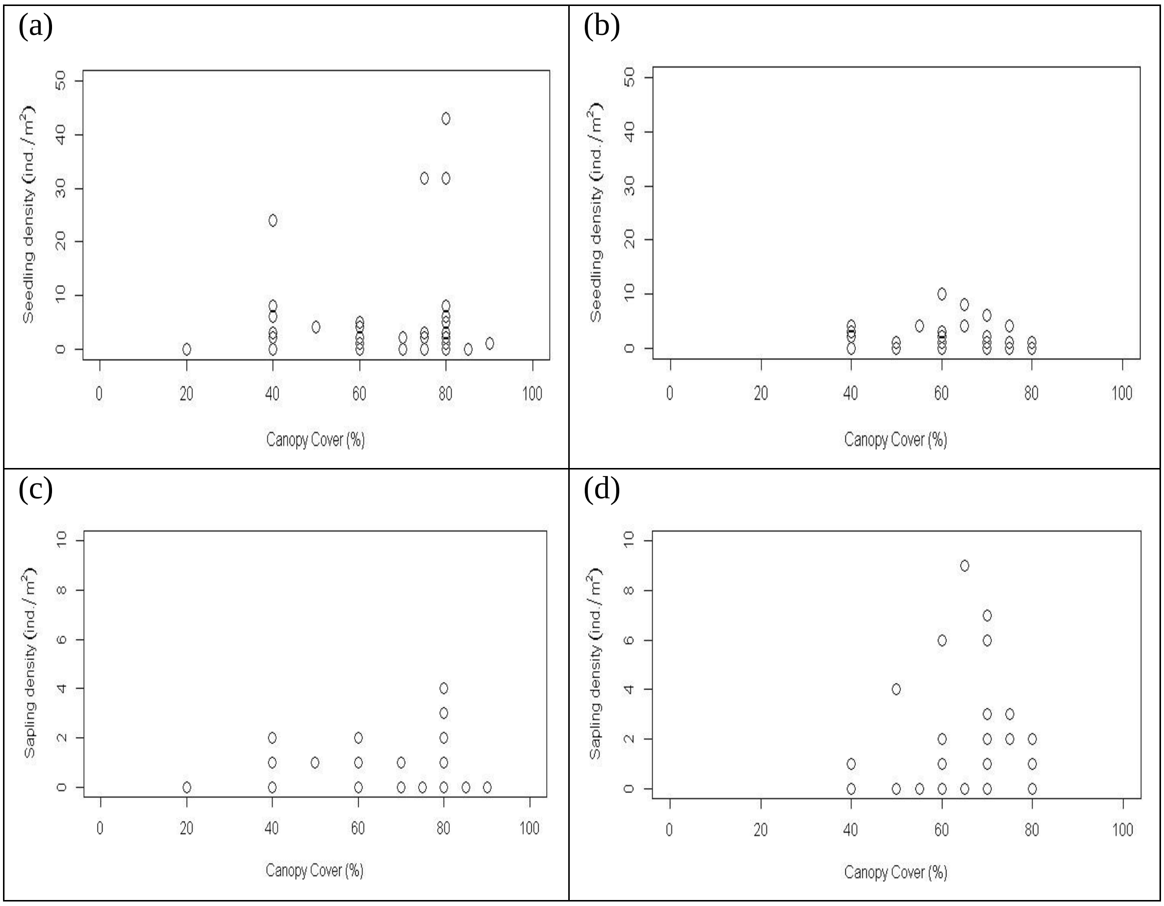

Figure 12: Correlation between Canopy Cover and Seedling Growth ((a) and (b)) and Sapling Growth ((c) and (d)) in the National Park and Buffer zone.

4.4.6 Litter Depth

The litter depth in buffer zone ranged between (1.9-18cm) and in national park the value was between (2-20cm).The p-value for correlation between litter depth and seedling growth was found to be 0.454 which is greater than 0.05 and r-value was found to be -0.122 inside national park and in case of buffer zone, the p-value was found to be 0.978 which is also greater than 0.05 and r-value was found to be 0.005 (figure 13 (a) and (b)).

The p-value for correlation between litter depth and sapling growth was found to be 0.578 which is greater than 0.05 and r-value was found to be 0.091 inside national park and in case of buffer zone, the p-value was found to be 0.836 which is also greater than

0.05 and r-value was found to be 0.035 (figure 13 (c) and (d)). There was no significant relation between litter depth and regeneration.

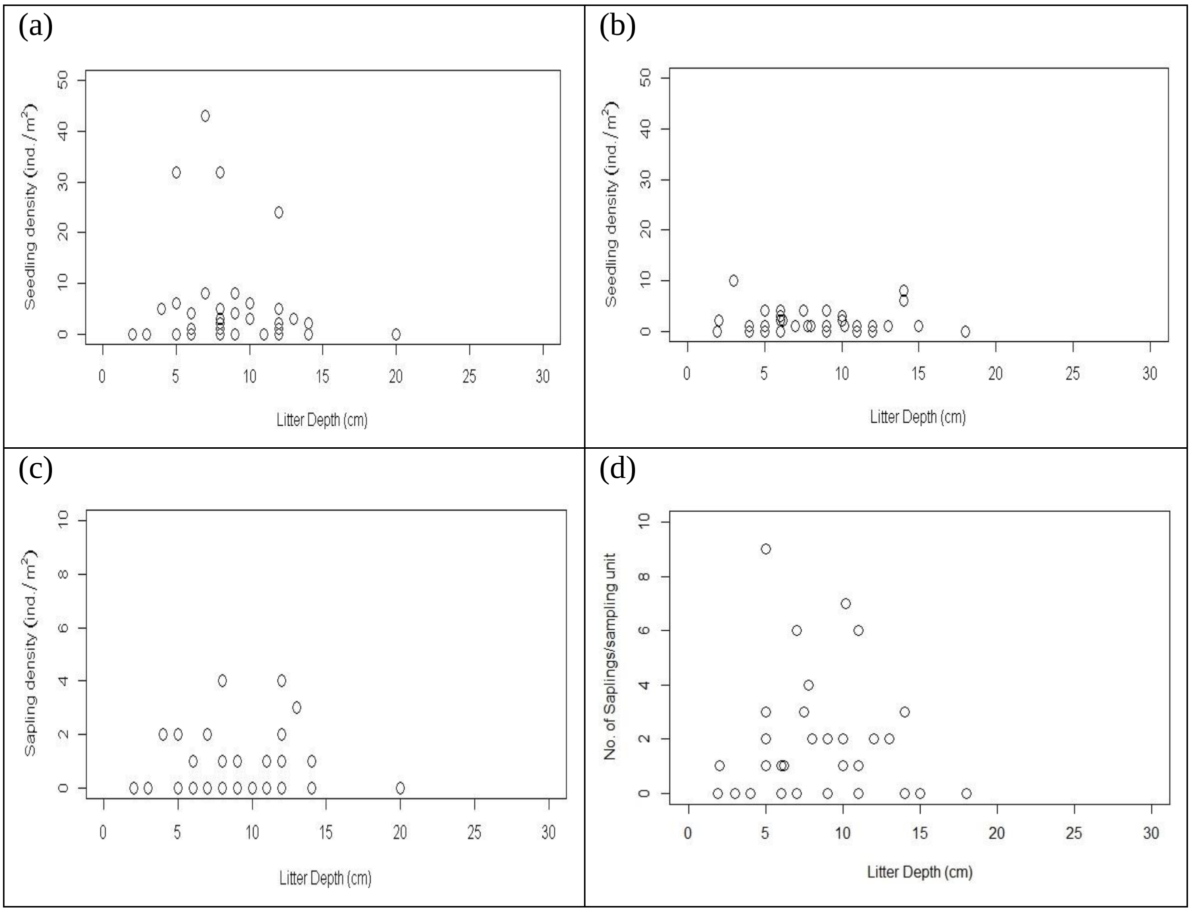

Figure 13: Correlation between Litter Depth and Seedling Growth ((a) and (b)) and Sapling Growth ((c) and (d)) in the National Park and Buffer Zone.

4.5 Disturbance Index

The disturbances like slashing, grazing, lopping, drain, coppice re-growth, access track, and litter collection were observed in the buffer zone and forests near the human settlement of buffer zone. The disturbance index (DI) of the national park was found to be 0.738% and that of buffer zone was found to be 2.028% which shows that the forest inside the national park was less disturbed than the forest in the buffer zone. But the species richness was found to be higher in disturbed area (17) than the undisturbed area (9). Both forests were found to be regenerating but the regeneration was better in buffer zone than in national park. The details of disturbance index is given in Appendix 8.

Table 5: Relationship between Disturbance Index and Regeneration.

Sites	Disturbance Index (%)	No. Seedlings (Stem/ha)	No. of Saplings (Stem/ha)	No. of Trees (Stem/ha)
National Park	0.738	166	21	158
Buffer Zone	2.028	59	53	248

CHAPTER 5: DISCUSSION

5.1 Vegetation Composition and Diversity

Disturbance whether of natural or anthropogenic in nature, leads to create different niches for the establishment and onward growth of tree seedlings. Whatever are the causes of increasing or decreasing disturbances, they changes overall community structure (Shaforth *et al.*, 2002; Sousa, 1979). The study was carried out in LNP (considered as undisturbed area) and its buffer zone (disturbed area). The species richness was found to be higher in the disturbed area (buffer zone) than the national park (undisturbed area). However, the result was different from Borah *et al.* (2014) where they recorded 75 and 56 tree species from undisturbed forest and disturbed forest respectively at Barak Valley, Southern Assam, which shows that species richness (diversity) was higher in undisturbed area than disturbed area. The result obtained by Lalfakawma *et al.* (2009) was also different as they also obtained higher tree species in undisturbed forest (32) than disturbed forest (17) at Lunglei district, Mizoram, North-East India. The value of Shannon-Weiner diversity showed that the diversity was higher in the BZ area than the NP. This might be because the BZ area is intermediately disturbed resulting higher diversity than NP (Willig and Presley, 2018). Similar result was obtained by Kumar *et al.* (2004) and Barik *et al.* (1992). Treefall or crown gaps, created due to lopping and felling of trees for fuel wood, fodder and grazing (Kumar *et al.*, 2004), creates specialized regeneration conditions to prevailing spatial and microenvironmental heterogeneity (Barik *et al.*, 1992) which promotes high tree diversity in the BZ area. But the diversity was higher in the undisturbed area than the disturbed area in the study of Lalfakawma *et al.*, 2009 and Borah *et al.*, 2014. The value of Simpson's index of diversity also showed the same result.

Fagaceae tree species are found to occur all over Nepal between 1700 and 3800m in 17 various forest types as described by TISC (2002). Fagaceae was a dominant family in the disturbed and undisturbed area as the study was carried out at moist subtropical and temperate zone similar to the findings of Singh and Singh, 2016 at Northeast India, in moist subtropical and temperate forest. Ericaceae was also dominant family in the study area similar to these findings of Wang *et al.*, 2018 at the elevation of 2454m.

5.2 Community Structure

The forests of both the study sites were composed of mixed type; 9 tree species with *Quercus semecarpifolia* were present in the undisturbed area and 17 tree species with *Quercus semecarpifolia* in the disturbed area with combined density 423 stems/ha and 508 stems/ha respectively. The heavy dependency and rapid extraction of tree species from disturbed forest sites leads to lower tree density than undisturbed sites (Borah *et al.,* 2014). *Q. semecarpifolia* alone had a tree density of 248 stems/ha in disturbed area and 158 stems/ha in undisturbed area. In many undisturbed and little disturbed oak forest, unfortunately, there are large old trees and seedlings, but saplings and recruits are absent (Metz, 1997); this indicates large-scale death of saplings and small trees before they reach canopy. Present value obtained from the study was slightly different from the reports of Shivapuri National Park (217 stems/ha) by Siluwal *et al.* (2001) and 203 stem/ha by Shrestha *et al.* (2017). In other studies, Kharsu density in Langtang National Park was 400 ha^{-1} (Vetaas, 2000) and in Kumaun it was 872 ha^{-1} (Singh and Singh, 1992).

Seedling density and sapling density of *Q. semecarpifolia* in the NP forest was 166 stems/ha and 21 stems/ha respectively and in the BZ forest, the values were 59 stems/ha (seedling) and 53 stems/ha (sapling). Comparatively, less number of seedlings of *Q. semecarpifolia* in BZ area (59 stems/ha) was observed than the NP (166 stems/ha). This might be due to the presence of grazing in the BZ area. Same cause was reported by Wangchuk and Gurung (2016) at Thimpu Dzongkhag district in western Bhutan, Buffum *et al.* (2008) at Bhutan and Joshi and Anderson (2020) at Tungnath, Chopta region of the Chamoli district in India. A comparative study has shown that Khasru tree lopped every year and at the interval of two years did not produce seeds, while trees lopped at the interval of three years or more produce seeds (Shrestha and Paudel, 1996). High seedling density was also obtained by Shrestha *et al.* (2017) in Shivapuri Hill, Central Nepal. Khasru forest elsewhere in Central Nepal also has well representation of seedling (Vetaas, 2000; Metz 1997) but in some forest of Kumaun Himalaya (India) seedlings were absent (Singh and Singh, 1992) under protected conditions.

Comparatively sapling density was lower in the NP (21 stems/ha) than the BZ area (53 stems/ha). This might be due to the study site being NP where large tree and seedlings are observed but saplings and recruits are absent (Metz, 1997). Shrestha *et al.* (2004) reported too low sapling density (62 stem/ha) and they were present only 10% of total sampling plot in Shivapuri Hill. Density of seedlings should be greater than the density of saplings for a normal demographic development (West *et al*., 1981). In the present study, in both NP and BZ sites, a normal demographic development was observed.

5.3 Regeneration and Size-Class Distribution

5.3.1 DBH-Class Distribution

Tree size class distribution is an important indicator of changes in population structure and species composition of a forest ecosystem (Newberry and Gartlan, 1996). The result obtained for undisturbed area was similar to Lalfakawma *et al.* (2009) and for disturbed area, it was similar to Borah *et al.* (2014) where positively skewed distribution pattern was obtained for undisturbed area and fluctuating pattern was obtained for disturbed area. In undisturbed area, the lower density of lower DBH class tree (10-29.9cm) than intermediate DBH class was observed which might be due to low tree mortality and lower removal rate across the intermediate diameter class similar to the result of Saxena *et al.* (1984) and West *et al.* (1981) and lower recruitment of component tree species. The lower density of higher DBH classes of trees in the undisturbed area, as compared to intermediate or lower DBH classes might be due to the relatively high mortality of large canopy trees similar to the result of Goff and West (1975) and Lorimer *et al.* (2001). Fluctuating distribution curve is generally common in disturbed forests (Borah and Garkoti, 2011) which indicates the practice of unplanned and unsustainable exploitation of trees in the forest similar to the result of Alelign *et al.* (2007). The number of large old trees was absent and low in the disturbed area of my study, indicating the heavy removal of mature trees from this site. The low abundance of large and mature tree in the disturbed forests might have had adverse effects on tree natural regeneration due to the reduction in the number of seeds produced by the forest similar to the result of Singh *et al.* (1997).

5.3.2 Height Class Distribution

The bar graph of height of *Quercus semecarpifolia* shows that the tree of height class (5-9.9m) was highest and further the density decreased with increase in height in case of disturbed area but in undisturbed area, the density of tree of intermediate height was found to be high. The density of tree greater than 20m and less than 5m was lower in both the sites. These data revealed that the forests of the study sites are young and in growing stages similar to the result of Chikanbanjar *et al.* (2020) at Bhadaure Tamagi, Kaski District. Lacasia (2014) reported the results of the height class diagrams, that regeneration is continuous in the least degraded forest and almost completely absent in the disturbed forest, which may lead to the displacement of this species by other tree species in the future.

5.4 Regeneration and Environmental Factors

Quercus semecarpifolia natural regeneration showed no significant correlation with any of the site factors like organic matter content, soil pH, soil nutrients (N, P, K), canopy cover and litter depth, etc. The similar result was reported by Tashi (2004), in the old growth *Q. semecarpifolia* forest in western Bhutan and Tshering *et al.* (2015), in the dry lower Paro valley of western Bhutan. High number of regeneration density in disturbed area shows the evidence that *Q. semecarpifolia* regenerates well under canopy openness, thus corroborating findings of Gamble (1972), Vetaas (2000), and Dorji (2012). Shrestha (2003) has mentioned that seed germination depends strongly on the quality and thickness of litter and quality of light in Shivapuri National Park. Thick litter generally reduces the rates of germination and seedling establishment. Litter raking along with thick litter cover was found to deter regeneration and their survival. Lower regeneration of seedling was observed at distance near to the village where anthropogenic disturbances like lopping, slashing, grazing, etc. were observed. This result was different from the findings of Tripathi and Khan (1990) at upper Shillong in Meghalaya and Dzwonko and Gawronski (2002) at Wierzbanowka valley in the northern part of the Carpathian foothills (southern Poland) as they found high regeneration at distance near to the village where frequent litter raking and lopping were present. Seedling relationship with canopy was found to be positive but showed weak relationship (not significant). Seedlings under moderate canopy had high performance and increased canopy seems to facilitate a very dense herbaceous ground layer and a dense thicket of shrubs in very open sites (Vetaas, 1997). Competition with the sub-canopy shrubs and herbaceous vegetation may play an important role as suggested by several other studies (Lorimer *et al.,* 1994; Negi and Naithani, 1995; Crow, 1988). In contrast, Gaire *et al.* (2010) found the significant positive correlation between seedling density and sapling density with tree canopy cover. Metz (1997) hypothesized that Khasru cannot regenerate under its own canopy and needs severe disturbance for successful regeneration. In *Q. suber* and *Q. ilex*, seedling establishment and survival are improved under shade (Espelta *et al.,* 1995; Pausas *et al.,* 2009b; Smit *et al.,* 2009). However, it has been also shown that low light suppresses growth, that these specie establish 'seedling banks' under dense tree cover and that more open canopy conditions are required for saplings and trees to develop (Espelta *et al.,* 1995; Pausas *et al.,* 2009b).

5.5 Disturbance Index

The primary reason for the over-exploitation of Khasru oak is the demand for dry season fodder, but large branches with foliage are lopped for firewood as well. In private forests, trees are lopped for fodder once every two years, and sometimes even less often (Mathema, 1991). In community forests, however, heavy and indiscriminate lopping continues throughout the year (Shrestha and Paudel, 1996). The higher disturbance index in the buffer zone showed higher species richness while lower value in the national park showed lower species richness. This might be due to the moderately disturbed forest of buffer zone because the forest with moderate disturbance has high species richness and diversity. The regeneration was also better in moderately disturbed forest than undisturbed. Same result was also reported by Borah *et al.* (2012) in tropical forest of Barak valley of Assam, India. But the result was found to be contrasting with findings of Borah *et al.* (2014) and Borah and Garkoti (2011) where they found high species richness in undisturbed forest than disturbed forest.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATION

6.1 Conclusions

The forests studied both in national park and buffer zone were of mixed type. The major tree species observed were *Quercus semecarpifolia*, *Quercus lamellosa*, *Abies spectabilis* and *Prunus cerasoides*. Since *Quercus semecarpifolia* was found in all the studied plot, it is a dominant tree species within and outside the national park thus forming a dominating forest in both north and south aspects.

Density-diameter curve for *Quercus semecarpifolia* in the forest has positively skewed distribution pattern and fluctuating distribution pattern in national park and buffer zone respectively. The forest in national park had low tree mortality, lower removal of intermediate diameter class and high mortality of large canopy tree while the forest in buffer zone indicated the unplanned and unsustainable exploitation of tree species. The order of tree, young and juvenile of *Quercus semecarpifolia* was seedlings> saplings> trees for both national park and buffer zone has shown the regeneration was good in both areas. However, the better regeneration inside the national park compared to the buffer zone is the result of controlled human activities such as lopping, grazing, slashing, access track, litter collection, etc.

Soil parameters such as organic matter, pH, nutrients content in soil (N, P, and K), canopy cover and litter depth showed positive correlation with the seedling and sapling growth but the values were insignificant. This indicates that soil nutrient plays important role in the seedling and sapling growth and organic matter adds the soil where it supports the rooting during the germination. Beside that both the seedling and sapling showed positive correlation with the tree canopy but not significantly. Partially open canopy is better for growth of seedlings establishment as it provides more light needed for germination. The dense canopy restricts the light requirement to the ground level which inhibits seedling growth and high canopy openness promotes higher herbaceous species and thus increases the competition to the seedlings.

6.2 Recommendation

The natural regeneration of *Quercus semecarpifolia* is still very perplexing. Following recommendation have been suggested on the basis of the results of present study:

1. More experimental works are needed covering larger areas in LNP and its buffer zone to further supplement the result of present study.
2. Seasonal grazing by cattle, slashing, lopping, litter collection, etc. were the main causes of forest disturbance. Thus they should be controlled to provide better regeneration of tree species.
3. The relationship between canopy coverage and seedling recruitment density in the forest was positive. So moderate canopy cover should be maintained. Plans for seasonal tree lopping should be developed and implemented. Fodder tree seedling should be produced and distributed free of cost to the local communities to reduce the pressure on forests.
4. The DBH and height class distribution of trees in the forest near to the human settlement showed lower regeneration of *Quercus semecarpifolia* is a real problem. The forest had unplanned and unsustainable exploitation of tree species. If forest management laws and policies will not be adopted from now, the forest will be dominated by other less useful species for the local communities. Therefore, strong management practices need to be applied for the conservation of the *Quercus* forest in the buffer zone.
5. Plantation of seedlings of *Q. semecarpifolia* on barren and steppe area should be done in order to protect and increase its population.

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APPENDICES

Appendix 1: List of Tree Species Found in Study Area (National Park).

SN	**Scintific Names**	**Common Names**	**Famliy**
1	*Quercus semecarpifolia* Sm.	Khasru	Fagaceae
2	*Rhododendron arboreum* Sm.	Gurans	Ericaceae
3	*Elaeagnus umbellate* L.	Guelee	Elaeagnaceae
4	*Elaeocarpus ganitrus* Roxb.	Rudrakshya	Elaeocarpaceae
5	*Abies spectabilis* (D. Don) Spach	Gobre Salla	Pinaceae
6	*Lindera pulcherrima* (Nees) Benth. ex Hook. f.	Phusre	Lauraceae
7	*Quercus lamellosa* Sm.	Phalant	Fagaceae
8	*Ilex dipyrena* Wall.	Seto Khasru	Aquifoliaceae
9	*Prunus cerasoides* (D. Don)	Paiyu	Rosaceae

Appendix 2: List of Tree Species Found in Study Area (Buffer zone).

SN	**Scintific Names**	**Common Names**	**Famliy**
1	*Quercus semecarpifolia* Sm.	Khasru	Fagaceae
2	*Rhododendron arboreum* Sm.	Gurans	Ericaceae
3	*Elaeagnus umbellate* L.	Guelee	Elaeagnaceae
4	*Elaeocarpus ganitrus* Roxb.	Rudrakshya	Elaeocarpaceae
5	*Abies spectabilis* (D. Don) Spach	Gobre Salla	Pinaceae
6	*Lindera pulcherrima* (Nees) Benth. ex Hook. f.	Phusre	Lauraceae
7	*Quercus lamellosa* Sm.	Phalant	Fagaceae
8	*Ilex dipyrena* Wall.	Seto Khasru	Aquifoliaceae
9	*Prunus cerasoides* (D. Don)	Paiyu	Rosaceae
10	*Lyonia ovalifolia* (Nutt.)	Angeri	Ericaceae
11	*Cinnamomum glaucescens* (Nees) Mazz.	Sugandhakokila	Lauraceae
12	*Citrus* sp. L.		Rutaceae
13	*Maesa macrophylla* Wall. ex Roxb.	Paha Phal	Primulaceae
14	*Acer pectinatum* Wall. ex Pax.		Sapindaceae
15	*Myrica esculenta* (Buch.-Ham. Ex D. Don)	Kaphal	Myricaceae
16	*Mahonia nepaulensis* DC.	Jamane Mandro	Berberidaceae
17	*Alnus nepalensis* (D. Don)	Uttis	Betulaceae

Appendix 3: Important Value Index (IVI) of Tree Species in the Study Sites of National Park.

SN	Name of species	D (per ha)	RD (%)	F (%)	RF (%)	Do	RDo (%)	IVI
1	*Quercus semecarpifolia* Sm.	157.56	37.29	100	22.37	0.3	30.93	90.59
2	*Rhododendron arboreum* Sm.	77.99	18.46	68	15.21	0.05	5.15	38.82
3	*Elaeagnus umbellate* L.	54.91	12.99	60	13.42	0.03	3.09	29.51
4	*Elaeocarpus ganitrus* Roxb.	31.04	7.35	58	12.98	0.04	4.12	24.44
5	*Abies spectabilis* (D. Don) Spach	54.91	12.99	53	11.86	0.37	38.14	63.00
6	*Lindera pulcherrima* (Nees) Benth. ex Hook. f.	6.37	1.51	20	4.47	0.02	2.06	8.04
7	*Quercus lamellosa* Sm.	11.94	2.83	30	6.71	0.09	9.28	18.82
8	*Ilex dipyrena* Wall.	24.67	5.84	50	11.19	0.03	3.09	20.12
9	*Prunus cerasoides* (D. Don)	3.18	0.75	8	1.79	0.04	4.12	6.67
	Total	422.57	100.00	447	100.00	0.97	100.00	300.00

Appendix 4: Important Value Index (IVI) of Tree Species in the Study Sites of Buffer Zone.

SN	**Name of species**	**D (per ha)**	**RD (%)**	**F (%)**	**RF (%)**	**Do**	**Rdo (%)**	**IVI**
1	*Quercus semecarpifolia* Sm.	247.77	48.82	100	25.45	0.15	12.20	86.46
2	*Rhododendron arboreum* Sm.	68.82	13.56	78	19.85	0.06	4.88	38.28
3	*Elaeagnus umbellate* L.	24.09	4.75	49	12.47	0.05	4.07	21.28
4	*Elaeocarpus lanceifolia* L.	10.32	2.03	14	3.56	0.03	2.44	8.03
5	*Abies spectabilis* (D. Don) Spach	35.27	6.95	41	10.43	0.54	43.90	61.28
6	*Lindera pulcherrima* (Nees) Benth. ex Hook. f.	4.30	0.85	11	2.80	0.01	0.81	4.46
7	*Quercus lamellosa* Sm.	0.86	0.17	3	0.76	0.03	2.44	3.37
8	*Ilex dipyrena* Wall.	5.16	1.02	14	3.56	0.02	1.63	6.20
9	*Prunus cerasoides* (D. Don)	90.33	17.80	46	11.70	0.04	3.25	32.75
10	*Lyonia* ovalifolia (Nutt.)	3.44	0.68	5	1.27	0.09	7.32	9.27
11	*Cinnamomum glaucescens* (Nees) Mazz.	4.30	0.85	8	2.04	0.03	2.44	5.32
12	*Citrus* sp. L.	4.3	0.85	5	1.27	0.02	1.63	3.75
13	*Maesa macrophylla* Wall. ex Roxb.	2.58	0.51	5	1.27	0.02	1.63	3.41
14	*Acer pectinatum* Wall. ex Pax.	0.86	0.17	3	0.76	0.05	4.07	5.00
15	*Myrica esculenta* (Buch.-Ham. Ex D. Don)	1.72	0.34	5	1.27	0.03	2.44	4.05
16	*Mahonia nepaulensis* DC.	0.86	0.17	3	0.76	0.01	0.81	1.75
17	*Alnus nepalensis* (D. Don)	2.58	0.51	3	0.76	0.05	4.07	5.34
	Total	507.56	100.00	393	100.00	1.23	100.00	300.00

Appendix 5: Data Sheet for Vegetation Sampling.

Date: Name/Number of recorder:

Site: Transect No.: Plot No.: Quadrate No.:

Altitude: Slope: Aspect:

Latitude: Longitude:

Canopy Cover (%): 1= , 2= , 3= , 4= , 5=

Litter Depth (cm): No. of cut stumps: Forest type:

For trees (with ≥10 cm gbh) **(A/C to Borah *et al.* 2014)**

S. N.	Name of Species	DBH (cm)	Height (m)	S. N.	Name of Species	DBH (cm)	Height (m)
1.				11.			
2.				12.			
3.				13.			
4.				14.			
5.				15.			
6.				16.			
7.				17.			
8.				18.			
9.				19.			
10.				20.			

For Saplings (≥3 to <10 cm girth) **(A/C to Borah *et al.* 2014)**

S.N.	Name of Species	DBH (cm)	Height (m)	S.N.	Name of Species	DBH (cm)	Height (m)
1.				11.			
2.				12.			
3.				13.			
4.				14.			
5.				15.			
6.				16.			
7.				17.			
8.				18.			
9.				19.			
10.				20.			

For Seedlings (<3 cm girth) **(A/C to Borah *et al.* 2014)**

S.N.	Name of Species	Height (cm)	S.N.	Name of Species	Height (cm)
1.			11.		
2.			12.		
3.			13.		
4.			14.		
5.			15.		
6.			16.		
7.			17.		
8.			18.		
9.			19.		
10.			20.		

Appendix 6: Data Sheet for Disturbance.

Field Data Sheet for Disturbance study

Site: Transect No.: Plot No.:

Date: Field Personnel/Number:

Freshly Cut stems **Dead/Rotten Stems**

S.N.	Name of Species	Girth at Base(m)	S.N.	Name of Species	Girth at Base(m)
1.			1.		
2.			2.		
3.			3.		
4.			4.		
5.			5.		
6.			6.		
7.			7.		
8.			8.		
9.			9.		
10.			10.		

Lopped trees

S.N.	Name of Species	Number
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Disturbance by Fire

Recently Burnt: Burnt Past:

Intensity of Fire: 1) A 2) B 3) C 4) D

S.N.	Name of Species	Number
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Other Disturbances (within 10m radius of Plot)

S.N.	Disturbances		Remarks
1.	**ER**	Erosion	
2.	**AT**	Access Track	
3.	**CR**	Coppice Re-growth	
4.	**DR**	Drain	
5.	**RD**	Rubbish Dumping	
6.	**SL**	Slashing	
7.	**GR**	Grazing	
8.	**LC**	Litter Collection	
9.	**EA**	Earthworks	
10.	**BQ**	Burrow/Quarry Pit	
11.	**FB**	Fire Breaks	
12.	**Ot**	Others	

Note: Circle= Present (⬭);

Cross through= Absent (/)

Appendix 7: Litter Depth, Canopy Cover of the Forests and Organic Matter, pH, Nitrogen, Phosphorus and Potassium Content of Soil and Number of Seedling and Sapling.

Sites	Categories	Litter Depth (cm)	Canopy Cover (%)	OM (%)	pH	N (%)	P (kg/ha)	K (kg/ha)	Seedlings	Saplings
Sermathang	BZ	6.00	40.00	6.74	3.25	0.27	58.97	268	3	1
Sermathang	BZ	6.00	40.00	11.35	3.11	0.45	87.53	160.8	4	0
Sermathang	BZ	7.80	50.00	11.48	3.52	0.46	93.06	321.6	1	4
Sermathang	BZ	12.00	80.00	14.14	3.44	0.57	100.43	428.8	1	2
Sermathang	BZ	10.20	70.00	14.96	3.6	0.61	138.20	509.2	1	7
Sermathang	BZ	11.00	70.00	11.75	3.48	0.47	117.93	415.4	1	6
Sermathang	BZ	7.00	60.00	17.10	3.54	0.68	371.30	603	1	6
Sermathang	BZ	8.00	60.00	15.45	3.58	0.63	125.30	442.2	1	2
Sermathang	BZ	6.20	70.00	16.28	3.46	0.65	116.09	442.2	2	1
Sermathang	BZ	1.90	50.00	19.40	3.68	0.72	257.98	388.6	0	0
Kutumsang	BZ	10.00	60.00	15.70	3.68	0.63	549.12	388.6	2	2
Kutumsang	BZ	14.00	65.00	15.04	3.55	0.60	263.50	335.0	8	0
Kutumsang	BZ	15.00	50.00	20.32	4.03	0.81	168.61	455.6	1	0
Kutumsang	BZ	14.00	70.00	16.85	3.97	0.67	23.03	375.2	6	3
Kutumsang	BZ	7.50	75.00	10.90	3.68	0.44	161.24	321.6	4	3
Kutumsang	BZ	10.00	60.00	19.00	3.90	0.76	222.04	428.8	3	1
Kutumsang	BZ	2.00	40.00	10.74	3.01	0.43	85.68	214.4	2	1
Melamchighyang	BZ	11.00	80.00	10.90	3.83	0.44	69.10	268.0	0	0
Melamchighyang	BZ	9.00	50.00	12.23	3.82	0.49	200.85	294.8	0	0
Melamchighyang	BZ	9.00	55.00	15.37	3.57	0.61	117.01	227.8	4	0
Melamchighyang	BZ	11.00	60.00	11.57	3.71	0.46	96.74	201.0	1	1
Melamchighyang	BZ	13.00	70.00	13.55	3.40	0.54	183.35	308.2	1	2
Melamchighyang	BZ	12.00	75.00	16.03	3.84	0.64	197.17	388.6	0	2
Melamchighyang	BZ	18.00	70.00	8.10	3.58	0.32	35.93	160.8	0	0
Melamchighyang	BZ	5.00	65.00	20.98	3.65	0.84	59.89	134.0	4	9
Melamchighyang	BZ	5.00	60.00	12.72	3.77	0.51	133.59	281.4	0	2
Melamchighyang	BZ	3.00	60.00	17.68	3.94	0.71	155.71	482.4	10	0
Setighyang	BZ	7.00	60.00	12.01	4.06	0.48	75.55	375.2	1	0
Setighyang	BZ	7.00	60.00	11.61	3.84	0.44	248.76	428.8	1	0
Setighyang	BZ	4.00	40.00	14.63	4.15	0.61	72.79	536	0	0
Setighyang	BZ	6.00	40.00	14.63	3.8	0.59	66.34	268	0	0
Setighyang	BZ	4.00	60.00	12.35	3.89	0.47	69.10	442.2	1	0

Setighyang	BZ	6.00	70.00	11.08	3.95	0.44	49.75	294.8	2	1
Setighyang	BZ	6.00	40.00	9.81	4.13	0.39	70.94	388.6	0	0
Setighyang	BZ	5.00	80.00	11.55	4.18	0.46	33.17	348.4	1	1
Setighyang	BZ	5.00	70.00	15.45	4.01	0.60	68.18	455.6	0	3
Setighyang	BZ	9.00	75.00	20.55	3.93	0.82	94.90	683.4	1	2
Melamchighyang	NP	12.00	40.00	18.34	3.70	0.73	231.26	348.4	24	0
Melamchighyang	NP	8.00	40.00	17.84	3.61	0.71	185.19	201.0	2	0
Melamchighyang	NP	8.00	75.00	21.15	4.39	0.85	59.89	241.2	32	0
Melamchighyang	NP	2.00	40.00	14.54	4.18	0.58	116.09	522.6	0	0
Melamchighyang	NP	6.00	60.00	18.01	4.51	0.72	72.79	469.0	0	0
Melamchighyang	NP	6.00	80.00	12.72	3.87	0.51	103.19	294.8	1	0
Melamchighyang	NP	8.00	70.00	20.49	4.28	0.82	130.83	361.8	0	1
Melamchighyang	NP	5.00	75.00	13.38	4.05	0.54	58.97	201.0	0	0
Melamchighyang	NP	7.00	80.00	16.03	4.28	0.64	52.52	335.0	43	0
Melamchighyang	NP	5.00	80.00	15.53	3.99	0.62	77.39	254.6	32	0
Melamchighyang	NP	12.00	80.00	16.52	4.04	0.66	101.35	268.0	1	1
Melamchighyang	NP	8.00	60.00	19.83	3.80	0.79	152.02	388.6	1	0
Melamchighyang	NP	9.00	80.00	14.54	4.31	0.58	96.74	536.0	8	0
Melamchighyang	NP	9.00	60.00	20.32	3.98	0.81	76.47	388.6	4	1
Melamchighyang	NP	12.00	90.00	15.37	3.97	0.61	70.02	361.8	1	0
Melamchighyang	NP	8.00	80.00	25.11	3.94	1.00	112.40	321.6	3	0
Melamchighyang	NP	12.00	75.00	21.81	3.33	0.87	109.64	268.0	2	0
Melamchighyang	NP	20.00	70.00	21.31	3.56	0.85	131.75	482.4	0	0
Melamchighyang	NP	14.00	80.00	20.49	3.51	0.82	117.01	455.6	2	0
Melamchighyang	NP	8.00	80.00	20.82	4.08	0.83	76.47	335.0	5	4
Laghang	NP	8.00	70.00	12.75	3.85	0.52	63.57	308.2	0	0
Laghang	NP	11.00	40.00	6.94	3.73	0.31	60.81	214.4	0	1
Laghang	NP	3.00	20.00	16.57	3.58	0.64	109.64	589.6	0	0
Laghang	NP	8.00	40.00	5.87	3.94	0.24	65.42	268	3	0
Laghang	NP	6.00	40.00	11.95	4.03	0.48	254.29	670	0	0
Laghang	NP	12.00	80.00	20.78	3.99	0.76	121.62	576.2	5	4
Laghang	NP	6.00	80.00	12.82	3.95	0.51	38.70	308.2	0	1
Laghang	NP	13.00	80.00	19.86	4.2	0.69	357.48	763.8	3	3
Laghang	NP	10.00	80.00	12.55	3.9	0.49	35.93	214.4	6	0
Laghang	NP	10.00	75.00	12.48	4.1	0.52	129.91	576.2	3	0
Laghang	NP	12.00	80.00	16.61	3.99	0.66	191.64	174.2	0	2

Laghang	NP	9.00	85.00	15.29	3.72	0.61	166.76	388.6	0	0
Laghang	NP	6.00	50.00	11.51	3.98	0.46	85.68	308.2	4	1
Laghang	NP	5.00	40.00	13.15	4.31	0.53	134.52	348.4	6	2
Laghang	NP	8.00	60.00	10.19	3.90	0.41	84.76	308.2	2	0
Laghang	NP	7.00	40.00	12.82	3.94	0.51	84.76	428.8	8	2
Laghang	NP	11.00	80.00	16.77	4.1	0.64	84.76	643.2	0	0
Laghang	NP	14.00	80.00	12.08	3.89	0.48	61.73	603	0	1
Laghang	NP	4.00	60.00	18.91	3.95	0.76	123.46	522.6	5	2
Laghang	NP	8.00	70.00	19.73	3.97	0.78	152.02	522.6	2	0

Note: BZ= Buffer Zone and NP= National Park

Appendix 8: Disturbance Index (%)

Categories	No. of cut stumps	BA of Cut stumps (m2)	BA of Standing Stems (m2)	Disturbance index (%)
Buffer zone	6	1.59	76.7954	2.028
National Park	1	0.71	95.2692	0.738

Appendix 9: GPS Positioning of Plots and Localities.

Plot	Latitude	Longitude	Altitude (m)	Slope	Aspect	Locality	Categories
1	27.951	85.5897	2515	60°	165°	Sermathang	BZ1
2	27.9512	85.5897	2574	57°	160°	Sermathang	BZ2
3	27.9514	85.5906	2635	54°	207°	Sermathang	BZ3
4	27.9515	85.5908	2688	56°	273°	Sermathang	BZ4
5	27.9517	85.5911	2747	45°	226°	Sermathang	BZ5
6	27.9519	85.5917	2809	60°	252°	Sermathang	BZ6
7	27.9521	85.5919	2658	51°	222°	Sermathang	BZ7
8	27.9523	85.592	2713	48°	210°	Sermathang	BZ8
9	27.953	85.5922	2768	46°	254°	Sermathang	BZ9
10	27.953	85.5924	2823	60°	201°	Sermathang	BZ10
11	28.588	85.8064	2907	57°	280°	Kutumsang	BZ11
12	28.585	85.8044	2872	56°	272°	Kutumsang	BZ12
13	28.593	85.8044	2793	43°	207°	Kutumsang	BZ13
14	28.585	85.8058	2708	52°	253°	Kutumsang	BZ14
15	28.584	85.8042	2659	48°	249°	Kutumsang	BZ15
16	28.578	85.8011	2583	61°	247°	Kutumsang	BZ16
17	28.942	85.4783	2521	62°	149°	Kutumsang	BZ17
18	28.0316	85.5196	2795	38°	85°	Melamchighyang	BZ18
19	28.0315	85.52	2790	61°	108°	Melamchighyang	BZ19
20	28.0322	85.5214	2765	28°	90°	Melamchighyang	BZ20
21	28.0324	85.5216	2744	22°	85°	Melamchighyang	BZ21
22	28.0324	85.5224	2725	32°	108°	Melamchighyang	BZ22
23	28.0325	85.52338	2702	38°	110°	Melamchighyang	BZ23
24	28.033	85.5243	2634	38°	89°	Melamchighyang	BZ24
25	28.0237	85.5281	2646	28°	102°	Melamchighyang	BZ25
26	28.02345	85.52713	2625	32°	115°	Melamchighyang	BZ26
27	28.02348	85.52634	2501	38°	130°	Melamchighyang	BZ27
28	27.9881	85.5587	2776	36°	222°	Setighyang	BZ28
29	27.9873	85.5588	2721	28°	202°	Setighyang	BZ29
30	27.9862	85.5584	2680	29°	198°	Setighyang	BZ30
31	27.9853	85.5584	2637	24°	186°	Setighyang	BZ31
32	27.9846	85.5586	2592	36°	190°	Setighyang	BZ32
33	27.9838	85.55869	2553	36°	190°	Setighyang	BZ33
34	27.9824	85.5586	2392	40°	170°	Setighyang	BZ34
35	27.9886	85.5633	2895	33°	178°	Setighyang	BZ35
36	27.9877	85.56336	2840	26°	190°	Setighyang	BZ36
37	27.98683	85.56368	2805	24°	178°	Setighyang	BZ37
38	28.024	85.5254	2763	35°	145°	Melamchighyang	NP N1
39	28.0241	85.524	2811	28°	135°	Melamchighyang	NP N2
40	28.0238	85.5223	2862	32°	115°	Melamchighyang	NP N3
41	28.0243	85.5209	2894	24°	82°	Melamchighyang	NP N4
42	28.0233	85.517	2955	38°	153°	Melamchighyang	NP N5
43	28.0228	85.51678	2904	39°	145°	Melamchighyang	NP N6
44	28.0221	85.517	2856	26°	147°	Melamchighyang	NP N7
45	28.0217	85.5171	2820	36°	154°	Melamchighyang	NP N8

46	28.02087	85.51749	2755	34°	148°	Melamchighyang	NP N9
47	28.02043	85.51824	2709	38°	131°	Melamchighyang	NP N10
48	28.0082	85.5148	2689	32°	81°	Melamchighyang	NP N11
49	28.0084	85.515	2777	29°	96°	Melamchighyang	NP N12
50	28.0085	85.5161	2740	32°	88°	Melamchighyang	NP N13
51	28.0085	85.5168	2714	32°	79°	Melamchighyang	NP N14
52	28.0076	85.5176	2692	33°	61°	Melamchighyang	NP N15
53	28.0074	85.51842	2675	35°	65°	Melamchighyang	NP N16
54	28.0071	85.5193	2648	23°	55°	Melamchighyang	NP N17
55	28.0074	85.5115	2592	33°	75°	Melamchighyang	NP N18
56	28.0076	85.52245	2536	35°	70°	Melamchighyang	NP N19
57	28.00698	85.52316	2524	35°	72°	Melamchighyang	NP N20
58	28.0118	85.5846	2838	45°	100°	Laghang	NP L1
59	28.0115	85.586	2704	38°	102°	Laghang	NP L2
60	28.0112	85.5868	2660	28°	106°	Laghang	NP L3
61	28.0106	85.5874	2712	22°	98°	Laghang	NP L4
62	28.0106	85.5886	2697	26°	96°	Laghang	NP L5
63	28.0146	85.5857	2829	26°	108°	Laghang	NP L6
64	28.0143	85.5863	2820	38°	114°	Laghang	NP L7
65	28.0143	85.5871	2751	42°	96°	Laghang	NP L8
66	28.01415	85.58804	2595	44°	88°	Laghang	NP L9
67	28.01396	85.58885	2538	36°	97°	Laghang	NP L10
68	28.017592	85.589708	2586.5	52.5°	108°	Laghang	NP L11
69	28.017944	85.588778	2632.5	55°	110°	Laghang	NP L12
70	28.018308	85.588011	2663.5	56°	88°	Laghang	NP L13
71	28.018527	85.586906	2727.7	53.5°	102°	Laghang	NP L14
72	28.018513	85.585909	2790.8	46.5°	105°	Laghang	NP L15
73	28.01846	85.5851	2864.9	55°	112°	Laghang	NP L16
74	28.018416	85.583985	2956.7	50°	115°	Laghang	NP L17
75	28.02271	85.588531	2520.5	54°	120°	Laghang	NP L18
76	28.022772	85.587481	2583.5	52.5°	118°	Laghang	NP L19
77	28.022725	85.586451	2658.8	68°	115°	Laghang	NP L20

PHOTO PLATES

(a) Firewood Collected by the Local People from Buffer Zone of National Park

(b) Annual Forest Fire, a Major Problem of Seedling Establishment.

(c) A Newly Established Seedling of *Q. semecarpifolia*

(d) Rural Road Construction, a Major Cause of Habitat Loss.

(e) Location of Sampling Plot inside National Park.

(f) *Q. semecarpifolia* Forest outside the National Park.

(g) Unsustainably Harvested Firewood of *Quercus semecarpifolia* and *Rhododendron arboreum* Kept for Drying.

(h) Interacting with Local People