ASSESSING THE EFFECT OF TREE CANOPY OPENING IN THE REGENERATION LAYER OF TERAI SAL (*SHOREA ROBUSTA*) FOREST

(A Case Study from Buddhashanti Collaborative Forest of Nawalparasi District)

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DECLARATION

I hereby declare that this project paper entitled, **"Assessing the Effect of Tree Canopy Opening in The Regeneration Layer of Terai Sal (*Shorea robusta*) Forest"** is my own task except wherever acknowledged. I have not submitted it or any of its part to any other academic institutions for any degree.

…………………………..

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Table of Contents

DECLARATION....iii
LETTER of ACCEPTANCE....iv
Table of Contents....v
List of Figures....vii
List of Tables....vii
Acknowledgement....viii
ABSTRACT....ix
शेध-सार....x
Abbreviations....xi
Glossary of Terms....xii
CHAPTER: 1....1
INTRODUCTION....1
1.1. Background....1
1.2. Rational of the Study....2
1.3. Objectives....4
1.3.1. General Objective....4
1.3.2. The Specific Objectives of the Study are:....4
1.4. Limitation of the Study....4
CHAPTER: 2....5
LITERATURE REVIEW....5
2.1 Introduction to Sal....5
2.1.1 Distribution of Sal....5
2.1.2 Morphology....5
2.1.3 Systematic Classification of Sal (Shorea robusta)....6
2.1.4. Canopy Effects on Regeneration....7
2.1.5 Regeneration....10
CHAPTER: 3....13
METHODOLOGY....13
3.1 Research Frame work....13
3.2 Study Area....14
3.2.1 Area Selection....14
3.3 Data Collection....16
3.3.1 Primary Data Collection....16
3.3.1.1 Reconnaissance Survey....16
3.3.1.2 Inventory of the Forest....16
3.3.2. Secondary Data Collection....16
3.4 Data Analysis....17
3.4.1 Quantitative Analysis....17
3.4.1.1 Forest Diversity and Diversity Indices....17
A. Simpson's Diversity Indices....17
B. Shannon Diversity Index....18
3.4.1.2 Relative Density of Species....19
3.4.2 Test Statistics....19
CHAPTER: 4....20
RESULTS AND DISCUSSION....20
4.1. Assessment of the Regeneration Survey....20
4.2. Simpson's Diversity index....21

4.3. Shannon's diversity index and evenness……………………………………………22
4.4. Relative Density of Regeneration…………………………………………………..25
4.4.1. Crown cover 0-25%...25
4.4.1.2. Seedling……………………………………………………………….....25
4.4.1.2. Sapling…………………………………………………………………...25
4.4.2. Crown cover 25-50%...26
4.4.2.1 Sapling……………………………………………………………….....26
4.4.2.2. Seedling…………………………………………………………………26
4.4.3. Crown cover 50-75%...27
4.4.3.2. Sapling………………………………………………………………...27
4.4.3.3. Seedling…………………………………………………………………27
4.4.4. Crown cover 75-100%...28
4.4.4.1. Sapling……………………………………………………………….28
4.4.4.2. Seedling…………………………………………………..……...28
4.5. Test Statics….…………………………………………………………………29
CHAPTER: 5 …………………..………………………………………………………31
CONCLUSION AND RECOMMENDATION……………………………………………...31
5.1. Conclusion……………………………………………………………………32
5.2. Recommendation……………………………………………………………...33
REFERENCES………………………………………………………………………......34
Appendix -1: List of Major Tree species found in sampled Plot…………………………......38
Appendix-2: Photo plate………………………………………………………………...39

List of Figures

Figure 1: Research Methodology framework 13
Figure 2: Map of Study Area 15
Figure 3: Summary of Regeneration stock per hector 20
Figure 4: line graph of Simpson’s Diversity index 22
Figure 5: line graph of Shannon’s Diversity index 23
Figure 6: line graph of Shannon’s Evenness index 23
Figure 7: Relative density of sapling in 0-25% crown cover 25
Figure 8: Relative density of seedling in 0-25% crown cover 25
Figure 9: Relative density of sapling in 20-50% crown cover 26
Figure 10: Relative density of seedling in 25-50% crown cover 26
Figure 11: Relative density of sapling in 50-75% crown cover 27
Figure 12: Relative density of seedling in 50-75% crown cover 27
Figure 13: Relative density of sapling in 75-100% crown cover 28
Figure 14: Relative density of seedling in 75-100% crown cover 28
Figure 15: Scatter plot diagram of crown cover Vs. Regeneration stock 29

List of Tables

Table 1: Regeneration Stock per ha of Study Area 20
Table 2: Simpson's diversity index of forest 21
Table 3: Shannon's diversity index and evenness 22
Table 4: Correlation test between crown cover and regeneration per hector. 29

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ABSTRACT

The effect of tree canopy opening in the regeneration layer of Sal (Shorea robusta) were investigated in four strata of forest viz. 0-25, 25-50, 50-75 and 75-100 percentage crown cover vegetation in Shorea robusta forests in Nawalparasi. Regeneration survey was carried in two blocks each of 10 hector, where one block was silviculturally operated with irregular shelter-wood system and another was undisturbed. The seedling density of Sal (shorea robusta,) is higher in the 0-25 and 25-50 percentage crown cover than others two strata. Likewise, sapling density was also higher in the 0-25 and 25-50 percentage crown cover than dense strata. The Simpson index, Shannon diversity index, and Shannon's Evenness, of the seedlings were increasing with increase in crown cover percentage which indicate less diversity in open crown cover due to dominance of sal regeneration. Crown cover percentage was found negatively correlated with regeneration stock per hectare. The study shows that, open strata maintain seedling density, favor regeneration of Sal forests and regeneration of Sal dependent to the intensity of light and suitable condition for germination. Opening of crown directly provide sunlight on land surface which helps in germination of Sal.

Keywords: Sal, Regeneration, Crown Cover; Species Diversity, Diversity Index.

शेध-सार

सालको पुनरुत्पादन तहमा छत्र घनत्वले पार्ने प्रभाब अध्ययनका लागी छत्र घनत्वलाई चार भागमा बर्गिकरण गरेर (जस्मा छत्र धनत्व ०-२५, २५-५०, ५०-७५, ७५-१०० प्रतिसत) नवलपरासीको वनमा अनुसन्धान गरियो । प्रत्यक दस हेक्टरको दुइवटा खण्डमा पुनरुत्पादन सर्बेक्षण गरियो जसमध्य एउटामा वन सम्बर्धन प्रणाली अनियमीत आस्रय काठ प्रणाली लागु गरिएको थियो भने अर्को खण्ड प्राकृकि अबस्थामा थियो । सालको पुनरुत्पादन छत्र प्रतिसत ०-२५ र २५-५० मा उच्च रहेको भेटियो । Simpson's सुचाङ्क, Shannon's सुचाङ्क , Shannon's Evenness क्रमश छत्र धनत्व बढ्दै जादा बढ्दै गएको पाइयो, जसले कम छत्र प्रतिसतमा बनस्पती बिभिधता कम र साल को पुनरुत्पादन घनत्व बढि भएको पाइयो । छत्र प्रतिसत बढ्दै जादा सालको पुनरुत्पादन घट्दै गएकोले छत्र प्रतिस र पुनरुत्पादनको बिचमा ब्युत्क्रमानुपातिक अन्तरसंबन्ध देखियो

सारास्समाः सालको पुनरुत्पादनको लागी सूर्यको प्रकास र अनुकुल वातावरण राम्रा हुने भएकाले राम्रो पुनरुत्पादनको लागी छत्र प्रतिसत कम राख्दा राम्रो हुने देखियो ।

मुख्य शब्दहरु : साल, छत्र प्रतिसत, पुनरुत्पादन, प्रजाती बिभिधता, बिभिधता सुचाङ्क ।

Abbreviations

AFO	Assistant Forest Officer
CFM	Collaborative Forest Management
DoF	Department of Forest
DFO	District Forest Office/District Forest Officer
DFOP	District Forest Operational Plan
DFRS	Department of Forest Research and Survey
OFMP	Operational Forest Management Plan
RD	Relative Density
SPSS	Statistical Package for Social Science
TISC	Tree Improvement and Silvicultue Component
BCFM	Buddhashanti collaborative forest management

Glossary of Terms

Bhabar: The outwash zone at the base of the Churia Mountains, often with very boundary soils in which many streams disappear underground.

Biodiversity: The biological diversity of plants, animals, and other living organisms in all their forms and levels of organization, including the biological diversity of genes, species, and ecosystems.

Canopy: The more or less continuous cover of branches and foliage formed collectively by the crowns of adjacent tree

Canopy closure The progressive reduction of space between crowns as they spread laterally, increasing canopy cover. The point in time when crown in a young stand begin to touch and interact.

Churia: Topography of small mountains adjoining to Bhabar at south. It is soft, weak, erodable and composed of bedded stone and crystalline rocks.

Climax forest: A forest community that represents the final stage of natural forest succession for its environment.

Collaborative Forest Management (CFM): part of national forest managed with sharing of responsibilities or investments among government, close and distant users, local government (such as protection, land development, silvicultural operations, etc.) and sharing of rights or benefits

Community Forestry: A situation, which intimately involves local people in forestry activities.

Ecosystem: A functional unit consisting of all the living organisms (plants, animals, and microbes) in a given area, and all the non-living physical and chemical factors of their environment, linked together through nutrient cycling and energy flow. An ecosystem can be of any size—a log, pond, field, forest, or the earth's biosphere—but it always functions as a whole unit. Ecosystems are commonly described according to the major type of vegetation (e.g., forest ecosystem, old-growth ecosystem, or range ecosystem).

Forest: All land with a forest cover, i.e. with trees whose crown cover more than 10% of the area, and not used for purposes other than forestry.

Forest inventory: A survey of a forest area to determine such data as area, condition, timber, volume, and species for specific purposes such as planning, purchase, evaluation, management, or harvesting."

Gap dynamics: The change in space and time in the pattern, frequency, size, and successional processes of forest canopy gaps caused by the fall or death of one or more canopy trees.

Inner Terai: The plain land between the mid hills and plain region (Terai).

.**Non-timber forest products**: Any commodity obtained from the forest that does not necessitate harvesting trees. It includes game animals, fur-bearers, nuts and seeds, berries, mushrooms, oils, foliage, medicinal plants, peat, fuel wood, forage, etc.

Old-growth forest: A forest that contains live and dead trees of various sizes, species, composition, and age class structure. Old-growth forests, as part of a slowly changing but dynamic ecosystem, include climax forests but not sub-climax or mid-seral forests. The age and structure of old growth varies significantly by forest type and from one biogeoclimatic zone to another.

Opening: An area denuded of trees due to harvesting, insects, disease, fire, wind, flooding, landslide, or any other similar events.

Operational Plan: Operational Plan is a written document aiming at managing the forest resources in a scientific and sustained basis trough a management agreement between the DFO and community in which terms and conditions are laid out.

Over storey: The uppermost continuous layer of a vegetation cover; for example, the tree canopy in a forest ecosystem or the uppermost layer of a shrub stand.

Pole: Refers to middle aged plants with the dimension of 10-29.9 cm DBH.

Preferred species: Those species those are ecologically suited to the site. Management activities are primarily aimed at establishing preferred species. The characteristics of these species are consistent with the desired timber and non-timber objectives for the opening."

Regeneration: "The act of renewing tree cover by establishing young trees naturally (natural seeding, coppice, or root suckers) or artificially (direct seeding or planting). Regeneration usually maintains the same forest type and is done promptly after the previous stand or forest was removed.

Regeneration survey: Carried out to determine the initial restocking of a site. It is used to describe the number of trees on a site that have reached acceptable standards.

Sapling: The stage of tree development in between the seedling and the pole stage. Saplings are typically 1–2 m tall and 2–4 cm in diameter, with vigorous growth, no loose, dead bark, and few (if any) dead branches.

Seedling: Small plants of height > 1 feet and DBH < 4 cm.

Shrub: Same as forest but well-defined stems can not be found.

Silviculture: The art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet the diverse needs and values of landowners and society on a sustainable basis."

Stand density: A quantitative measure of tree cover on an area in terms of biomass, crown closure, number of trees, basal area, volume, or weight. In this context, "tree cover" includes seedlings and saplings; hence the concept carries no connotation of a particular age. Often described in terms of stems per hectare.

Tree: Big sized plants having dimension of ≥ 30 cm DBH.

Understorey: The lower level of vegetation in a forest. Usually formed by ground vegetation (mosses, herbs and lichens), herbs and shrubs, but may also include subdominant trees.

CHAPTER: 1

INTRODUCTION

1.1 Background

Nepal has over 35 major forest types ranging from tropical to alpine forests. The tropical forests, confined within the Terai region (southern part), are composed of Sal (*Shorea robusta*) and its associates. Sal is the main tree species in terms of total volume with 28.2% of the country's total volume, which dominates the tropical and lower sub-tropical zone. The majority of Sal forest is distributed in the Terai, Inner Terai, and Bhabar zone of the country.

In addition, the species has ecologically important timber characteristics and economically important timber species of Nepal. The species is viewed as a climax (Climatic, edaphic or bio-edaphic) formation throughout and also capable to colonize new areas with heavy growth of seedlings. However, it prefers the Bhabar region and the alluvium of Terai where water logging does not happen.

Certain local variations become apparent between the western and eastern Nepal forest type as a result of various factors especially those of differences in precipitation (Forest and Vegetation Types of Nepal, TISC Document Series No.105, 2002, NARMSAP). This is better indicated by the associated species of *Dillenia*. In the eastern Terai, Sal is associated with *Dillenia indica* while, in the central Terai, it is replaced with *D. pentagyna*. In western Nepal, the forest is dry and *Dillenia* is not as frequent, however, *Butea frondosa* is found more often as an associated species (Forest and Vegetation Types of Nepal, TISC Document Series No.105, 2002, NARMSAP).

All the Sal forests are natural. Due to the rapidly increasing population and a high demand for forest products, the Sal forests are being destroyed. The future of tropical forests has been a major environmental concern. The conventional view is that tropical forests should be protected against utilization, the felling of tropical timber species such as Sal in Nepal should be stopped and, since any human interference reduces biodiversity, but Sapkota I. P.(2009) concluded that forests subjected to moderate level of disturbance maintained species diversity and enhanced regeneration performance, which in turn was coupled with the regeneration strategy of dominant tree species in line with the Intermediate Disturbance and Recruitment Limitation Hypotheses. He also concluded that the moderate level of disturbance may be touted as a management tool for Sal forests.

During the past decades, the forest policy of Nepal has emphasized the protection of forests. For instance, a green tree felling ban imposed strictly. This has lead to passive management, producing over mature forests that degrade and eventually disappear. Almost half of the standing volume consists of Sal, an indigenous tree species with good regeneration, fast growth and a high value (FRISP, 1993, Rautiainen, 1994).

The natural growth of Sal has been considered to be a slow, yet unpredictable process. Regeneration of this species normally divided in to two phases: recruitment phase and established phase. As mentioned above the main tropical timber species of Nepal's Terai is Sal, which suffers from the die-back phenomena. Die-back is the phenomenon linked to the recruitment phase. The shoot dies annually due to unfavorable growing conditions, but the root remains alive and continues to send up new shoots each year until, eventually, a very strong shoot stock develops producing a shoot continues to grow and forms a tree (Rautiainen, 1996). Some seedlings die during the rainy season, some during the winter and yet some other during the summer (Khanna, 1984). Ultimately, the dying back affects the growth rate of Sal and it takes some time 40 years to establish. However, this annual die-back is by no means universal, and under good condition the seedlings will produce a shoot which will continue to grow without dying back (Jackson, 1994). The establishment period of Sal in India working plan is 32 years. In Nepal conditions are more favorable than Indian condition and establishment period considered being 10 years (Amatya et al., 1995).

1.2.Rational of the Study

Sal (*shorea robusta)* is the main tropical species growing widely and occupies the largest area of forest in lowland (Terai) region of Nepal. It is a major commercial timber species. Tropical Sal forests have been heavily exploited either to collect the revenue or to meet the forest product demand of people and resettlement. Moreover, Sal forest is converting into agriculture land, since it is in accessible area.

Sal is the light demander climax species which requires the full sunlight but some side shade to establish the regeneration in natural state. Well-established regeneration is the first step for successful management of forest. The future of the tropical forest has been a major environmental concern. The conventional view is that tropical forests should be protected against utilization, the felling of tropical timber species such as Sal in Nepal should be stopped and, since any human interference reduces biodiversity, the best alternative is to try to keep the forest as they are now. According to Budhathoki, 1995, 80 % of the Terai forests are Sal they are rich pocket of biodiversity. If Sal alone is protected at the cost of others, the biodiversity balance may be upset.

The artificial regeneration of Sal is difficult and slow growing than the natural regeneration. Natural regeneration comes out every year but not reach the established stage. The dying back is the main problems to establish the Sal seedlings. The canopy opening is another problem of Sal seedling for establishment.

Regeneration processes in gaps depend on a range of biological factors, such as the life history, physiology and behavior of regenerating species (Lawes et al. 2007); the intensity of the growth of advanced regeneration of predisturbance origin and the colonizing ability of species (Arriaga 2000). It is also not clear if gap disturbance regimes and regeneration processes in Sal forests are similar to those in tropical and temperate forests (Barik et al. 1992). In addition, selective logging of dead and diseased trees, a traditional management strategy in Nepal, has been in practice since the inception of local timber trade, which in turn results in formation of gaps in this forest type. Moreover, issues about conservation of biological diversity in Nepalese old-growth seasonally dry Sal forests have also been realized and substantial researches on forest management practices have been required.

Furthermore, selective logging in Nepalese Sal forests results in frequent gap formation (Sapkota et al. 2009), at rates similar to those observed in India (Chandrashekara and Ramakrishnan 1993, 1994) and Malaysia (Okuda et al. 2003). However, tree regeneration processes in these artificially created gaps have not been studied in Nepalese Sal forests (Sapkota et al.2009). Therefore, there is a need for more knowledge of the gap dynamics in order to predict future trajectories of species composition and stand structure and to optimize silvicultural strategies for the Nepalese Sal forests, which have been selectively and unsystematically logged for a long time, with too little awareness of the potential consequences.

1.3 Objectives

1.3.1 General Objective

- ❖ To assess the effects of tree canopy opening in the regeneration layer of terai Sal (*Shorea robusta*) forest.

1.3.2 The Specific Objectives of the Study are:

- ❖ To assess the relationship between canopy opening and plant species density at regeneration level.
- ❖ To analyze the regeneration status of *Shorea robusta* after canopy opening.
- ❖ To analyze the regeneration diversity and correlation in open and closed canopy area.

1.4 Limitation of the Study

- ❖ The finding of this research are based on case study and don't necessarily represents the regional or national scenario but the findings can be used as baseline for similar type of forest for further research.
- ❖ The study area was too small.
- ❖ Although maintaining high accuracy in the field some error may arise due to human error.

CHAPTER: 2

LITERATURE REVIEW

2.1 Introduction to Sal (*Shorea robusta*)

2.1.1 Distribution of Sal

Sal (*Shorea robusta*) is one of the most important species from commercial and ecological point of view. It is large genus, having about 103 (Troup, 1980) described species but Symington described there may be 167 species in existence. It is widely distributed from Nepal, Sri Lanka and India on the west through Burma and other countries of South-East Asia, up to the Philippines (Troup R.S., 1980). In Nepal, Sal (*Shorea robusta*) is most famous species for the utilization purposes.

Sal (*Shorea robusta*) forest is dominant in the Bhabar Terai, except in area of very high rainfall, where it is replaced by mixed forest, and along streams. It also covers most of the Siwalik Hills, and the duns between them. Along river valleys it penetrates deep into the midlands, along the lower slopes of the hills, sometimes up to 80 km from the plains. Its maximum altitude is about 1500 m, but it is not common above 100 m. A number of different types of *Shorea robusta* forest have been distinguished; Dobremez (1976) lists nine, and Champion and Seth (1968a) more, many of which can be expected to be found in Nepal. However for the present purpose it is sufficient, following Stainton (1972), to distinguish the Bhabar Terai and Terai *S. robusta* forests from the hill *S. robusta* forest which includes the forest along river valleys in the midlands. In the former the trees are much larger and the species composition richer, while in the latter the trees rarely exceed 15 m in height. At its upper limits it is replaced by *Pinus roxburghii* or Schima-Castanopsis forests.

2.1.2 Morphology

Sal is moderate to slow growing tree, which can grow up to 30-35 m tall, with a trunk diameter of up to 2-2.5 m. The bark of the young tree is smooth with a few long deep and vertical furrows. The leaves are ovate-oblong, 10-25 cm long and 5-15 cm broad. In wetter areas, it is evergreen; in drier areas, it is dry-season deciduous, shedding most of the leaves in between February to April, leafing out again in April and May. The Sal flowers, whitish in color, appear in early summer. These are borne in raceme-like panicles in leaf axils, covered with white pubescence. Sal is one of the most important sources of hardwood timber in Nepal, with hard, coarse-grained wood that is light in colour when freshly cut, and becoming dark brown with exposure. The wood is resinous and durable, and is sought after for construction, although not well suited to planning and polishing.

2.1.3 Systematic Classification of Sal (*Shorea robusta*)

Domain: Eukaryota - Whittaker & Margulis,1978 - eukaryotes

Kingdom*:* Plantae - Haeckel, 1866 - Plants

Subkingdom: Viridaeplantae - Cavalier-Smith, 1981

Phylum: Tracheophyta - Sinnott, 1935 Ex Cavalier-Smith, 1998 - Vascular Plants

Subphylum: Euphyllophytina

Infraphylum: Radiatopses - Kenrick & Crane, 1997

Class: Magnoliopsida - Brongniart, 1843 - Dicotyledons

Subclass: Dilleniidae - Takhtajan, 1967

Superorder: Malvanae - Takhtajan, 1967

Order: Clusiales - Dumortier, 1829

Family: Dipterocarpaceae

Tribe: Shoreae

Genus: Shorea - Roxburgh ex C. F. Gaertner, Suppl. Carp. 47. 1805. - Shorea

Specific epithet: *robusta* - C. F. Gaertner, Suppl. Carp. 48. 1805.

Botanical name: - *Shorea robusta* C. F. Gaertn.

Dipterocarps demand partial shade between the germination and pole stages, while they require increasing amounts of light as they mature (Mauricio 1985). Therefore, the natural regeneration of Dipterocarps is likely to be most efficient in relatively small gap environments, which provide partial light and wind shelter (Tuomela et al.1996).

Sal (*Shorea robusta*) is a dominant species of the Dipterocarpaceae family in Nepal and dominant in the Terai, Bhabar, Siwalik Hills and Duns, and along the lower slopes of the middle hills in Nepal (TISC 2004; Shrestha 1992). Indigenous Sal forests are well adapted to Terai condition. Sal forests occur at elevations up to 1500 m above sea level (Lamprecht 1989). Sal also grows well even on poor and porous soils with a low water table, which are common in the Terai.

2.1.4. Canopy Effects on Regeneration

Light is the very important factors in seedling establishment but its requirement varies from species to species and climatic condition and age. Natural regeneration of species can be obtained by the judicious opening of the canopy to admit sufficient light to enable the regeneration to come up (Khanna, 1984).

Sal is a light demander and climax species that tends to dominate mature stands if there is no human interference. The natural regeneration of Sal is divided into two phases: recruitment phase and established phase. Sal has an enormous regeneration capacity under suitable conditions. Natural regeneration is the only relevant regeneration method for Sal (Joshi et. al., 1995). Best development is where there is full overhead light but light side shade. Khanna (1984), states that Sal is able to persist under moderate shade but its best development is obtained by admission of complete overhead light from the earliest stage.

Champion and Seth (1968) stated that Sal when grown in open starts to produce seed in about 15 years, but in closed crops flowering typically commences much later and is restricted in amount even in trees with good crowns, till height growth is largely finished. It was already proved 75 years ago, that in heavy shade and dense undergrowth seedlings continued die-back and die-off. If not causing die-back or die-off, dense canopy and middle storey cause stagnation in seedling growth, so opening up of top canopy and middle storey promote seedling growth better. The development of taproot under natural conditions in shade is much slower than in those grown in open (Troup R.S., 1980). Root lengths were 35.8 and 53.1 cm in two plots in the open, as against 11.9 and 18.5 cm in two plots in the shade, indicating that the vigorous growth of seedlings could be obtained by the complete removal of the overhead canopy (Troup, 1986). Similar differences of growth performances were recorded in Nepal Terai (Suoheimo, 1999).Thick weed growth resulting from opening of canopy tend to swamp the seedlings. The other effect of the weed to shut off light from the seedlings and to reduce their growing space

In the proceeding of XI Silvicultural Conference (1967), Seth had given that, a fairly heavy opening up of the top canopy, retaining 0.5 to 0.6 of it and felling the rest is most beneficial to seedling growth in the first stage; at that time retained only a few light-crowned species, removing the middle storey (Troup, R.P., 1980).

In very moist Eastern Bhabar and Terai types of Sal forests experiments have shown that spacing of top canopy trees at 27m × 27m to 37m to 37m gives significantly the best survival of Sal recruitment (Rajkhowa, 1964).

Qureshi, I.M. et al. (1967) stated that it is therefore essential that good light conditions should be maintain during cultural operations (Soil working and weeding) in order to get best results. They also stated that height increment is maximum in the open and the survivals & establishment are also closely related to the initial number of seedlings and the optimal spacing on the limited area where the seeds fell and germinated (Proceedings of the Eleventh Silvicultural Conference, Volume-II, 1967).

Regeneration also heavily depends on physical gap characteristics. Many authors have proposed gap size to be the most important gap characteristic affecting the recruitment and establishment of various tree species (Brokaw 1985; Li et al. 2005), but it is not the only gap characteristic affecting their establishment (Chandrashekara and Ramakrishnan 1994; Lima and Moura 2008).

Gautam and Devoe (2006) states ecological issues of Sal forest management are related to light (opening of the canopy). Khan et al. (1986) found higher survival and better growth of seedlings in the forest periphery than under dense canopy, signifying the role of light in forest regeneration and early growth. Light is thus very important in the development of Sal stands. Light plays mainly two roles, increasing photosynthesis and ground temperature, which accelerates litter decomposition.

Regeneration processes in gaps depend on several physical and biological factors involving canopy closure, intensive growth of advanced regeneration of pre-disturbance origin, and species colonization (Arriaga 2000). The prevailing regeneration strategy following a tree fall, including seed rain, seed bank, suppressed seedlings and saplings, vegetative regeneration, or lateral growth of peripheral trees, depends heavily upon the characteristics of gaps and disturbed areas (Runkle 1985; Lawton and Putz 1988; Brokaw and Scheiner 1989; Arriaga 2000).

Sapkota et al. (2009) concluded that moderate disturbance intensity not only ensures high stand density, but also enhances the advanced regeneration of socio- economically important tree species and affects their dispersion patterns. Future management strategy must balance the consumptive needs of the local community with those of species conservation by allowing regulated access to the forests (Spatial distribution, advanced regeneration and stand structure of Nepalese Sal *(Shorea robusta)* forests subject to disturbances of different intensities).

Sal forests are relatively rich in floral diversity (Gautam & Devoe, 2006). Besides trees and shrubs, the ground flora of Sal forests comprises ferns, herbs, grasses and liana species (Maithani, Sharma & Bahuguna, 1989; Gautam & Devoe, 2006), which vary in abundance between different forests (Cited in Sapkota, I.P, 2009. Species Diversity, Regeneration and Early Growth of Sal Forests in Nepal: Responses to Inherent Disturbance Regimes.)

Sapkota et al. (2009) concluded that stem density of tree and shrub components is higher in the gap than in the intact vegetation. Seedling densities of *S. robusta* and *Terminalia alata* (*B. Heyne ex Roth.*) are higher in the gap than in the intact vegetation. Gap size can explain species richness and species establishment rate. Gaps created by multiple tree falls in different years have higher seedling density of *S. robusta* than gaps created by single and/or multiple trees falls in the same year. Gap maintains species diversity by increasing seedling density, and favor regeneration of Sal forests. Gap size, other gap attributes also affect species diversity and regeneration. Lower the seedling growth and regeneration when larger trees are present around the gap while making the small gaps may natural regeneration and the early stimulation of seedling growth.

The importance of natural disturbance in shaping landscapes and influevcing ecosystem is now well reconized in ecology of forestry (Muscolo A. et. Al 2014). Disturbance, defined as "any relatively discrete event in time that disrupts ecosystem, community or population structure and change resources, substrate availability, or the physical environment" (White and Pickett 1985), plays an important role all natural ecosystems. Both small scale (death of one or few trees) and large- scale disturbances (fires, wind stroms, insect outbreaks and others) can creat gap in forest canopies that are often ideal locations and conditions for rapid plant reproduction and growth. Perhaps the most thoroughly studied impact of gap formation is how increased light helps to maintain floristic richness. Denslow (1987) theorized that the rich species diversity in tropical systems exists because each species is competitively superior for a portion of its life. Since most trees have long life spans, they exist in variety of microenvironments as they grow. The death of a nearby tree dramatically changes light, temperature, soil moisture and available nutrients. These conditions will favor some species, but not all. As the gap is filled, the microclimate and nutrient status return to pre-disturbance levels and the resulting conditions will tend to favor a different suite of species. If a growing tree is competitively superior for a portion of its life, it will persist (Denslow 1987; Wright 2002).

The immediate and perhaps greatest effect of canopy opening is an increase in duration and intensity of direct sunlight to lower strata of forest. The amount of solar radiation received by the gap depend on gap size, shape and orientation, local topography and the height of the surrounding forest (Denslow, 1987). The light environment is one of the factors, which affect natural reheneration and germination of seed. Natural disturbance to the forest canopies creat broad varieties of opportunities for the growth of nearby plant and establishment of new ones, largely by increasing the amount of light penetrating into the forest interior (Lawton, 1990).

Increase in canopy gaps results is expected to benefit tree seedling survival and growth, but it can also increase cover of non-tree understory vegetation (Collins et al.,1985). This in turn can reduce the survival and growth of seedlings and saplings (Romagosa and Robinson, 2003) vai competition for light and soil resources (Randall, 2007). The understory vegetation did not seem to have a marked effect (Adili et al., 2009)

2.1.5 Regeneration.

Seedling bank, or "regeneration", is a reproductive strategy used by species adopted to environments in which opportunities for recruitment are infrequent (Grime, 1979). The term regeneration refers to the process including production, dispersal and germination of tree seeds and the subsequent establishment of seedlings. The vegetative re-growth or sprouting following death of above ground portions of mature trees can also be termed regeneration. It may be promoted by certain types of forest manipulation that can lead intentionally to new and more productive stages of forest growth. Because of its importance to forest management, the dynamics of regeneration after exploitation has recovered particular attention (Bazzaz, 1991). The natural regeneration of forest in forest ecosystem is fundamental for evoulation (ackzel,1994). The rate of establishment of the diversity, distribution and composition of the regeneration depends on many factors.

Natural regeneration is the process of re-growing or reproducing of plants by their juvenile and this is the main process a forester can influence to maintain the dynamics of forest stands and to preserve the genetic characteristics of local tree populations. Forest regeneration will guarantee its future to provide wood and the other forest services continuously. Thus, we need a permanent and suitable productivity in forests. Therefore, having enough knowledge and study about forestry characteristics about different species of trees in order to guarantee forest's natural regeneration is essential (Mousavi et al., 2010). Population structure, characterized by the presence of sufficient population of seedlings, saplings and young trees indicate a successful regeneration of forest species (saxena et al., 1984). Different environmental factors may determine seed germination, although the essential are inappropriate combination of temperature, moisture and light (Mayer and Poljakoff-Mayber, 1989; Bewley and Black, 1994; Baskin and Baskin, 1998). In addition, the chemical environment surrounding the seed must be suitable (Karessenand Hilhorst, 1992), and the presence of allele-chemicals inhibitors released by the surrounding vegetation may also determine germination success (Rice, 1984; friedman, 1995)

As canopy trees are large and long-lived, they can substantially influence environmental conditions in the understory (Boettcher and Kalisz, 1990), thus determine pattern of seedling regeneration beneath them (Pacala et al., 1994). The study by Shrestha et al., (2007) in Trans-Himalayan dry valley of central Nepal shows that *Betula utilis* seedling could not thrive under closed *Betula* canopy even if seed produced were viable. Different mortality among species in seedling bank strongly influences future stand composition (Clark et al., 1999), so it is useful to identify the biotic and abiotic determinants of seedling density and distribution (Rooney et al., 2002)

Regeneration involves both the physiological development, which are inherited (genetic), as well as external ecological factors such as interactions with other plant and animals, climate and disturbances like fire or landslide (price et al., 2001). Seed production of a tree is related to species, age ,size, vigor and seed mast years of the parent tree, whereas long distance dispersal and germination of seeds are largely stochastic process (as opposed to deterministic processes) such as wind speed or animal moments (Price et al., 2001). As the gap size in the canopy becomes larger, the local microclimate is altered further, making it suitable for some pioneer and light depending species. Low quality organic matter results in low mineralization rates, keeping the quality of available nitrogen consistently low (Riley, 2001). Herbivores have strong influenced on survival of seedlings (Grubb, 1977).

Seed dispersal, may increase seed and seedling survival by carrying seeds to better habitats (Schupp, 1988). After germination avability of soil moisture, nutrient, and light affect seedling growth (Walters and Reich 1997), survival (Caspersen and Kobe, 2001), and species richness (Tubbs, 1977; Runkle, 1982). Ghimire and Lekhak (2007) in upper Manang found that the plots with high soil moisture have large number of seedling because maximum moist condition always promotes photosynthesis, which ultimately influences all eco-physiological process of species (Bhattarai and Vetaas, 2003). Panthi et al., (2007), found that moisture and factors influencing evaporation (i.e. canopy and aspects) are the main environment factor impacting plant species richness and composition in Trans- Himilayan inner valley of Manang district.

Future forest structure and composition are strongly influenced by current recruitment patterns, which depends on the interactions between stand composition and seedling regeneration will determine the long-term dynamics of the forest community (Connell and Slatyer, 1977). The altitude and aspect play a key role in determining the temorature regime and atmospheric pressure of any site. Within one altitude the cofavtors like topography, aspect, inclination of slope and soil type affect the forest composition (Shank and Noorie, 1950). The microenvironment of different aspect of hill slopes is influenced by the intensity and duration of available sunlight (Yadav and Gupta, 2006).

To mitigate problems of deforestation, forest degradation, and improve the potential of forest regeneration, development of sustainable forest managenment plans that maintain and conserve the ecological, an economical and social benefits of forest is becoming a matter of global, regional, national and local concern. Biodiversity is a fundamental concept in sustainability because it views present conditions of regeneration abundance and richness from the perspective of the future.

Knowledge of the forest resources, its geographical environment and the requirements of the different species in the stand are all essential for proper planning of sustainable forest management. To meet those requirements, precise and up-to-date information regarding the status of the forest resources and potential of forest regeneration in poorly managed forest is important to upgread and to design proper management for future improvement of the forest stand. In order to understand what is truly happening to our forestland, we need to monitor the resources to measure and predict change (IUFRO, 1995). Forest inventories have been undertaken in many parts of the world but most of them were concentrate on properly managed and protected areas such as plantation,; (Thompson, 1983). There are number of important and current issues related to spatial and temporal information such as the extent, location, distribution and pattern of deforestation plus its effect on potential of regeneration and species composition that are worth investigating for developing sustainable forest management and scientific researches (Samsulwahab, 2001). Better we understand the forest better we will be able to protect, conserve and manage them.(Sandalow, 2000).

CHAPTER: 3

METHODOLOGY

3.1 Research Frame work

A forest inventory was employed in order to assess the degree of canopy opening and plant species richness in regeneration level.

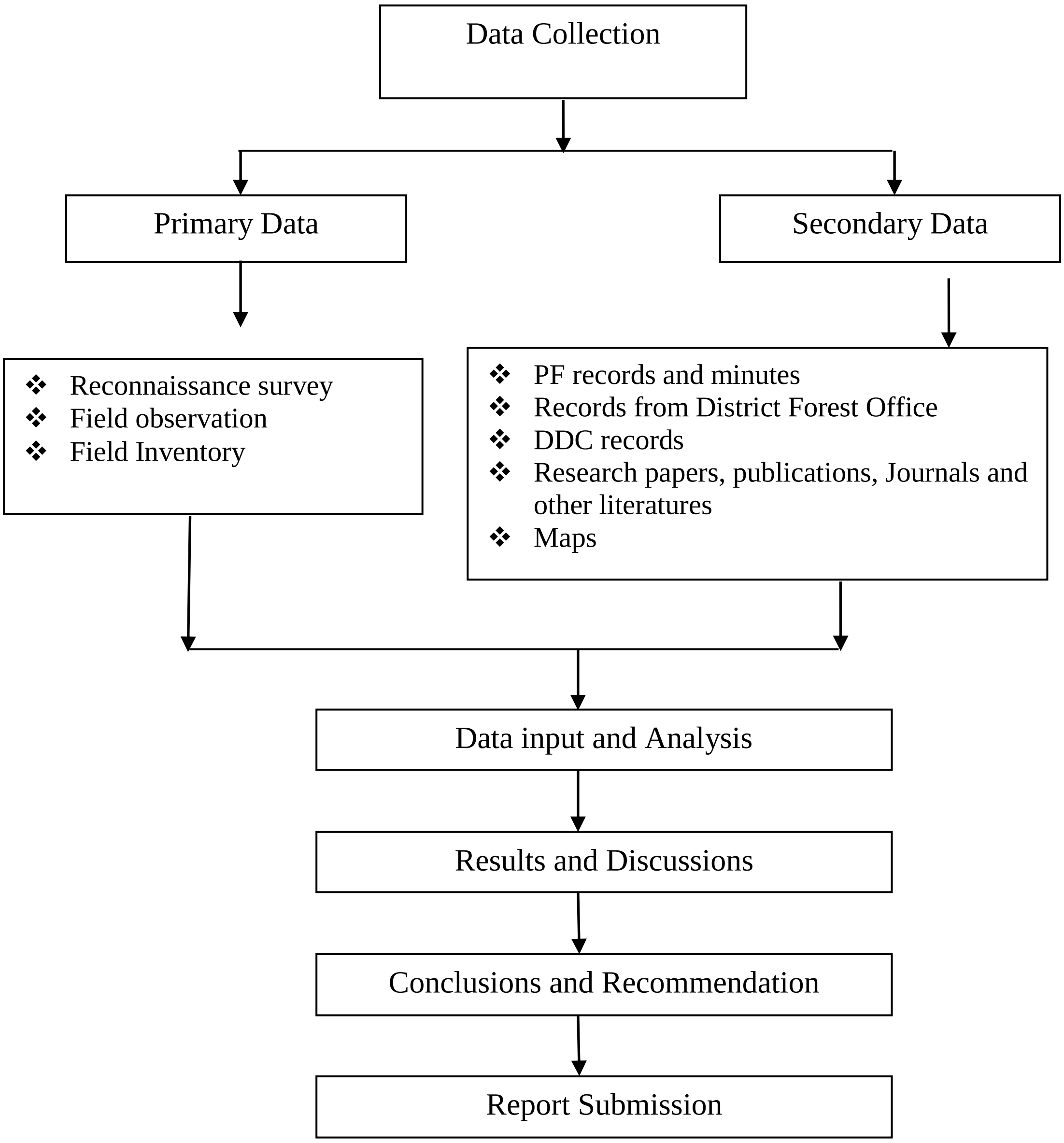

Figure 1: Research Methodology framework

3.2 Study Area

3.2.1 Area Selection

The vegetation of seasonally dry Sal (*Shorea robusta*) forest was selected in the Terai region of Nawalparasi (west) district, western Nepal, Province No. 5. This forest type was chosen as it is the best representative of Sal forests in Nepal. It is considered to be one of the largest chunks of Sal forest in the locality. This is the oldest forest of Sal in this locality and it has artificial or natural gap made departmental felling.

The study area Bhudda Shanti collaborative forest of Nawalparasi district was selected on the basis of discussion made with Advisor, DFO (District Forest Officer), AFO (Assistant Forest Officer), Ranger, other staffs and local users who involved in that collaborative forest.

3.2.2 General Description Study Area

BCFM forest area lies in south-west part of some wards of Sunawol municipality, Ramgram municipality and Palinandan rural-municipality respectively. BCFM forest area lies in Amraut Illaka under the Bardaghat sector forest office of Nawalparasi district. It's forest area ended with west part of Kajarar stream. From headquarter of Nawalparasi district its area extent upto 9 km in east. The north part is connected with Mahendra highway where 2.6 km of this highway lies in the north part of this forest area and the forest area extent in the southern part of Mahendra highway. It lies between 27°30'00" to 27°40'00" latitude and 83°35'00" to 83°40'00" longitude. Altitudinal variation is seen from 200 m ASL to 300 m ASL. It occupies 1781.32ha out of 1204.10 ha of core area and 577.22 ha. fringe area. The whole forest is divided into three compartments and twenty four sub-compartments. Average size of forest is 3.62 km (east- west) X 6.78 km (north-south). Buddha Shanti CFM group includes 11,422 households in which Ramgram(14,15) & Sunawal(7,8,9) lies inside 5km area and Ramgram(6,10,15,16) & Palinandan(4,5,6) are 5km far from forest area.

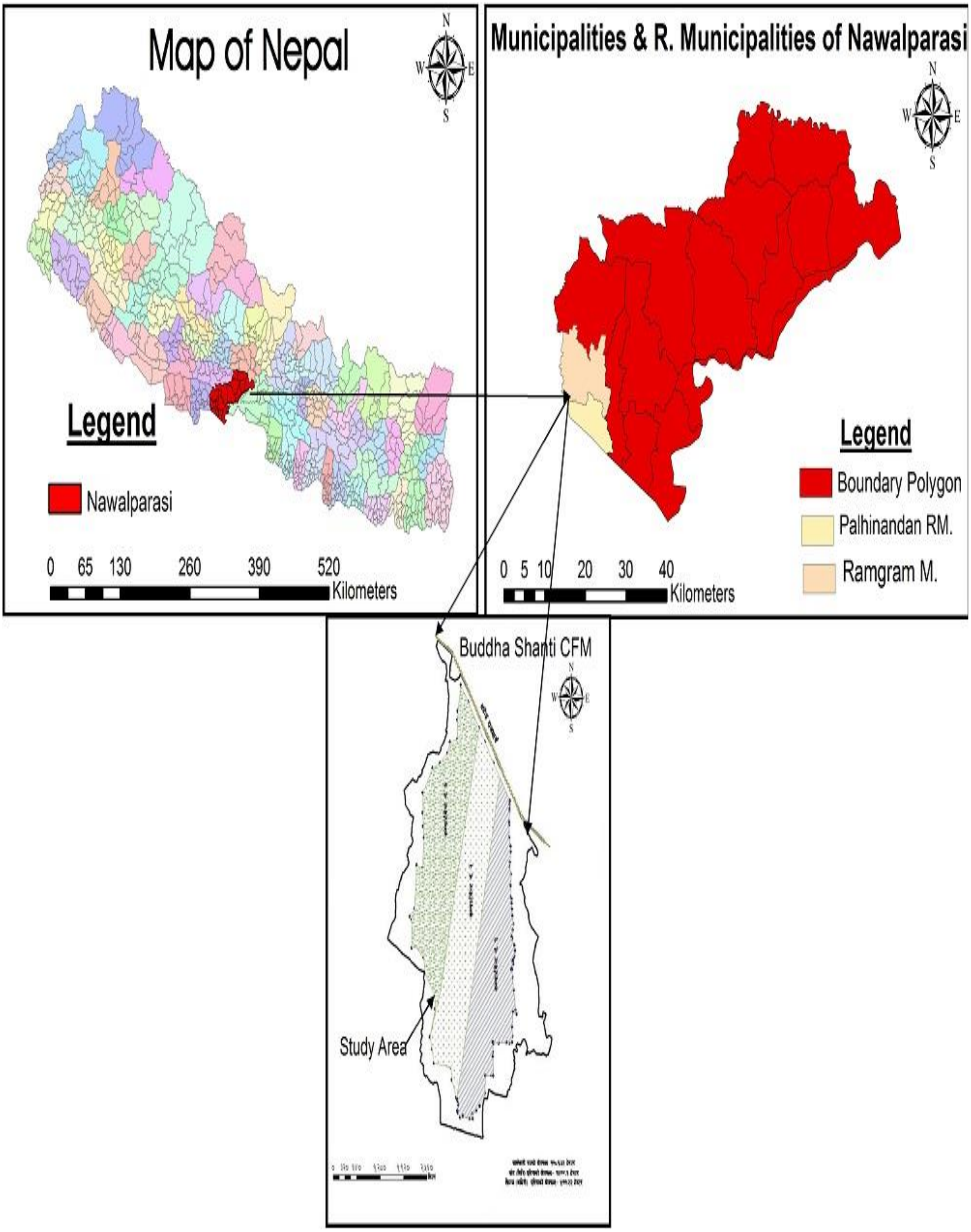

Figure 2: Map of Study Area

3.3 Data Collection

3.3.1 Primary Data Collection

3.3.1.1 Reconnaissance Survey

Reconnaissance survey was carried out to familiarize with the general situation of forest site and people of the study area. It had helped to build a rapport with forest official, to design and plan sampling strategy.

3.3.1.2 Inventory of the Forest

Parts of two sub compartments i.e. C1S2 and C1S3 were taken each of 10 hectares and total 20 sample plots were laid in study block, where irregular shelter-wood system was adopted in C1S2 and C1S3 was undisturbed. Systematic sampling with 0.25% sampling intensity was carried out for the regeneration survey of these parts of sub compartment of the forest. Regeneration survey was done to determine canopy opening in each plot and plant regeneration. GIS 10.3 was used to create forest map and to locate sample plot. For the study of open strata, part of sub compartment C1S2 , where irregular shelter-wood system adopted was taken and for the medium and dense strata, part of c1s3 sub compartment, which was undisturbed was taken. Densiometer was used to find the crown cover percentage. Regeneration survey to find regeneration was carried out according to revised Community Forest Inventory Guideline 2061.

S I = (N*sample size in m^2 * 100)/(Total area in ha*10000)

Where, SI is the intensity of sampling,

N is the number of sample plots

So, SI = (20*25*100)/(20*10000)

= 0.25%

3.3.2. Secondary Data Collection

Secondary data was collected by different published and unpublished literature, reports, articles, case studies, journals related to the objectives. Furthermore, essential information was gathered from District Profile of the district, different documents in District Forest Office and other Organizations and other needed information was downloaded from related websites.

3.4 Data Analysis

The data collected from primary and secondary sources were analyzed using both qualitative and quantitative methods depending on the nature of the field data and were interpreted through statistical tools. The descriptive (mean, frequencies and percentage) statistics were used to analyze the quantitative data. Microsoft Excel 2010 software was used to analyze the quantitative data.

3.4.1 Quantitative Analysis

3.4.1.1 Forest Diversity and Diversity Indices

From the data obtained from above described inventory, Simpson's and Shannon's diversity Index were used to quantify the richness and evenness of the forest. The formula used for the diversity assessment was:

A. Simpson's Diversity Indices

The term 'Simpson's Diversity Index' can actually refer to any one of 3 closely related indices. **Simpson's Index** (**D**) measures the probability that two individuals randomly selected from a sample will belong to the same species (or some category other than species). There are two versions of the formula for calculating **D**. either is acceptable, but be consistent.

$D = \Sigma (n / N)^2$	$D = \frac{\Sigma n(n-1)}{N(N-1)}$
n = the total number of organisms of a particular species **N = the total number of organisms of all species**	

The value of **D** ranges between 0 and 1

With this index, 0 represents infinite diversity and 1, no diversity. That is, the bigger the value of D, the lower the diversity. This is neither intuitive nor logical, so to get over this problem, D is often subtracted from 1 to give:

Simpson's Index of Diversity 1 - **D**

The value of this index also ranges between 0 and 1, but now, the greater the value, the greater the sample diversity. This makes more sense. In this case, the index represents the probability that two individuals randomly selected from a sample will belong to different species.

Another way of overcoming the problem of the counter-intuitive nature of Simpson's Index is to take the reciprocal of the Index:

Simpson's Reciprocal Index 1 / **D**

The value of this index starts with 1 as the lowest possible figure. This figure would represent a community containing only one species. The higher the value, the greater the diversity. The maximum value is the number of species (or other category being used) in the sample.

B. Shannon Diversity Index

$$H = \sum_{i=1}^{s} - (P_i * \ln P_i)$$

Where,

H = the Shannon diversity index

P_i = fraction of the entire population made up of species i

S = numbers of species encountered

$\sum$ = sum from species 1 to species S

Note: The power to which the base e (e = 2.718281828.......) must be raised to obtain a number is called the **natural logarithm** (ln) of the number.

To calculate the index:

- Divide the number of individuals of species #1 you found in your sample by the total number of individuals of all species. This is P_i
- Multiply the fraction by its natural log ($P_1 * \ln P_1$)
- Repeat this for all of the different species that you have. The last species is species "s"
- Sum all the - ($P_i * \ln P_i$) products to get the value of H

High values of H would be representative of more diverse communities. A community with only one species would have an H value of 0 because P_i would equal 1 and be multiplied by ln P_i which would equal zero. If the species are evenly distributed then the H value would be high. So the H value allows us to know not only the number of species but how the abundance of the species is distributed among all the species in the community.

Shannon's Equilibility (Evenness)

Shannon's equitability (E_H) can be calculated by dividing H by H_{max} (here H_{max} = ln$S$). Equitability assumes a value between 0 and 1 with 1 being complete evenness.

$$E_H = H / H_{max} = H / \ln S$$

3.4.1.2 Relative Density of Species

Relative density of individual species within the plots was to know the diversity of individual species as well as the supply potential of species from the forest side. The formula used for relative density was:

$$\text{Relative Density (RD)} = \frac{\text{No. of individuals of a species}}{\text{No. of individuals of all species}} \times 100$$

3.4.2 Test Statistics

A correlation test was applied between indexes and stems number in the upper layer to the index and stem number in regeneration layer.

Formula for calculating correlation:

$$r = \frac{\text{Cov. }(X,Y)}{\sigma_x \sigma_y}$$

Where, Con.(X,Y) = Covariance of X and Y.

$$= \frac{\Sigma(X-\overline{X})(Y-\overline{Y})}{N}$$

$$\sigma_x = \frac{\sqrt{\Sigma(X-\overline{X})^2}}{N} \quad \text{and} \quad \sigma_y = \frac{\sqrt{\Sigma(Y-\overline{Y})}}{N}$$

CHAPTER: 4

RESULTS AND DISCUSSION

4.1.Assessment of the Regeneration Survey

The table 1 shows the regeneration density in the dense strata is higher than open and medium strata where sapling and regeneration density is higher in 0-25, 25-50, 50-75, than 75-100 percentage crown cover.

Table 1: Regeneration Stock per ha of Study Area

crown cover %	Species	Collected Data		Plot Number	Per Hector Data		Remarks
		Seedling count	Sappling Count		Seedling	Sappling	
(0-25)%	Sal	112	55	6	18667	3667	
	Saj	17	2	6	2833	133	
	Valayo	4		6	667	0	
	Total	**133**	**57**		**22167**	**3800**	Good
(25-50)%	Sal	67	34	6	11167	2267	
	Saj	15	2	6	2500	133	
	Total	**82**	**36**		**13667**	**2400**	Good
(50-75)%	Sal	50	25	6	8333	1667	
	Saj	20	2	6	3333	133	
	Total	**70**	**27**		**11667**	**1800**	Good
(75-100)%	Sal	15	6	2	7500	1200	
	Saj	3	2	2	1500	400	
	Karma	4		2	2000	0	
	Total	**22**	**8**		**11000**	**1600**	Good

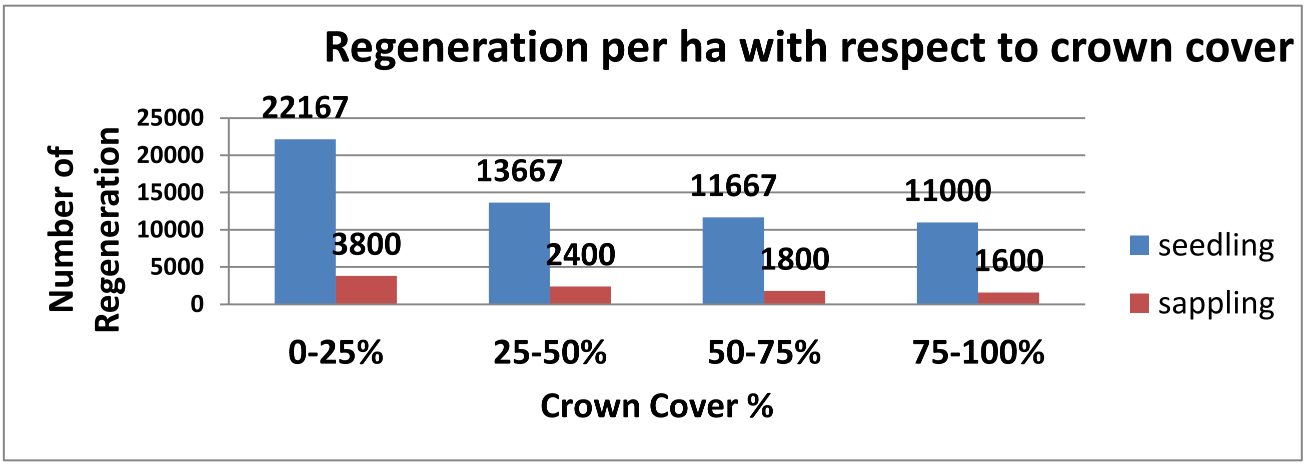

Figure 3: Summary of Regeneration stock per hector

Source: Regeneration survey, 2018

Crown cover 0-25% have an extremely high seedling and sappling density to those other strata which are in line with the findings made by Sapkota et all (2009). At the individual species level, higher seedling densities of *S. robusta* and *Terminilia tomentosa* were observed in all four strata. Canopy gaps are always found to have higher light intensities at soil surface and hence often higher soil temperature than closed vegetation (Denslow et al. 1998). Moreover, competition for one or more resources (e.g. light, nutrients, and water) is less in canopy gaps than in intact vegetation (Bullock 2000). Thus, seedling establishment in open strata is easier and faster than dense strata due to the combined effect of enough light, soil moisture and less competition of weed. During the time of inventory, in plot open canopy cover the recruitment (current year seedling) seedlings of the *S. robusta* in the forest were found. This may be due to the application of silviculture system, irregular shalter-wood system.

A shrub density was found less in 0-25% and 20-50% crown cover than other two strata which was opposite reported by Sapkota, et al (2009) because there was frequent grazing and human presence in order to collect fodder and firewood. Therefore, in open strata which were heavily disturbed, species richness is directly influenced by the human activities rather than natural process.

Above graph clearly shows that as per increasing crown cover percentage the regeneration of Sal is going decreasing which indicates that opening of crown and intensity of light is most necessary for the regeneration to Sal which is similar to Gautam and Devoe (2006)

4.2.Simpson's Diversity Index

Table 2: Simpson's diversity index of forest

Vegetation Layer	Strata											
	0-25			25-50			50-75			75-100		
	D	1-D	1/D	D	1-D	1/D	D	1-D	1/D	D	1-D	1/D
Sapling	0.93	0.07	1.07	0.90	0.10	1.12	0.86	0.14	1.16	0.62	0.38	1.60
Seedling	0.73	0.27	1.38	0.70	0.30	1.43	0.59	0.41	1.69	0.52	0.48	1.94

Source: Regeneration survey, 2018

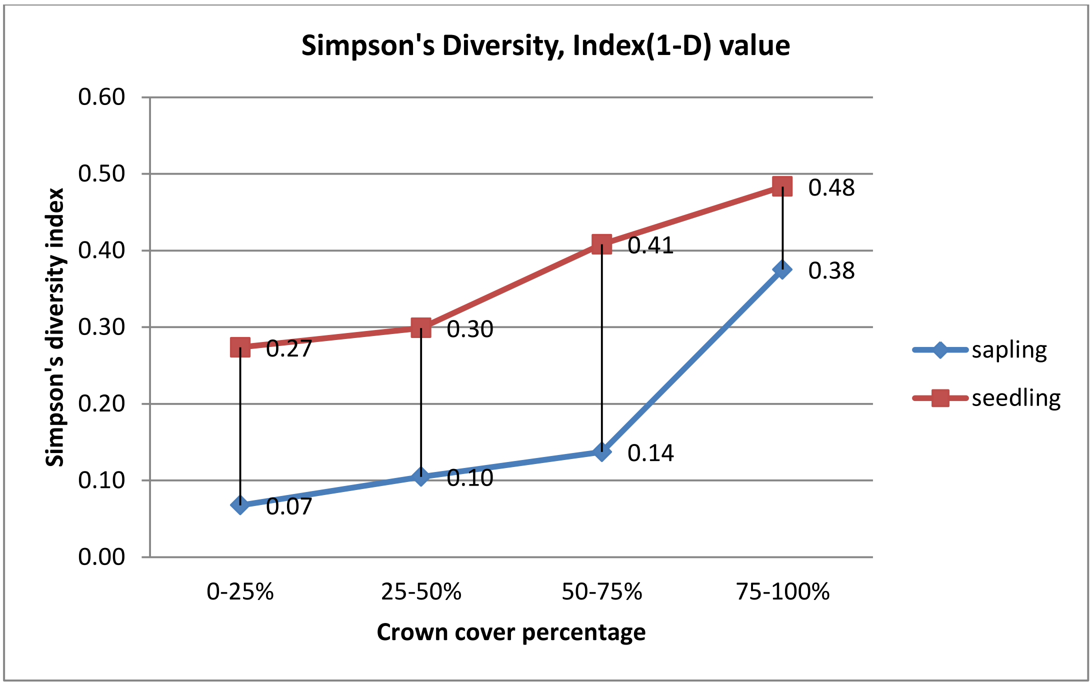

Figure 4: line graph of Simpson's Diversity index

The table 2 shows that seedling diversity is high in 50-75% and 75-100% crown cover than in0-25 and 25-50% crown cover and sapling diversity is also high in 50-75% and 75-100% crown cover than in0-25 and 25-50% crown cover, which indicate that as per increasing crown cover percentage the plant diversity is going increasing and number of regeneration of sal is going decreasing, Which proves the necessity of opening of the crown cover to assure the regeneration of sal.

4.3.Shannon's Diversity Index and Evenness

Table 3: Shannon's diversity index and evenness

Vegetation layer	Shannon's diversity Index and equitability (Evenness)							
	Strata							
	0-25%		25-50%		50-75%		75-100%	
	H	E	H	E	H	E	H	E
Sapling	0.17	0.25	0.23	0.33	0.26	0.38	0.57	0.82
Seedling	0.53	0.48	0.47	0.68	0.6	0.87	0.84	0.76

Source: Regeneration survey, 2018

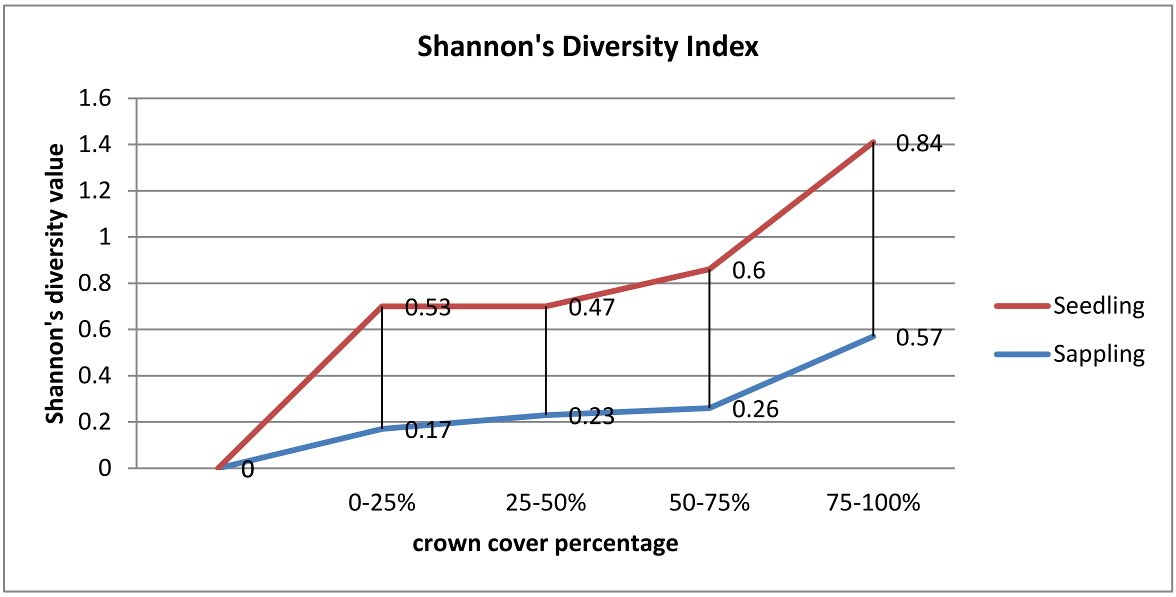

Figure 5**:** line graph of Shannon's Diversity index

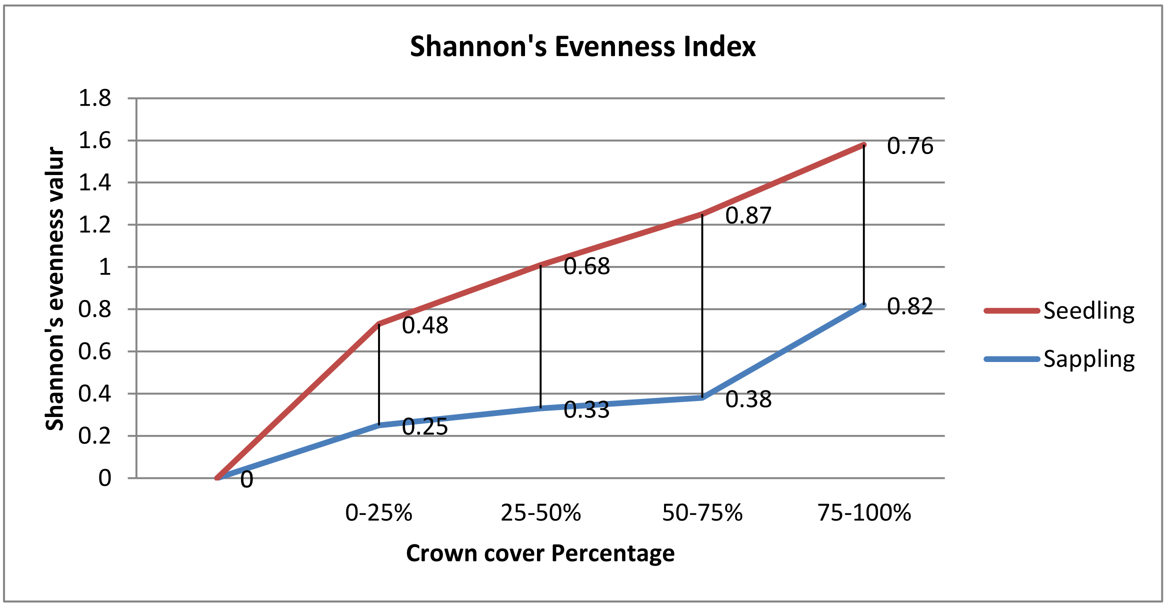

Figure 6: line graph of Shannon's Evenness index

The table 3 shows the Shannons' diversity index and evenness. The sapling distribution is high in 75-100 percentage crown cover but which is more or less same distribution. Evenness of regeneration is high in 50-75 percentage and less in 0-25 percentage crown cover. According to the Intermediate Disturbance Hypothesis (IDH), too much disturbance leads to the loss of late successional species, whereas too little leads to the exclusion of species adapted to colonize ecosystems immediately after disturbance (Sheil & Burslem, 2003-Cited in Sapkota, I.P, 2009. Species Diversity, Regeneration and Early Growth of Sal

Forests in Nepal: Responses to Inherent Disturbance Regimes.). So that, the researcher findings is consistent with this hypothesis. They show diversity is high in the medium disturbance Sal forest.

The Simpson's diversity index and Shannon's diversity index did not vary consistently for sapling and regeneration between four strata (Table 2 & 3). Sapkota, I. P. et al. (2009) reported that the total number of individuals (N) for all the four growth forms was higher in the gap than in the intact vegetation which is similar to this study shows that regeneration and sapling are higher in open than dense in term of number. The Shannon-Wiener index (H´), the complement of Simpson’s index (1–D) and the Shannon’s measure of evenness (E’) was slightly higher in the intact vegetation than in the gap for shrubs and trees while nearly the same for herbs (Sapkota. I. P. et al., (2009) but in this study shows that seedling and sapling diversity is slightly higher in dense strata and regeneration evenness is higher in 50-75 percentage strata (Table 2 & 3). It is mainly due to the regenerations were not disturbed in the 50-75 percentage stand. Naturally, diversity index of the regeneration should be high in the open and/or medium. But in this study diversity index is higher in the dense strata because dominance of Sal regeneration due to the enough light intensity and suitable environment for germination.

4.4. Relative Density of Regeneration

4.4.1. Crown Cover 0-25 %Sapling

4.4.1.1.Sapling

The figure 7 reveals that the major tree species in 0-25 percentage crown cover comprise of Sal and Saj. The species with the highest relative density value is Sal (96.49) and then is Saj (3.14). This indicates that the species with their higher relative densities in the strata are potential species from supply side (resource availability in the forest).

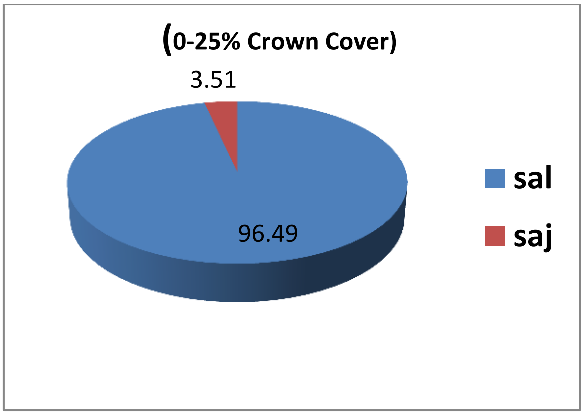

Figure7**:** Relative density of sapling in 0-25% crown cover
Source: Regeneration survey, 2018

4.4.1.2. Seedling

The figure 8 shows that the major species in regeneration level in open strata comprises of Sal, Saj and Valayo. The relative density of Sal (84.21%) is the highest among all species while Saj and Valayo has relative density 12.78 and 3.01% respectively. There are more mother trees of Sal in upper canopy than other species, so the regeneration of Sal is more in these strata.

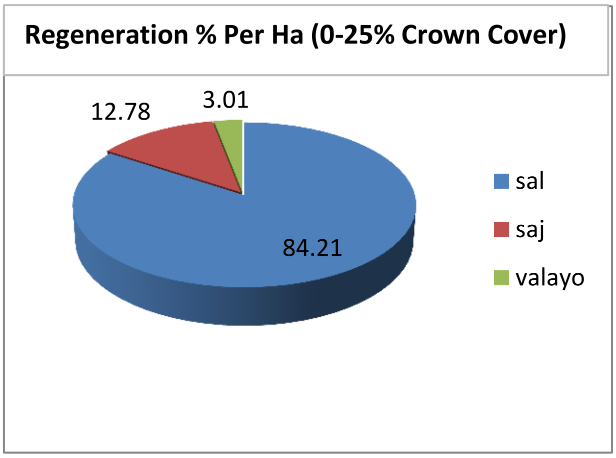

Figure8**:** Relative density of seedling in 0-25% crown cover
Source: Regeneration survey, 2018

4.4.2. Crown cover 25-50%

4.4.2.1 Sapling

The figure 9 reveals that the major tree species in 25-50% crown cover comprise of Sal and Saj. Among them Sal (94.44%) has the highest relative density and Saj has (5.56%). This indicates that the species with their higher relative densities in the strata are potential species from supply side (resource availability in the forest).

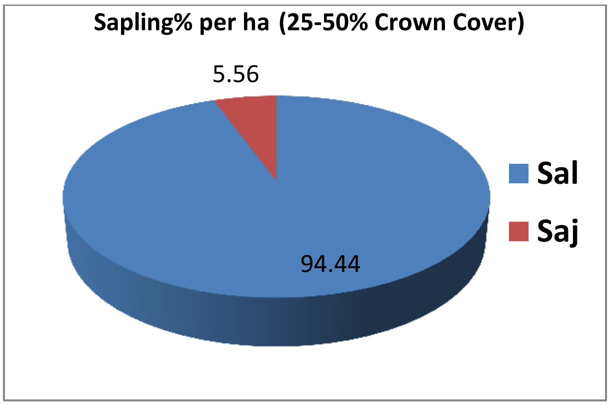

Figure 9: Relative density of sapling in 20-50% crown cover

Source: Regeneration survey, 2018

4.4.2.2.Seedling

The Figure 10 shows that the major species of seedling in 25-50% crown cover comprise of Sal and Saj. The species with highest relative density is Sal (81.71%) and of Saj is (18.29%).

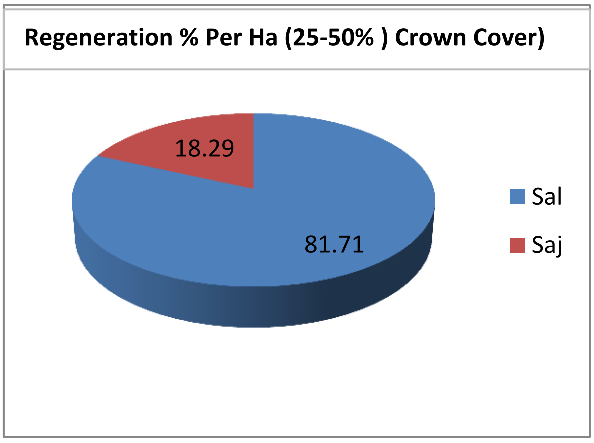

Figure 10: Relative density of seedling in 25-50% crown cover

Source: Regeneration survey, 2018

4.4.3. Crown Cover 50-75%

4.4.3.2.Sapling

The figure 11 reveals that the major tree species in dense strata comprise Sal and Saj. Among them relative density of Sal (92.59%) is the highest and relative density of Saj is (7.41%). This indicates that the species with their higher relative densities in the strata are potential species from supply side (resource availability in the forest). Sapkota I.P.(2009) Concluded that the advanced regeneration of most of the species analyzed was poor in the least disturbed forest and L. parviflora, were absent in forest , which indicates that these species have been over-exploited and that their fitness may have declined. The researcher findings also coincided with the findings of Sapkota I.P. (2009).

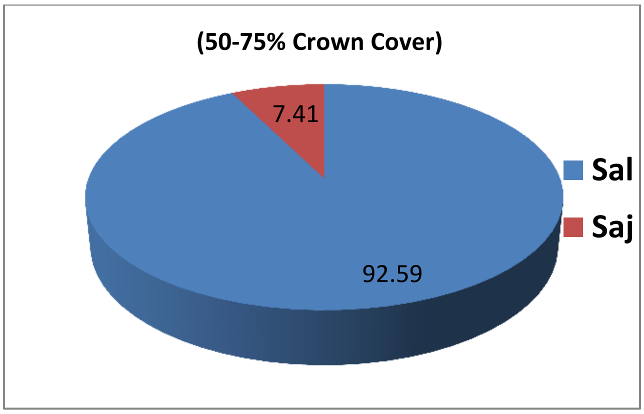

Figure 11: Relative density of sapling in 50-75% crown cover

Source: Regeneration survey, 2018

4.4.3.3.Seedling

The figure 12 shows that the major species of seedling in 50-75% crown cover comprise of Sal and Saj. The species with the highest relative density is Sal (71.43%) and Saj (28.57%).

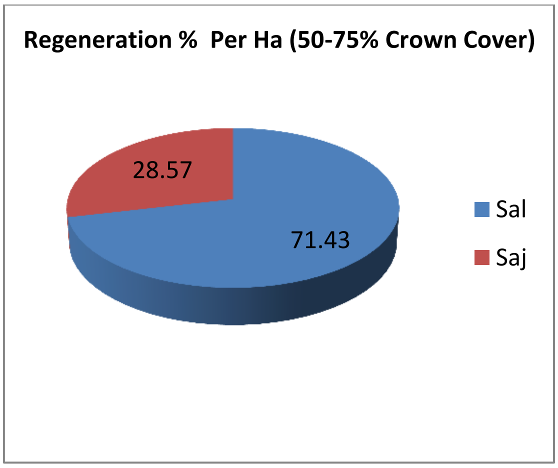

Figure 12**:** Relative density of seedling in 50-75% crown cover

Source: Regeneration survey, 2018

4.4.4. Crown Cover 75-100%

4.4.4.1. Sapling

The figure 13 revels that the major species of sapling in 75-100% crown cover comprise of Sal and Saj. The species with diversity of sapling of Sal (75%) and of Saj is (25%).

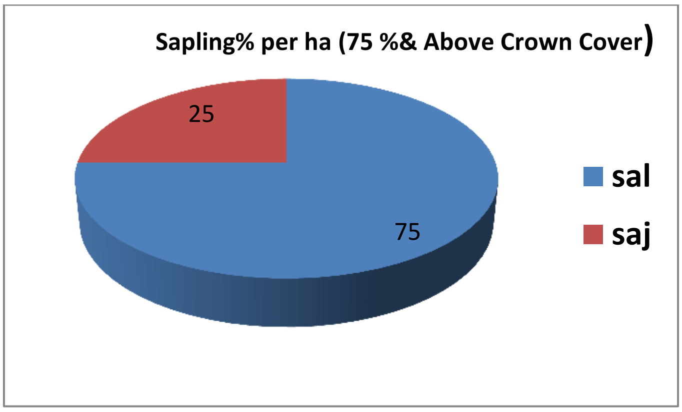

Figure 13: Relative density of sapling in 75-100% crown cover

Source: Regeneration survey, 2018

4.4.4.2. Seedling

The figure 14 revels that the major species of seedling in 75-100% crown cover comprise of Sal, Saj and Karma. The species diversity of seedling of Sal (68.18%), Saj (13.64%) and of Karma is (18.18%).

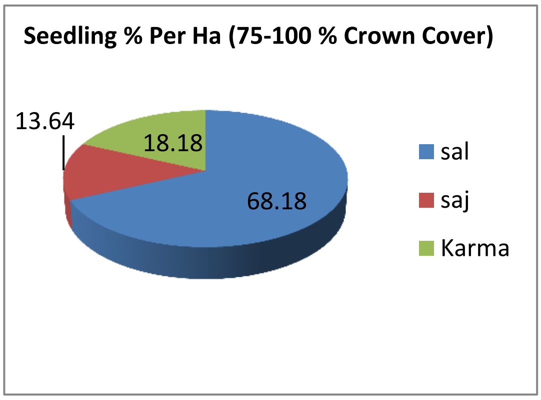

Figure 14**:** Relative density of seedling in 75-100% crown cover
Source: Regeneration survey, 2018

4.5. Test Statics

Table 4: Correlation test between crown cover and regeneration per hector.

Correlations

		Crown cover %	Seedling	Sapling
Crown cover %	Pearson Correlation	1	-.889	-.936
	Sig. (2-tailed)		.111	.064
	N	4	4	4
Seedling	Pearson Correlation	-.889	1	.992**
	Sig. (2-tailed)	.111		.008
	N	4	4	4
Sapling	Pearson Correlation	-.936	.992**	1
	Sig. (2-tailed)	.064	.008	
	N	4	4	4

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

It is found that as crown cover going increasing regeneration stock is going decreasing so crown cover percentage was found negatively correlated with regeneration stock per hectare with correlation value -0.889 for seedling and -0.936 for sapling significant at the 0.01 level (2-tailed) as shown in table

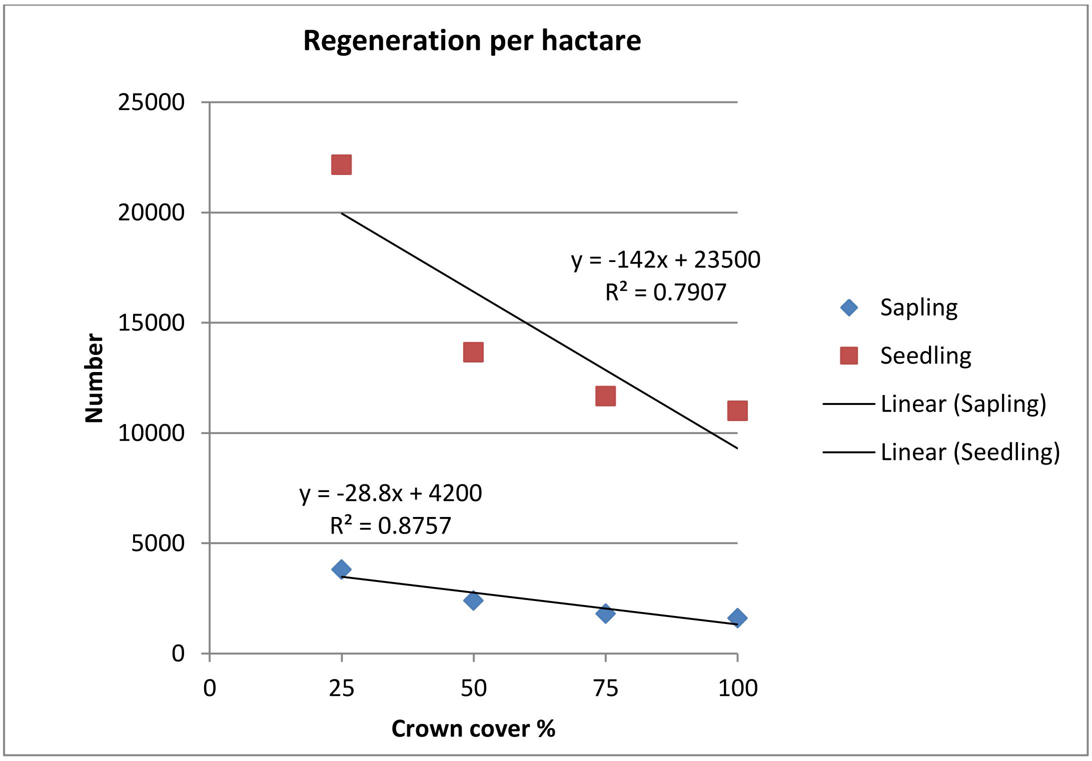

Figure 15: Scatter plot diagram of crown cover Vs. Regeneration stock

The field survey shows negative correlation between crown cover percentage and regeneration. Using the observation result, regression equation for computation regeneration with respect to crown cover percentage (i.e. 0-25, 25-50, 50-75 and 75-100% crown cover) was calculated

From the scatter plot diagram, the regression equation was found to be;

$y = -28.8*x + 4200$ (for sapling)

$y = -142*x + 23500$ (for seedling)

Where, y = Number of regeneration per hectare

x = Crown cover percentage

4.6. Discussion

- The result of the study shows that light intensity has direct positive effect on regeneration which is similar to the study of Gautam and Devoe (2006), ecological issues of Sal forest management are related to light (opening of the canopy).
- Signifying the role of light in forest regeneration and early growth which support to Khan et al. (1986), higher survival and better growth of seedlings in the open canopy than under dense canopy.
- Sapkota et.al. (2009), concluded that regeneration of *Shorea robusta* and *Terminalia alata* is higher in the gap than in the intact vegetation which is similar to the findings of this study.
- This result supports to Dhakal, B.P. (2009), the diversity of regeneration is high in dense strata than in medium and open strata but open strata has less regeneration diversity than other
- Correlation test shows that regeneration is negatively correlated with crown cover percentage with correlation value -0.889 for seedling and -0.936 for sapling significant at the 0.01 level, which is similar to Raich James W. and Gong Wooi Khoon, 1990.

CHAPTER: 5

CONCLUSION AND RECOMMENDATION

5.1.Conclusion

A few conclusions are drawn based on the findings. They are as follows:

- The relative density in regeneration layer of Sal was inversely proportional to the crown cover i.e. decrease in crown cover, increase regeneration by 61%.
- The regeneration per hectare was high in open strata (0-25% crown cover) i.e. light intensity has direct positive effect on regeneration.
- Simpson's Index of Diversity was increased with increase in crown cover % for both seedling and sapling.
- Shannon's Diversity Index and evenness increase with increase in crown cover % for both seedling and sapling except diversity index in 25-50% crown cover and Evenness in 75-100% crown cover for seedling which indicates decreasing diversity and increasing dominance of Sal regeneration in less crown cover percentage.
- Correlation test shows that regeneration is negatively correlated with crown cover percentage with correlation value -0.889 for seedling and -0.936 for sapling significant at the 0.01 level.

5.2.Recommendation

- Artificial opening of canopy by adopting suitable silvicultural system seems more effective for regeneration of Sal.
- Physical barrier like fencing need to install to protect regeneration from direct human and animal influenced in silviculturally operated plot.
- Invasive species are hampering in growth and development of regeneration so they need to be removed for advancing regeneration.

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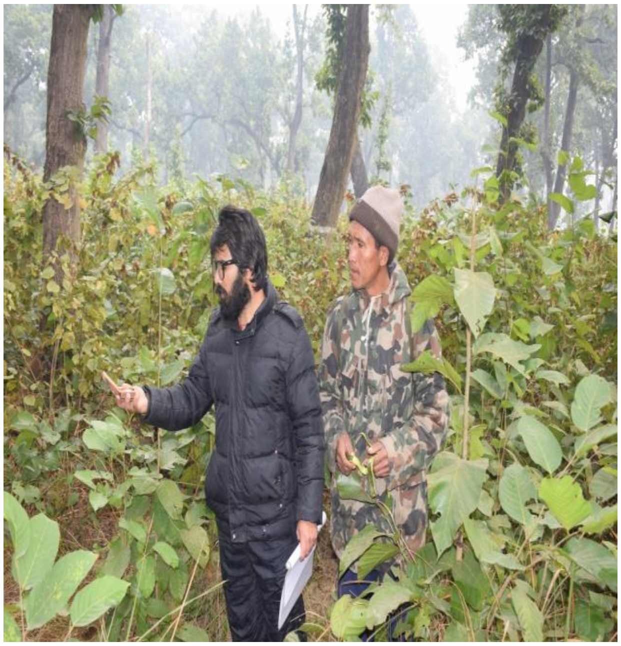
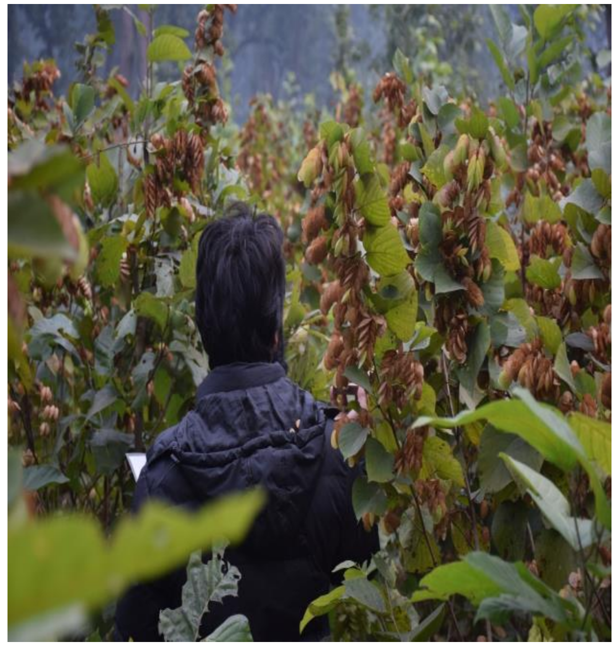
Appendix -1: List of Major Tree species found in sampled Plot

SN	Local Name	Scientific Name
1.	Sal/Sakhuwa	*Shorea robusta*
2.	Saj (Asna)	*Terminalia tomentosa*
3.	Karma (Haldu)	*Adina cordifolia*
4.	Valayo	*Semecarpus anacardium.*

Appendix-2: Photo plate



Use of Densiometer to find crown cover percentage



Invasive Species in the forest

Regeneration Survey

Regeneration after Canopy Opening