Plant Diversity, Regeneration and Carbon Stock ofThree Community Managed Forests, Kailali, Western Nepal

A Dissertation Submitted for the Partial Fulfillment of the Requirements for theMaster's Degree in Botany

Submitted by

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DECLARATION

I, Bimala Bhatta, hereby declare that the work presented in this dissertation is my own original work and has not been submitted for any other academic degree. All the sources of information have been specifically acknowledged by reference wherever adopted from other sources.

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RECOMMENDATION LETTER

This is to certify that Mrs. Bimala Bhatta has completed the dissertation work entitled **"Plant Diversity, Regeneration and Carbon Stock of Three Community Managed Forests, Kailali, Western Nepal"** under my supervision. The entire work is based on her own fieldwork and laboratory work and has not been submitted in any other academic degree. I, therefore, recommend this dissertation work to be accepted for partial fulfillment of Masters' degree in Botany from Amrit Campus, Tribhuvan University.

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LETTER OF APPROVAL

The M.Sc. dissertation entitled "**Plant Diversity, Regeneration and Carbon Stock of Three Community Managed Forests, Kailali, Western Nepal**" Submitted by Mrs. Bimala Bhatta to the Department of Botany, Amrit Campus, Tribhuvan University has been accepted for the partial fulfillment of the requirement for Master's Degree in Botany.

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ABBREVIATIONS AND ACRONYMS

°C	–	Celsius
ABA	–	above ground biomass
Asl	–	Above sea level
BGB	–	below ground biomass
C	–	Carbon
CF	–	Community Forest
CFUGs	–	Community Forest Users Groups
cm	–	centimeter
DBH	–	Diameter at breast height
DFRS	–	Department of Forest Research and Survey
GCF	–	Gwasisamaigi Community Forest
Ha	–	hectare
IVI	–	Importance Value Index
LCF	–	Laxmi Community Forest
No.	–	Number
REDD	–	Reducing emission from deforestation and degradation
SCF	–	Shiva Parbati Community Forest

ABSTRACT

Forest is an integral component of majority of people ofNepal. Community forestry program has been involved as a potential solution to the problem of deforestation. This study is intended to assess the status of plant diversity, regeneration and carbon stock of three community managed riverine forest (Gasisamaigi, Laxmi and Shiva Parbati) of Kailali Western Nepal. All these forest were riverine forest with different management period. To asses Important Value Index (IVI), species diversity, regeneration and carbon stock altogether 90 sample plots (30 plots in each forest) of size 10m×10m were established for tree applying stratified random sampling method. Within the 10 m× 10 m 3 sub plots of 5m×5m for shrubs and 3 subplots of 2m×2m for herbs was laidonJanuary (2020). Tree biomass was estimated using equation of Chavel *et al*., (2005) and regeneration was estimated by calculating the density of each species in seedling, sapling and tree phases. Carbon stock of Gwasisamaigi Community Forest was found higher (146.58t/ha) than in Laxmi Community Forest (69.10t/ha) and Shiva Parbati Community Forest (59.2t/ha) and it increased with increasing management period of community forest. Similarly total species diversity was found higher in GCF but herbs species diversity was found higher in SCF.SCF had good regeneration statusopen canopy of SCF might have favored the regeneration of forest. This result revealed that species diversity and carbon stock increases with increase in management period of community managed riverine forest.

Keywords:carbon stock, Diversity, Regeneration,Riverine forest

CHAPTER 1: INTRODUCTION

1.1 Background

Nepal has proved a forerunner in implementing policies related to forest management, starting early 1970s. Since then, efforts at maintaining forest cover and biodiversity have included initiation of wide variety of programs. Diversity is the variety and variability of diverse form of living organisms on the earth. Tree species diversity is the variability of the tree species in a forest. Riparian systems are biologically important components of landscapes worldwide, supporting a disproportionate amount of ecosystem services and species diversity compared to adjacent terrestrial ecosystems (Ward 1998, Brauman *etal*., 2007).

In Nepal, forest covers 5.96 million ha (40.36%) and other woodland cover 0.65 million ha (4.38%). Forest and other woodland together comprise 44.74% of the total area of the country (DFRS, 2015). Out of the total forest area of Nepal, 6.09% lies in the terai where as 16.94% lies in the Far Western Development Region (DFRS, 2015). Community forestry has contributed to high tree species diversity but in recent years most community forests are moving toward promoting timber yielding species that have high economic value (Pandey *et al.,* 2014). Diversity indices provide important information about the composition of a community. Ecologists have developed many indices of species diversity among which Simpson's index (Simpsons, 1949) and Shannon-wiener Index, H1 (Shannon and Weaver, 1949) are the most commonly used indices. Simpson's index (C) reflects dominance while Shannon-Wiener Index (H1) is thought to represent uncertainty or information of a community. The value of the diversity index is higher in rich forests and lower in forests dominated by single species. Therefore more diverse the forest more will be value of diversity index.

The presence of young plant at growing stage is called regeneration. Forest showing highest regeneration has highest carbon sequestration. Regeneration helps us to determine whether it meets the objective of sustainable forest management, and in particular, whether the productive capacity and biological diversity of forest are maintained (Lutze *etal.,* (2004). Regeneration is said to be good if forests have seedling >5000 and sapling >2000 per hectare (HMG, 2004) (cited in Pandey *et al*.,2012). The regeneration and productive character of forest is determined by presence of different age group of seedling and sapling and tree (Chauhan *et al.*, 2008).

Carbon pools are components of the ecosystem that can either accumulate or release carbon and have classically been split into two main categories such as biomass carbon stocks and soil carbon stocks. . Noble *et al*., (2000) defined biomass carbon stock as the removal of atmospheric carbon dioxide and storage in green plant biomass through the process of photosynthesis. Carbon is held in the terrestrial system in vegetation and soils. Carbon is one of the essential elements of life and green plants have unique ability to assimilate it in the form of carbon dioxide as raw material mainly for food preparation (Jain, 1983).Globally, forests act as a natural storage for carbon. It contributes approximately 80% of terrestrial above-ground, and 40% of terrestrial below-ground biomass carbon storage (Dixon, *et al.*, 1994). Compared to other terrestrial ecosystem forests store the most carbon (Pan *etal*., 2011). Carbon sequestration from atmosphere can be advantageous from both environmental and socio-economic perspectives.In Nepal, 40.36 % (forest + shrubland) i.e. 5.96 million ha is occupied by forest (DFRS, 2015). More dense the forest more will be the carbon storage. Tropicalriverine, Pine and *Alnus nepalensis* forests are important that play important role in carbon sequestration of trees biomass in Nepal, as seen from the comparatively higher carbon accumulation rates (Baral *etal*., 2009). The rate of C sequestration which is much faster in young and regenerating forest than the old and matured forest but C-stock is more in old and mature forest (Luyssaert *et al.*, 2008. Carbon storage is largely influenced by species composition (Bunker *et al.*, 2005; Henry *etal*., 2009) .The world 's forest contain up to 80%of all above ground C and nearly 40% of all below ground (soil, litter and roots) terrestrial carbon (Dixon *et al.*,1994). The forest diversity and carbon stock relation has become animportant consideration in the carbon cycle and in adapting to climate change (Midgley *etal*., 2010).

Majority forests of terai region of Nepal are community managed in order to protect the species from extinction. Community Forestry (CF) management system is based on the sustainable utilization of forest products. There are indications that CFUGs are moving towards providing forest product sustainably whereas the biodiversity issue has received less priority (Malla, *et al*., 2001). Terai regionposses riverine forest covering specific area. *Shorea robusta* is the dominant forest tree species in the plains to Terai while riverine areas are occupied by *Acacia -Dalbergia* association. As *Acacia* and *Dalbergia* are listed as threatened species of Nepal, these species present on riverine belt are under great threat.Majority of riverine forest in Nepal are community managed forest. A total of 2237670.5 ha of CF was handed over to 22,266 community forest users group through the country (DOF/CFD., 2018).

Management has its own importance, to get more diversity of species management of forest need to be in good condition. When forest is managed properly, its biodiversity has strong potential to contribute to the reduction of wide-spread poverty (Edwards 1996).To protect forests from declining, it is essential to examine the current status of species diversity as it will provide guidance for the management of protected areas.In spite of the vital significance of biodiversity conservation for our own existence, the CF program has not encompassed biodiversity conservation within its objectives of forest management (Chhetri 1997).The regenerating and productive character of forest is mainly determined by presence of different age-group of seedling,sapling and tree (Chauhan *et al.*,2008).As deforestation is currently a common phenomenon of the developingcountries, plantation of more trees and trees having high capacity to absorb more carbon is important. Forest carbon sequestration is a safe, environmentally acceptable, and cost-effective way to capture and store substantial amounts of atmospheric carbon, so conservation of forests may be important strategy for dealing with climate change. Carbon sequestration of plant species vary from species to species.Forest is only which plays an important role in mitigating global climate change (Kaul*et al.*, 2010)through carbon-dioxide sequestration. The community forest user group apply different siviculture practices (like prooning, cutting down old branches, thining, fodder collection, litter collection).These practices may adversely impacts the plant diversity. Hence this study aims to compare and analyze impacts of forest management on plant diversity in riverine forest of Kailai district. Forest located in riverine belt with different management period are studied in this research.

1.2 Justification of the Study

There are numerous work related to plant diversity, regeneration and carbon stock in various parts of Nepal. But there are few research work related to plant diversity, regeneration and carbon stock based on management period of riverine forest. It is not clear if difference in management periods will have impacts on plant diversity, regeneration and carbon stock in reverine belt. So, this work was proposed to examine three community managed riverine forests having different years of management practices in Kailali district of Western Nepal. The information obtained from this research will be helpful in planning and implementing the forest management and conservation.

1.3 Research Questions

i. What is the role of management pratices in riverine forest on plant diversity?
ii. What is the role of the ages of the management pratices of riverine forest on carbon stocks of trees?

1.4 Objectives

General objectives

- To compare plant diversity of three community managed riverine forest of Kailali district based on their management period**.**

Specific objectives

i. To study plant species diversity of the riverine forest in three community forest having different ages.
ii. To compare the regeneration status of trees in three community forest.
iii. To estimate tree carbon stock of trees of three riverine forests having different ages at Kailali district.

1.5 Limitations

i. The diversity of herbs and shrubs could not be covered during rainy season.
ii. Only tree carbon stock was calculated.

CHAPTER 2: LITERATURE REVIEW

2.1. Plant Diversity

Nepal occupies about 0.1 percent of the global area but harbours over three percent of the world's known flora. A total of 284 flowering plants are endemic to Nepal. In Nepal there are 6073 angiosperms, 26 gymnosperms, 534 Pteridophytes, 1,150 bryophytes, 365 lichens, 1822 fungi and 1,001 algae are known (GoN, 2014). The loss of biodiversity are due to loss and fragmentation of habitat, unscientific land use, unsustainable use of bio-resources, uncontrolled forest fire, overgrazing, illegal logging and poaching, unplanned development activities and pollution (MoFE, 2018). Tree species diversity is always found highest along the river while the lowest tree diversity is away from the river (Iqbal *etal.*, 2012). Thus maintaining high species diversity should be a major objective of community forestry. Forest with small area can be very important for maintaining plant species diversity only if they are of high habitat quality and if management of forests is correct (Honnay, *etal.,* 2006)In riparian zones along the banks of streams and rivers, flooding often causes large changes in environmental conditions immediately downstream of confluences and local species diversity are likely to be affected by spatial heterogeneity of flooding along rivers and streams (Osawa, *et al.,* 2010). Riverine forests which are being destroyed haphazardly should be declared as 'biosphere reserves' to restrict anthropogenic implications for certain period of time and the ecosystem be allowed todevelop naturally with minimum human interference (Amanullah, *et al.*,2015). Forestmanagement by its name typically has a marked affect on plant species diversity, which is an important ecological indicator (Lindenmayer, *etal.*, 2006). Understandingthe effects of forest management practices on plant species diversity is important forachieving ecologically sustainable forest management (Peter, *etal.,* 2018).

2.2 Regeneration and Carbon stock

Regeneration of species in the forest helps in existence of species in that forest for further studies. Riparian vegetation includes plant communities in streams on river banks and flood plains and is an integral part of riverine ecosystem. Riparian vegetation along streams and rivers is diverse in various factors like species structure and regeneration process (Maingi *et al*., 2006). A reverse J-shaped size class distribution was attributed to undisturbed old-growth forest with sustainable regeneration (West *etal*., 1981) whereas disturbed forest shows a bell-shaped size class distribution (Saxena *etal*., 1984). Sapkota *et al.,* (2009) studied spatial distribution; advanced regeneration and stand structure of in seasonally deciduous *Shorea robusta* forest of Nawalparasi district of Nepal and found that most disturbed forest had less trees species richness, in the more disturbed plots greater density of saplings and no significant difference in stem basal area. Aryal *etal.*, (2021) studied regeneration status and species diversity of major tree species under scientific forest management in Kapilbastu district and concluded homogeneity of the tree species and increased the number of regeneration of the seedlings and saplings whereas it eventually decreased the species diversity within the felling series.

Carbon stock can be defined as the removal of atmospheric carbon dioxide and its storage in green plant biomass through the process of photosynthesis (Noble *et al*., 2000). Carbon storage is one which is largely influenced by species composition (Bunker *etal*., 2005; Henry *etal*., 2009).The vegetation types, age of the stand, the surrounding environment, management activities and other human induced disturbances play vital role in variation of carbon stock and carbon sequestration in the forest (Pandit, 2014). Forest plays a profound role in reducing ambient carbon dioxide (CO_2) levels as they sequester 20-100 times more carbon per unit area than cropland (Brown and Pearce, 1994). IPCC (2000) estimated about 19 % of the carbon in earths biosphere is stored in plants and 81 % in the soil. Tropical, temperate and boreal forests together believed to store approximately 31 % of the carbon in biomass and 69 % in the soil. Tropical forest alone stored approximately 50 % of carbon as biomass and 50 % in its soil. Karki and Banskota (2007) estimated about 79 % of the total carbon stock in plants and about 11 % of the total carbon in soil at tropical forests of Lamatar, Lalitpur. The old growth forest has higher standing carbon stock than the newly regenerating forest (Singh and Singh 1992). Shrestha (2009) carried out the study to quantify total carbon sequestration in two broadleaved forests (*Shorea* and *Schima-Castanopsis* forests) of Palpa district. Total biomass carbon in *Shorea* and *Schima-Castanopsis* forest was found 101.66 and 44.43 t/ha respectively. The most important gap concerning C stocks of riparian forest is the lack of knowledge across diverse climates and related vegetation types.

The main objective of community forest is the production of forest products and multipurpose use. Some of the management activities in community forests have reduced species richness. For example, during thinning non timber and low quality timber yielding species are indiscriminately removed and some species are over exploited at the expense of conservation of dominant species such as Sal (Shrestha, 2005). This increased the number of individual trees but reduced the species diversity. It is the large number of less common species that largely determine the species diversity of tropic groups and whole community (Odum, 1971). Forest community which posses low species diversity may be less stable (Chapman and Reiss, 1995).

Thus maintaining high species diversity should be a major objective of community forestry. Forest with small area can be very important for maintaining plant species diversity only if they are of high habitat quality and if management of forests is correct (Honnay, *etal*., 2006). In riparian zones along the banks of streams and rivers,flooding often causes large changes in environmental conditions immediately downstream of confluences and local species diversity are likely to be affected by spatial heterogeneity of flooding along rivers and streams (Osawa, *etal*., 2010). Riverine forests which are being destroyed haphazardly should be declared as 'biosphere reserves' to restrict anthropogenic implications for certain period of time and the ecosystem be allowed to develop naturally with minimum human interference(Amanullah, *et al*., 2015). Forest management by its name typically has a marked affect on plant species diversity, which is an important ecological indicator (Lindenmayer, *etal*.2006). Understanding the effects of forest management practices on plant species diversity is important for achieving ecologically sustainable forest management (Dobbertin, *etal*., 2008).

Forest management plays a vital role in maximizing carbon stock and species diversity. Community forestry programs focus on the protection and production of forestry related needs for users rather than conserving existing life forms in the forest (Belbase, 1999). As there was not any work related to periods of community forest management and its impact on plant diversity, regeneration and carbon stock especially at riverine forests of Kailali, hence this work intends to investigate on these aspects. This study will help to find out the relation of different management period of Community forest on plant diversity, regeneration and carbon stock of three community forests.

CHAPTER 3: MATERIAL AND METHODS

3.1 Study Area

Study forests are located in far-western Nepal. The study was carried out in three community managed riverine forests. All three community forest have different management period within Godawari municipality and Gauriganga muncipality Attariya, Kailali (Fig.3.1). The forest lies over and latitude 28˚48'N to 80˚38'E longitude. It is placed at an altitude of the 197m to 254m above sea level (asl) and climatic zone is tropic.

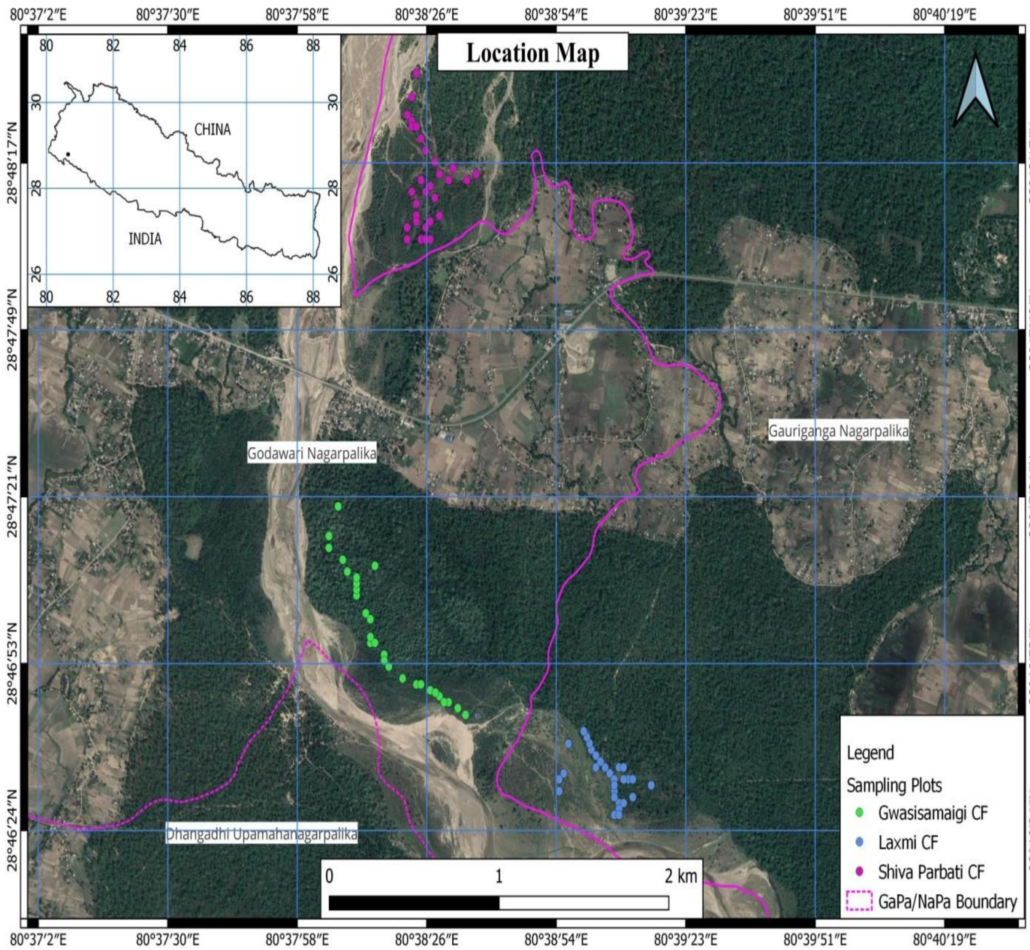


Figure 3.1: Map of study area showing sapling plots of Gwasisamaigi CF, Laxmi CF and Shiva Parbati CF.

3.1.1 Climate and Hydrogoly

The mean yearly maximum and minimum temperature of the area is 31.04°C and 19.94° C respectively. The area experiences the maximum average monthly temperature during May with 37.92° C and minimum during January with 8.94° C. Wet season in Kailali starts from April and it lasts till September. The average annual precipitation of the area is 188.07mm and area receives the highest precipitation in July. The average annual Relative Humidity of the area is 76.97%.

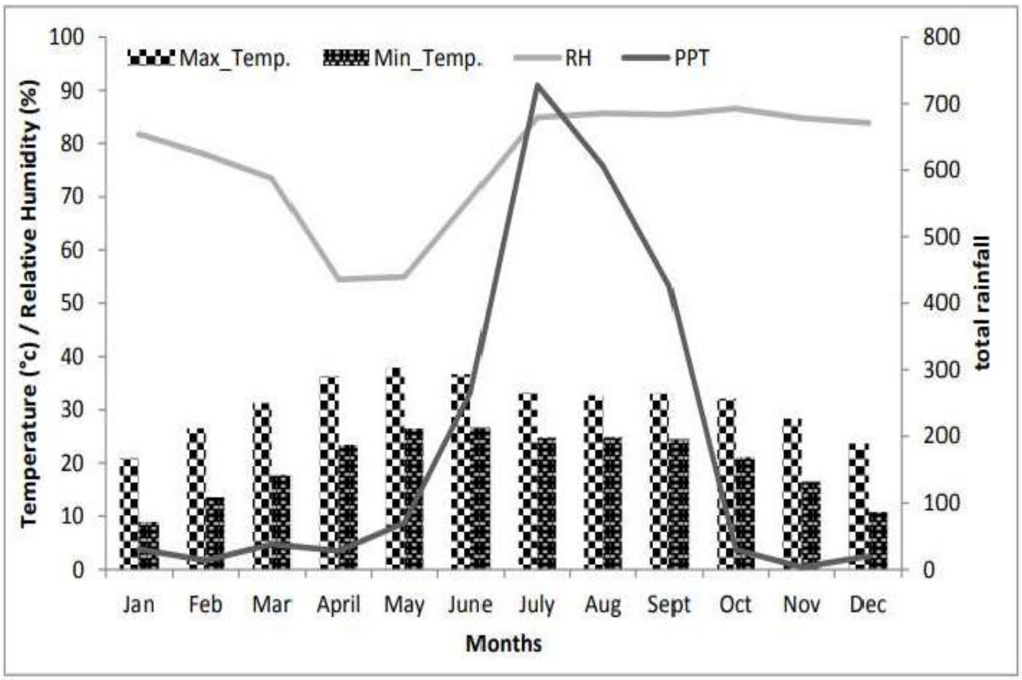


Figure 3.2: Five years (2015-2019) climatic graph showing Average monthly temperature, Humidity and Rainfall of kailali – Godawari station.

Source: climatedata.org

3.1.2 Study Forest

The study was conducted in Gwasisamaigi community forest, Laxmi community forest and Shiva Parbati Community forest (Figure 3.1). GCF is located between 28˚46'33"N to 28˚47'0"N and 80˚38'5"E to 80˚38'33"E, LCF is located between 28˚46'27"N to 28˚46'52"N and 80˚38'44"E to 80˚39'15"E in Gauriganga municipality and SCF is located between 28˚48'4"N to 28˚48'32"N and 80˚38'22"E to 80˚3'37"E with the altitude ranging from 197m to 254m asl (Figure 3.1) at

Godawari muncipality in Kailali district. The study area consists of plane slopes 0˚ to gentle slope 1˚.

Vegetation type of all these three forest is tropical deciduous riverine forest. The Gwasisamaigi community Forest is located on the southern parts of Mahendra highway, Laxmi community forest located at eastern part of Gwasisamaigi Community forest and Shiva Parbati Community forest is located at northern part of Mahendra highway. All the three forest are located at riverine belt of Khutiya river which is second level riverin Nepal originating from Mahabharata range.Gwasisamaigi Community Forest was handed over community in 2057 B.S. It covers an area of 259 hector and 823 house's member takes membership of this forest.Gwasisamaigi community forest was managed earlier it has highest tree density with dense forest. As this forest is fenced from all side it is safe from animals and human distruction. Laxmi Community Forest was handed over to community in 2066 B.S. It covers an area of 322 hector and 1084 house's member take membership of this forest As Laxmi Community Forest was community managed before Shiva Parbati Community Forest it has somewhat higher diversity of plant than SCF. Management committee of this forest has restricted illegal logging and grazing.In the same way Shiva Parbati Community Forest was handed to community in 2071 B.S. It covers an area of 301 hector and 704 house's member takes membership of this forest. Shiva Parbati Commuity Forest is managed later it has lowest diversity than other two forest. As this forest is near from human settlement it is highly disturbed byhuman activites. Before handling to community members this forest was in highly disturbed condition which is clearly reflected by lower density of sapling and tree. Activities like cutting down sapling of tree for fencing and timber, cattle grazing andlitter collection were common in this forest. This forest is highly dominated by *Holoptelea integrifolia* leaf litter collection of this tree is highest in this forest. All these tropical deciduous riverine forest are dominated by *Acacia catechu* and *Dalbergia sissoo* along with *Holoptelea integrifolia* and *Syzygium cumini*.Gwasisamaigi Community Forest is manged earlier it has larger sized trees like *Bombax ceiba, Adina cordifolia.* Other common associated species in all three forest were*Trewia nudiflora, Adina cordifolia, Murraya koenigii, Aegle marmelos*.

3.2 Field Sampling

The field sampling was conducted in the Janauary, 2020. The stratified random sampling method was used for locating the sampling plots, the forest blocks designated by the Community Forest User's Group(CFUGS) were considered as strata. Total number of plots to be sampled was proportionately distributed among the blocks based on their area. To estimate the carbon stock of the tree 30 square quadrats (10 m× 10m) were sampled in each forest. In each quadrat the number of individual trees [diameter at breast height (1.37 m), dbh ≥ 10 cm] of each species was counted and dbh of each tree was measured .Trees on the border were also included if ≥50% of their basal area fell within the plot. While measuring the DBH of trees of unusual shape (like tree with fork stem) practice of MacDicken (1997) was adapted. DBH tape was used for measuring diameter and a clinometer was used to estimate the tree height. The 10m×10m square qudrats was divided into 3 sub plots of 5m×5m for shrub and 3 sub plots with 2m×2m for herbs to estimate biodiversity. Similarly,seedling >5000 and sapling >2000 per hectare (HMG, 2004) (cited in Pandey *et al*., 2012) were considered for regeneration. Forest regeneration saplings were considered with height 15 cm as Thapa Magar and Shrestha (2015) in shrubs plot. Each shrub species inside the plots and if species ≥ 50% of their basal area fell within the plot were also recorded. Similarly, seedling of tree species was considered with height < 15cm in the herbs plot.

Geographicallocation (latitude, longitude and elevation) of each main plot was recorded using GPS at the center of the plot. Canopy cover for each plot was estimated by visual estimation method from the center of the plot. Most of the specimens were identified at the time of sampling measurement with the help of fieldguides (members of CFUGS) and consulting with local experts. Unidentified specieswere collected, tagged and pressed with the help of newspapers and these unidentified herbarium specimens were identified with the help of the book "Plant Resources of Kailali, West Nepal" (DPR, 2016)..

3.3 Quantitaive Analysis

For the vegetation analysis different parameter such as density, frequency, relative density, relative frequency, importance value index (IVI), and diversity index

(Shannon and Weiner 1963) were calculated for the species. Vegetation analysis was carried out by using Zobel *et al*., (1987).

$$\text{Density} = \frac{\text{Total no.of species occured}}{\text{Total no.of quadrat studied}} \times \frac{1}{\text{area of quadrat}}$$

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

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

$$\text{Relative Frequency} = \frac{\text{Frequency of individual species}}{\text{Total frequency of all species}} \times 100\%$$

$$\text{Abundance} = \frac{\text{Total number of plant species}}{\text{No.of plots in which species occured}} \times 100\%$$

$$\text{Relative Abundance} = \frac{\text{Total no.of individual species}}{\text{Total no.of individual of all species}} \times 100\%$$

3.3.1 Importance Value Index (IVI)

Importance value index is a measure of how dominant a species is in a given forest area. In this research work it was calculated by the following formula.

Important Value Index (IVI) =RD + RF + RA

Where, RD = Relative Density

RF = Relative Frequency

RA = Relative Abundance

3.3.2 Plant Diversity Index

Plant diversity index defined as the number of plants and abundance of each plant that live in a particular location. Plant species diversity was calculated based on Shannon diversity index and Simpson diversity index. Shannon diversity index was calculated using the general formula (Shannon and Weaver, 1949,Simpsons, 1949).

$$H = -\sum pi \times \ln pi$$

Where, H = Shannon's diversity index

Pi = Species proportion (based either on species count or species basal area)

Ln = natural logarithm

Simpson's diversity index was calculated using the formula;

Ds = 1-D

Ds value ranges between 0 and 1.

Where,

D = Simpson's index

Simpson's index (D) = $\frac{\sum(n-1)}{N\ (N-1)}$

N = total number of individual species (all species)

n = number of individuals of a particular species

3.3.3 Index of Similarity (IS)

Inter-specific association can be evaluated by calculating the index of similarity. It gives the degree of similarity between any two stands, which depends on the quantitative characters of species common to both stands. It is utilized to compare two existing groups.

Sorenson similarity index (ISs) = $\frac{2C}{(A+B)} \times 100$

Where, A= the total number of species in one sample

B= the total number of species in other sample

C= the number of species which occur in both samples

3.3.4 Basal Area

Basal area refers to the ground, penetrated by the stems in the soil. It is expressed in square meters. Basal area is regarded as an index of dominance of a species. Higher the basal area, greater is the dominance. Basal area of a tree species was determined by measuring either the diameter or circumference of the average tree at the breast height (1.37m) and was calculated using the following formula of Zobel *et* al., (1987).

Basal area (m^2) = $\frac{\pi D^2}{4}$

Where, $\pi = 3.14$

D=Diameter at breast height

Basal area in each plot was obtained by the summation of basal area of all trees in the plot and is given as m^2/ha.

3.4 Estimation of Biomass and Carbon Stock of trees

3.4.1 Estimation of Above and Below Ground Biomass

The equation developed by Chave *etal*., (2005) for moist forest stand was used to estimate above ground tree biomass. The equation was;

AGTB = $0.0509 \times \rho D^2 H$

Where, AGTB = above ground tree biomass (kg)

P = dry wood density (gm/cm^3)

D = tree diameter at breast height (cm)

H=height of tree (m)

Similarly, below ground biomass was calculated assuming 15% of the above ground tree biomass (Mack Dicken, 1997).

3.4.2 Wood Density

It was measured by wood density index given by Zanne *etal*., (2009).

3.4.3 Estimation of Carbon Stock

Total tree biomass was obtained by adding the above ground and below ground biomass of tree layer. When above ground biomass was multiplied by 0.47 and belowground biomass with 0.2 separately by default carbon fraction (IPCC, 2006), gave total C-stock in Kg. Then the area of all plots was calculated. Then after carbon stock in kg were divided by total area of plot. The obtained value in kg/m^2 was multiplied with 10,000 and divided by 1000 gave the C-stock in t/ha. Total carbon stock in the forest was obtained by adding above ground and below ground C-stock.

3.4.4 Carbon Stock of tree species

Carbon stock of an individual species in a forest was determined by adding the carbon stock values of that particular species in all plots of that forest. Percentage contribution of carbon stock of each species in a forest was calculated by taking the proportion of sum of carbon stock (t/ha) of all species in forest to the sum of carbon stock of a particular species in the same forest. It was calculated by following equation.

$$\text{Carbon stock of tree species (\%)} = \frac{\text{Carbon stock of a particular tree species}}{\text{Sum of carbon stock of all tree species}} \times 100$$

3.5 Regeneration Status of Forest

To estimate the regeneration status of forest, density of seedling, sapling and tree of each species were determined separately following the method described by Zobel *et* al., (1987).

Density was estimated by following equation;

$$\text{Density (stem/ha)} = \frac{\text{Tota no.of individual of each species in each life forms}}{\text{Total number of plot studied} \times \text{size of plots}} \times 10000$$

Total counts of plants were obtained by summation of the number of plants from all sampling plots.

3.6 Data Analysis Method

All statistical analysis were performed using SPSS 16.0 and excel 2016. One way ANOVA was used to compare Biomass and carbon stock between three different forests. Most of the species which were unidentified during field were identified with the help of field guides (members of community forest) and consulting with local experts. Unidentified herbarium specimens were identified with the help of the book "Plant Resources of Kailali, West Nepal" (DPR, 2016)

CHAPTER 4: RESULT

4.1 Vegetation Structure

4.1.1 Species Richness

Altogether 48 plant species were recorded in Gwasisamaigi Community Forest(GCF), 43 in Laxmi Community Forest (LCF) and 44 in Shiva Parbati communityforest(SCF). Species richness of trein previously managed Gwasisamaigi Community Forestwas found higher than other twes o forests which were managed by community later.Species richness of shrubs and herbs were found to be higher in SCF (Figure 4.1).

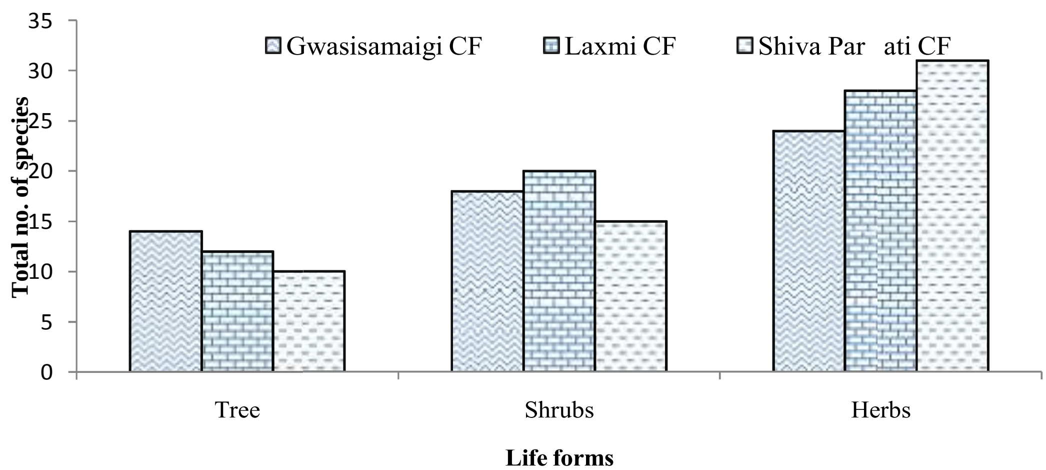


Figure 4.1: Species richness in Gwasisamaigi Community Forest, Laxmi Community Forest and Shiva Parwati Community Forest.

4.1.2 Importance value index (IVI)

For determination of IVI frequency, density, abundance and their relative values was considered for all life forms. In GCF, LCF and SCF all together 24, 28 and 31 species of herbs were recorded respectively.Among them in GCF *Oplismenus brumanii* and*Cynodon dactylon*had highest IVI i.e.42.71 and 36.46. Similarly in LCF and SCF*Cynodon dactylon* had highest IVIi.e 30.88 and 23.24. *Ageratum houstorium* and *Senna tora* were common herbs species found in all three forests with somewhat similar IVI (Table 4.1).IVI of all the recorded herbs in GCF, LCF and SCF are given in (AppendixV)

Table 4.1: Herbs species having highest IVI of Gwasisamaigi Community Forest (GCF),Laxmi Community Forest (LCF) and Shiva Parbati Community Forest (SCF).

Name of species	GCF(IVI)	LCF(IVI)	SCF(IVI)
Oplismenus brumanii	42.71	18.80	20.16
Cynodon dactylon	36.46	30.88	23.24
Barleria cristata	31.40	25.40	18.09
Ageratum houstorium	20.50	28.80	21.59
Senna tora	17.12	18.24	19.50

Altogether 18, 20 and 15 species of shrubs were recorded in GCF, LCF and SCF respectively. The IVI of shrub species collected from GCF, LCF and SCF is given in Annex V and some common shrubs with high IVI value is given in table 4.2. In GCF *Ziziphus nummularia, Acacia catechu* and *Urena lobata* had highest IVI of 27.19, 24.90 and 24.75, respectively. In LCF *Urena lobata* had highest IVI i.e 33.04 but in SCF *Murrya koeginii* and *Sida cordifolia* had highest IVI i.e. 47.05 and 43.34 respectively(Table 4.2). IVI of all the recorded shrubs in GCF, LCF and SCF are given in (AppendixVI).

Table 4.2: Shrubs species having highest IVI of Gwasisamaigi Community Forest, Laxmi Community Forest and Shiva Parbati Community Forest.

Name of species	GCF(IVI)	LCF(IVI)	SCF(IVI)
Ziziphus nummularia	27.19	31.44	24.90
Acacia catechu	24.90	16.62	18.78
Urena lobata	24.75	33.04	27.20
Bombax ceiba	24.05	8.24	_
Mallotus philippensis	26.80	19.78	16.30
Bidens pilosa	_	24.11	_
Murrya koeginii	_	16.96	47.05
Solanum Viarum	_	16.57	
Sida cordifolia	18.38	14.69	43.34

In GCF, LCF and SCF altogether 14, 12 and 10 Species of trees were recorded respectively. Among them*Acacia catechu* had highest IVI in all three forest i.e.61.96, 51.42 and 62.51 respectively. In GCF *Syzygium cumini* had lowest IVI i.e.8.34. In LCF *Adina cordifolia* had second highest IVI i.e. 35.97 and *Salix plectilis* had lowest IVI i.e. 11.46. Similarly in SCF after *Acacia catechu* species having highest IVI was*Holoptelea integrifolia* i.e. 49.66 and species with lowest IVI was *Terminalia Chebula*i.e. 14.16(Table 4.3).

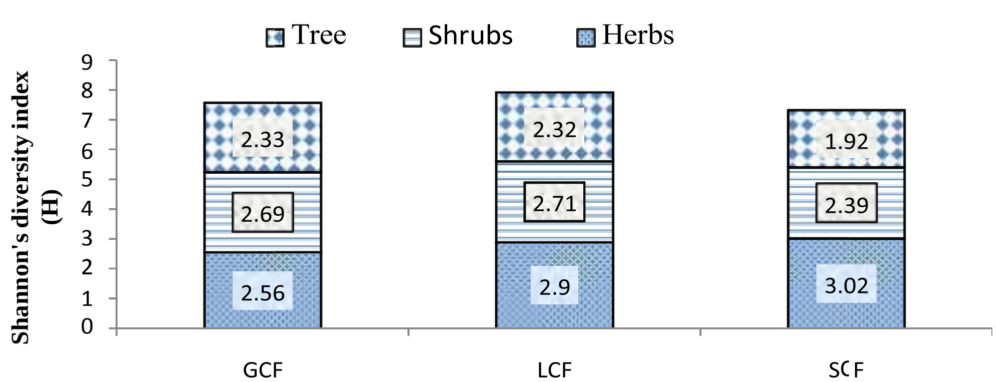
Table 4.3: Importance Value Index (IVI)of tree species in three community forest(GCF, LCF and SCF)

Name of species	Gwasisamaigi CF	Laxmi CF	Shiva Parbati CF
Acacia catechu	61.96	51.42	62.51
Adina cordifolia	45.16	35.97	25.51
Alstonia scholaris	33.79	30.62	22.70
Bombax ceiba	23.52	23.01	_
Trewia nudiflora	22.59	29.60	29.55
Mallotus philippensis	19.72	19.94	25.52
Dalbergia Sisoo	11.27	22.97	31.53
Aegle marmelos	10.19	13.56	_
Holoptelea integrifolia	16.64	30.12	49.66
Salix plectilis	9.12	11.46	22.33
Terminalia alata	10.19	_	_
Terminalia Chebula	11.27	_	14.16
Syzygium cumini	8.34	18.81	_
Garuga pinnata	11.27	12.51	16.55

4.1.3 Diversity indices

Diversity indices of herbs, shrubs and trees found in GCF, LCF and SCF are given in (Fig 4.2). Shannon Wiener (H) and Simpson diversity (Ds) indices values for herbs was found highest (i.e. H=3.02 and Ds=0.94) in SCF, for shrubs were found highest (i.e.H=2.71 and Ds=0.93) in LCF and that of tree were found highest (i.e H=2.33 and Ds=.92) in GCF.

(A)



(B)

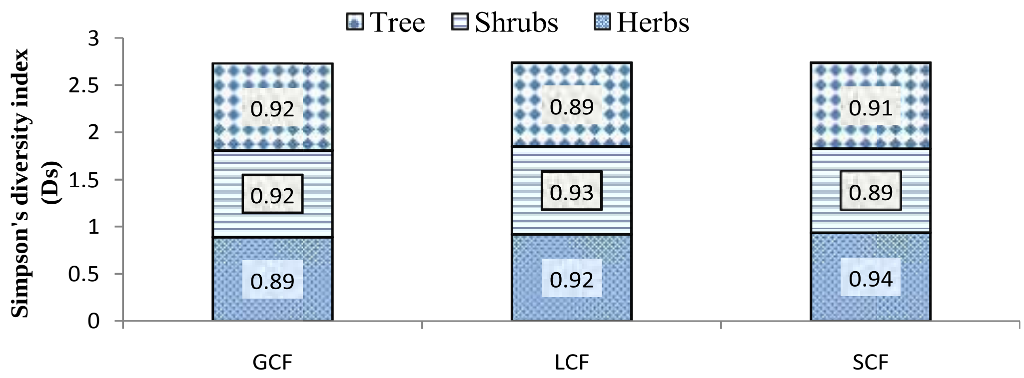


Fig4.2: (A) Shannon diversity index of all species, (B) Simpson's diversity index of all species.

GCF, LCF and SCF had large number of common herbs, shrubs, and trees species, hence the index of similarity among these three forests was calculated and given in (Table 4.4). The highest similarity index for herbs was observed between LCF and SCF (i.e.91.52%), for shrubs between GCF and SCF(i.e.90.90%), and for trees between GCF and LCF(i.e 84.61%).

Table 4.4: Similarity index (%) between Gwasisamaigi Community Forest (GCF),Laxmi Community Forest (LCF) and Shiva Parbati Community Forest (SCF).

Habit	**Index of similarity (%)**		
	GCF-LCF	**GCF-SCF**	**LCF-SCF**
Herbs	76.92	80	91.52
Shrubs	73.68	90.90	68.57
Tree	84.61	37.5	72.72

4.2 Forest Regeneration

Total density of seedling, sapling and tree of all species in GCF were 2870,5893.33 and 753 stem/ha respectively (Fig4.3). Similarly, in LCF the density of seedling,sapling and tree were3750, 4103 and 703stem/ha respectively, where as in SCF the densityof seedling, sapling and tree were 5547, 3633and700 stem/ha respectively. Density of seedling was found to be higher at SCF than other two community forests, density of sapling was found higher at GCF and that of trees at GCF than other two CFs.

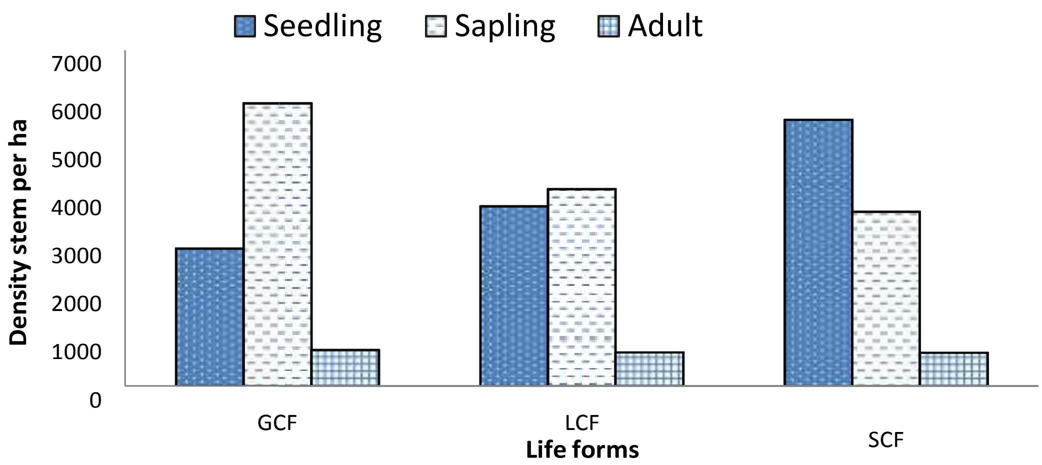


Figure4.3: The regeneration status of all trees species in Gwasisamaigi Community Forest, Laxmi Community Forest and Shiva Parbati Community Forest.

4.2.1 Density Diameter Relationship of Tree

Tree density was highest in diameter class 50-60cm (230stem/ha) followed by 40-50cm (213stem/ha) in GCF. In LCF tree density was highest in diameter class 50-60cm dbh (213stem/ha) followed by 40-50cm dbh (167stem/ha) where as in SCF tree density was highest in diameter class 50-60cm (193stem/ha) followed by 40-50cm (160stem/ha).This showed that most of the stands were at intermediate stage of growth. Density rapidly increased at DBH class 40-50 cm and 50-60 cm and then it decreased rapidly or drastically (Fig 4.4). Very few trees were recorded having DBH higher than 100cm at GCF and LCF and not recorded in SCF. In all three community forest omega 'Ω' shaped density diameter curve was observed which refers density of very young trees and very old trees are less, but the density of matured (mid sized) trees are high.

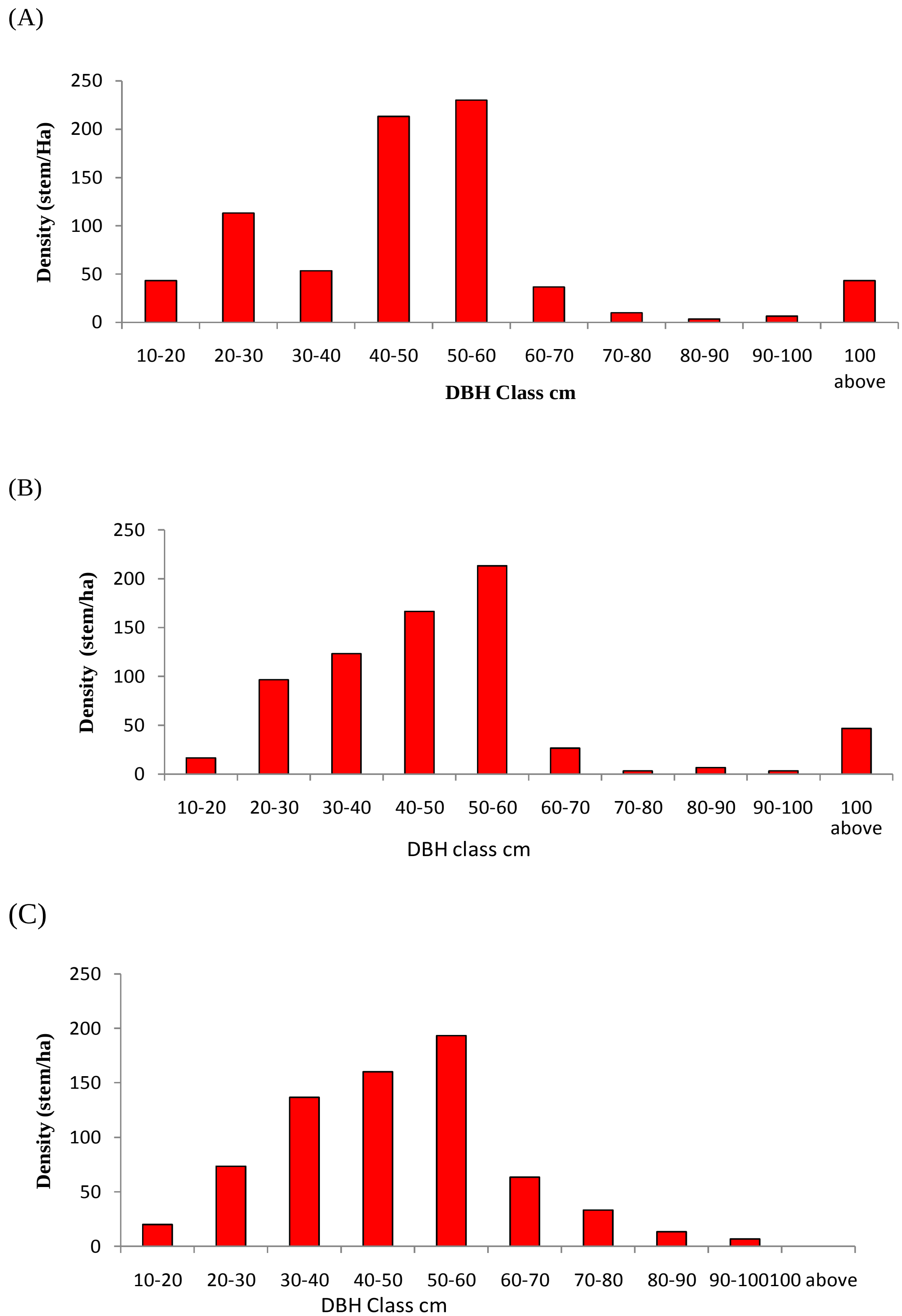
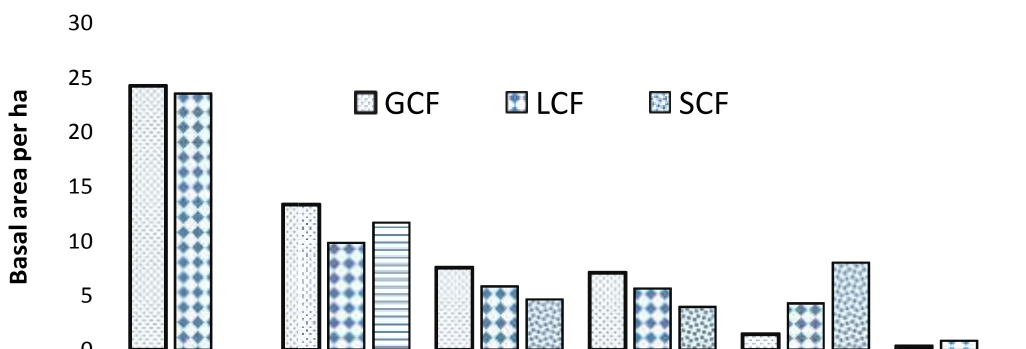


Figure 4.4: Density diameter relationship of trees in (A) Gwasisamaigi Community Forest, (B) Laxmi Community Forest, (C) Shiva Parbati Community Forest.

4.2.2 Basal Area

In Gwasisamaigi CF, basal area of *Bombax ceiba*, *Acacia catechu*and *Alstonia scholaris*were 24.21, 13.33 and 7.55m^2/ha, respectively, but at Laxmi CF basal area of *Bombax ceiba*, *Acacia catechu* and *Alstonia scholaris*were 23.49, 9.81 and 5.81m^2/ha. At Shiva Parbati CF basal area of *Acacia catechu*, *Holoptelea integrifolia* and*Alstonia scholaris*were 11.67, 8.01 and4.62m^2/ha respectively. Other major associated species were *Adina cordifolia*, *Dalbergia sisoo, Trewia nudiflora, Gruga pinnata.* Highest value of basal area of *Bombax ceiba* i.e. 24.21 was recorded at GCF and LCF and that of*Acacia catechu* i.e.11.67was at SCF (Fig 4.5). This indicated that the forest at GCF and LCF were dominatedby *Bombax ceiba* and at SCF with*Acacia catechu* species.



	Bombax ceiba	Acacia catechu	Alstonia scholaris	Adina cordifolia	Holoptelea integrifolia	Syzium cumini
GCF	24.21	13.33	7.55	7.09	1.46	0.32
LCF	23.49	9.81	5.81	5.61	4.28	0.86
SCF		11.67	4.62	3.93	8.01	

Name of species

Figure 4.5: Basal area of species in Gwasisamaigi Community Forest, Laxmi Community Forest and Shiva Parbati Community Forest.

4.3 Tree Biomass and Carbon stock

4.3.1 Tree Biomass

Among three forests, GCF had highest total biomass in plots having an area of 100m^2 (Table 4.7). One way ANOVA followed by Duncan's multiple range test at p=0.05 was done to investigate if the biomass of one forest differs from other or not. It was found that the biomass of trees at the community forest which were managed for longer period of time i.e. GCFshowed significant difference (p=0.05) than other two community forests (Fig4.6)

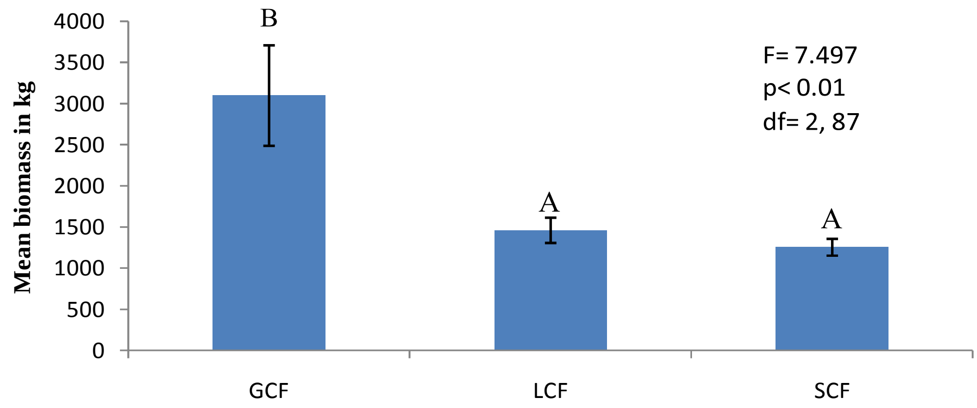


Figure 4.6: Total biomass of trees (mean and Std. error) found in 100m^2 area at GCF, LCF and SCF.

Same capital letters above the graph indicatesthe biomass is (mean±std. error) insignificantlydifferent according to oneway ANOVA followed by Duncan's multiple range test (N=90).

Among tree species *Bombax ceiba* had highest biomass inbothabove (i.e 171.28t/ha) and below ground (34.26t/ha) in two forests in GCF and 41.5t/ha in above ground and 8.3t/ha in below ground inLCF (Table 4.5). As the tree species *Bombax ceiba*was not recorded at SCF, highest biomass was recorded in *Acacia catechu*(46.95t/ha) in above ground and 9.39t/ha in below ground carbon stock (Table 4.7). At GCF *Dalbergia sisoo* had lowest biomass (0.23t/ha in above ground 0.045t/ha in below ground). At LCF*Aegle marmelos* had lowest biomass (i.e. 0.9t/ha in above ground and 0.1t/ha in below ground, and at SCF, *Mallotus philippensis*had lowest biomass (1.36t/ha in above ground and 0.27 t/ha in below ground).

Table 4.5: Above and below ground biomass of tree species in Gwasisamaigi community forest (GCF),Laxmi community forest (LCF) and Shiva parbati community forest (SCF)

Tree Species	AGB (t/ha) of GCF	BGB (t/ha) of GCF	AGB (t/ha) of LCF	BGB (t/ha) of LCF	AGB(t/ha) of SCF	BGB(t/ha) of SCF
Acacia catechu	50.19	10.03	37.82	7.56	46.95	9.39
Adina cordifolia	15.07	3.014	14.56	2.91	10.83	2.16
Alstonia scholaris	9.96	1.99	7.7	1.54	6.81	1.36
Bombax ceiba	171.28	34.26	41.5	8.3		
Trewia nudiflora	0.92	0.19	1.89	0.38	3.02	0.6
Mallotus philippensis	0.78	0.16	1.43	0.29	1.36	0.27
Dalbergia Sisoo	0.23	0.045	2.4	0.48	6.99	1.39
Aegle marmelos	0.28	0.05	0.9	0.18	-	-
Holoptelea integrifolia	3.31	0.66	9.9	1.98	20.49	4.09
Gardneria angustifotia	2.64	0.52	2.49	0.49	5.12	1.02
Salix plectilis	0.95	0.18	0.16	0.032	1.8	0.36
Terminalia alata	3.15	0.63				
Terminalia chebula	0.54	0.1			1.52	0.3
Syzygium cumini	0.57	0.11	1.71	0.34		
Total	**259.87**	**51.939**	**122.46**	**24.482**	**104.89**	**20.94**

4.3.2 Carbon stock

Among three forests GCF had highest carbon stock (146.58t/ha),followed byLCF(69.10t/ha)and least was observed at SCF (59.2t/ha) (Table 4.6). In GCF Bombax ceibahad highest contribution for carbon stock(i.e 96.61t/ha) followed by

Acacia catechu(28.31t/ha, Adina cordifolia(8.50t/ha), Alstonia scholaris(5.62t/ha) and so on (Table 4.8). In LCF Bombax ceiba had highest contribution for carbon (i.e 23.41t/ha) followed by Acacia catechu(21.33t/ha), Adina cordifolia(8.21t/ha) and so on. But in SCF Acacia catechu had highest contribution for carbon stock(i.e 26.48t/ha) followed by Holoptelea integrifolia(11.56t/ha),Adina cordifolia(6.11 t/ha) and so on (Table 4.6).

Table 4.6: Species wise carbon stock in Gwasisamaigi Community Forest (GCF), Laxmi Community Forest (LCF) and Shiva Parbati Community Forest (SCF).

Tree Species	**GCF carbon stock(tons/ha)**	**LCF carbon stock (tons/ha)**	**SCF carbon stock (ton/ ha)**
Acacia catechu	28.31	21.33	26.48
Adina cordifolia	8.50	8.21	6.11
Alstonia scholaris	5.62	4.35	3.85
Bombax ceiba	96.61	23.41	_
Trewia nudiflora	0.52	1.07	1.71
mallotus philippensis	0.44	0.81	0.77
Dalbergia Sisoo	0.13	1.35	3.95
Aegle marmelos	0.16	0.51	_
Holoptelea integrifolia	1.87	5.59	11.56
Garuga pinnata	1.49	1.41	2.89
salix plectilis	0.53	0.09	1.02
Terminalia alata	1.78	_	_
Terminalia chebula	0.31	_	0.86
syzygium cumini	0.32	0.97	_
Total	**146.58**	**69.10**	**59.2**

One way ANOVA followed by Duncan's multiple range test at p=0.05 was done to investigate if the carbon stock of one forest differs from other or not. It was found that the carbon stock of trees at the community forest which were managed for longer period of time i.e. GCF showed significant difference (p=0.05) than other two community forests (Fig4.7).

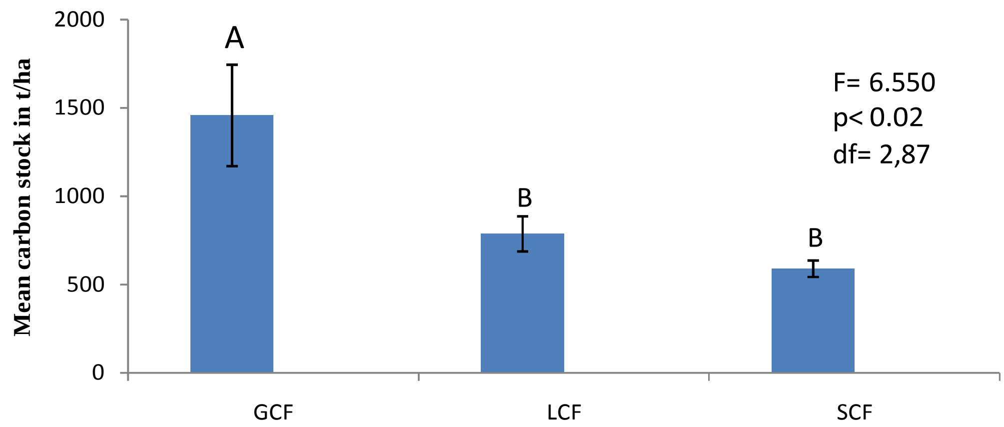


Figure 4.7: Total carbon stock of trees (mean and Std. error) found in 100m^2 area at GCF, LCF and SCF

Same capital letters above the graph indicates the carbon stock is (mean±std. error) insignificantly different according to oneway ANOVA followed by Dunca's multiple range test (N=90).

4.3.2 Contribution of Species in Tree Carbon Stock

The value of carbon stock measured 146.58t/ha in GCF, 69.10t/ha in LCF and 59.2t/ha in SCF (Table 4.6). Average contributions were highl in GCF with maximum carbon stock(65.90%) from*Bombax ceiba* and relatively low percentage of carbon from *Dalbergia sisoo* (0.09%) and other species in (table 4.9). In LCF also the highest contribution of Carbon stock were from *Bombax ceiba*(33.87%), followed by*Acacia catechu*(30.87%), *Adina cordifolia*(11.89%) (Table 4.7.b).At SCF contribution of carbon stock of *Acacia catechu*(44.74%) was highest and was followed by*Holoptelea integrifolia*(19.52%), *Adina cordifolia*(10.33%) and *Dalbergia sisoo*(6.67%) and were almost propotional (table 4.7).

Table 4.7: Carbon stock with percentage contributionof different tree species at GCF, LCF and SCF.

Name of species	GCF carbon stock(tons/ha)	Carbon stock(%)	LCF carbon stock(tons/ha)	Carbon stock(%)	SCF carbon stock (ton/ha)	Carbon stock(%)
Acacia catechu	28.31	19.31	21.33	30.87	26.48	44.74
Adina cordifolia	8.50	5.80	8.21	11.89	6.11	10.33
Alstonia scholaris	5.62	3.83	4.35	6.29	3.85	6.50
Bombax ceiba	96.61	65.90	23.41	33.87	_	_
Trewia nudiflora	0.52	0.36	1.07	1.55	1.71	2.88
Mallotus philippensis	0.44	0.30	0.81	1.17	0.77	1.30
Dalbergia Sisoo	0.13	0.09	1.35	1.96	3.95	6.67
Aegle marmelos	0.16	0.11	0.51	0.74	_	_
Holoptelea integrifolia	1.87	1.28	5.59	8.08	11.56	19.52
Garuga pinnata	1.49	1.02	1.41	2.04	2.89	4.89
Salix plectilis	0.53	0.36	0.09	0.13	1.02	1.72
Terminalia alata	1.78	1.21	_	_	_	_
Terminalia chebula	0.31	0.21			0.86	1.46
Syzygium cumini	0.32	0.22	0.97	1.40	_	_

CHAPTER 5: DISCUSSION

5.1 Plant Diversity

Diversity is the variety and variability of diverse form of living organisms on the earth and Plant diversity is the variability of the tree species in a forest. Plant diversity was found higher in old community managed forest (GCF) than other two forests.The result obtained in this study was similar to Brockyway (1998); he suggested that old growth forests were known to support high level of plant diversity. Diversity indices, Shannon Wiener (H) and Simpson diversity (Ds) value for tree and shrubs were found highest in both GCF and LCF than SCF.This discontinuity in tree and shrub species in SCF might be due to higher habitat heterogeneity, weak management committee, over grazing by cattle and fodder collection. The result of this study resembled to the results of Shrestha (1997) in natural and degraded forests of Chitrepani Makawanpur District. However diversity of herbs was higher in recently managed community forest (SCF) than in previously managed community forest (LCF and GCF). Similarly, by comparing the similarity index value of herbs among these three forest lowest value for this was found between(GCF-LCF) and (GCF-SCF) than in Community forest which are under recently community managed forest (LCF-SCF), which might be due to low density of shrubs and sapling in SCF and LCF. Berlow *et al.*, (2003), also observed higher species diversity of herbs in the area with less shrubs cover due to response of herbs to removal of shrubs or low availability of shrubs. In this study possibly GCF with greater management period must have supported more species of shrubs and trees. Similarly, diversity indices- , Shannon Wiener (H) and Simpson diversity (Ds) value for herbs was found higher in SCF which might be due to the presence of more open canopy which facilitates understory vegetation like *Oplismenus brumanii*, *Cynodon dactylon* and*Ageratum houstorium* were most common herbs species. Tree species diversity varied among forest mainly due to variation in biogeography, habitat and disturbance(Sagar *etal*., 2003).

Tree density varied among three CFs. Lower numbers of tree species in all studied CFs might be due to over exploitation of the trees and habitat degradation in the past. Presence of high sapling and seedling density than tree density in all CFs indicated that all forests were regenerating. Tree density in Gwasisamaigi CF was 753.32 stem/ha, Laxmi CF 703 stem/ha, and in Shiva Parbati CF 699.97 stem/ha (Figure 4.2).

The tree density found in these three CFs were higher than the values reported by Kandel (2007) in community forest of Chitwan (202 stem/ha) and Basyal (2005) in sal forest of Palpa district (209 stem/ha). The tree density in these three CFsresembled to the reported values from different CFs of midhill, 429 stem/ha to 94 stem/ha (Karmacharya *et al*., 2004). Gautum (2002) reported that, tree density in Dhulikhel forest were 407 to 503, stem/ha. But the tree density reported by Shrestha(2005) in community forest of Gorkha (909 stem/ha), Shrestha (1997) in Chitrepani (Siwalik region) of Makawanpur district (1326 stem/ha), Marasini (2003) in Churia forest of Rupandehi district (1153 stem/ha) were higher than the tree density of present studied forests. Therefore the total tree density of studied forests showed intermediate value. This might be due to over exploitation and lack of management group of studied forests in the past. But it seems to be regenerating after handover to community groups.

Total tree basal area was found to behigher at Gwasisamaigi CF (58.63 m^2 /ha). In Laxmi and Shiva Parbati CF its values were 55.2 and 37.64 m^2 /ha, respectively. High basal area of GCF can be attributed due to presence of greater number of tree species in this community forest because of its longest duration among the three CF and also good practices under community forest management system. These values were higher than the value reported by Webb and Shah (2003) in natural forest of terai (11 m^2 /ha), Kandel (2007) in natural sal forest in Chitwan (17.65 m^2 /ha). The basal area is an important criterion for evaluating the timber productionin forest ecosystem (Agrawal, 1992). There existed differences in total basal area among three forests. Total tree basal area of Shiva Parbati Forest was the lowest while it was highest in Gwasisamaigi CF and Laxmi CF. Tree basal area was found the least in Shiva Parbati CF, which might be due to low density large sized trees. A forest with low basal area was found in Shiva Parbati CF because the forest was totally regenerating.

5.2 Regeneration

The abundance and density of seedling and saplings indicates the regeneration potential of a community forest (Pallardy, 2010). However, the population density of seedlings was twice as high in SCF as in GCF. Mild disturbance in the forest causes open canopy of the forest which allows the growth of seedling and sapling and this ensures sustainable regeneration. As GCF is a mature forest with closed canopy, seedling establishment is constrained by low light intensity on forest floor. Removal of canopy trees increased light intensity to the forest floor and reduced litter accumulation, which is favorable for seed germination and sapling establishment of species (Carlton *etal.*, 1998). As *Acacia catechu* and *Holoptelea integrifolia* are strong light demanding species and donot tolerate shade during regeneration that's why seedling of these trees were found more in SCF, as this forest has open canopy. Similarly sapling density was found higher in GCF than LCF and SCF. Though the trees of associated species like *Dalbergisa sisso, Salix pectalis, Alstonia scholaris, Garuga pinnata* and *Terminalia chebula* were found in SCF but their sapling were not found in this forest which was due to lack of proper management, illegal logging, high pressure of fodder collection and timber collection. Sapling density in all CFs was higher than the reported value from Terai and Siwalik (3,393 to 3,127 stem/ha, Acharya *et al.,* 2006). In all three forests regeneration is proceeding well with more number of seedlings and sapling then the adult Trees. Forest with low dense tree density in comparison with high dense tree density show good result for regeneration, It might be due to faster nutrient cycling and plenty of light availability on the forest floor in the warmer climate (Aiba *et al.,* 1999).

Regeneration status of the forest is said to be good if the forest has seedling >5000 and sapling >2000 per hectare (HMG, 2004) (cited in Pandey *et al*., 2012). Regeneration status of forests in the present study was 2870 seedlings and 5893 saplings stem/ha in GCF, seedling 3750 and sapling 4103 stem/ha in LCF and 5547 seedling and 3633 stem/ha in SCF. Among three community forest, SCF meets the target for both seedling and sapling number mentioned above (as in HMG, 2004). Hence, the regeneration statusof SCF can be considered in good condition in comparison to other two forests. The other two forests also meet the number of sapling more than 2000 hectare and hence can be considered to have good regeneration. The seedlings were less than 5000/hectare in GCF and LCF, which might be due to less availability of light due to more sapling and canopy cover of trees and other shrubs.To maintain stability of forest, regeneration is important. GCF and LCF are comparatively older community forest than the young SCF, As SCF was young community forest, rapid regeneration was observed, but GCF and LCF had already reached certain maturity to some extent.

5.3 Biomass and Carbon stock

The carbon stock measured was found to be higher(146.5 t/ha) at GCF, than at LCF (69.10 t/ha) and SCF (59.2 t/ha). At GCF contribution of maximum carbon stock (i.e 65.90%) was of *Bombax ceiba* and relatively least were of *Termanalia chebula* (0.21%) and *Syzium cumini* (0.22%).*Bombax ceiba* was the highest contributor of Carbon stock in Gwasisamaigi community forest (i.e. 65.90% in old forest), because of its highest basal area in old forest. The rate of carbon sequestration is much faster in young and regenerating forest but C-stock is more in old and mature forest (Luyssaert *et al.*, 2008; Nair *et al.*, 2009). The trees present at GCF scored even more than 100cm DBH as it is a regenerating forest. Hence, the Standing C- stock of old growth forest (GCF) was higher than the newly regenerating forest SCF. Similar result was also observed by Singh and Singh, (1992) in forest of western Himalaya, India. Above ground biomass was found 259.87t/ha in GCF and *Bombax ceiba* had contributed the highest in this forest, which was mainly due to the highest basal area than other species. But this *Bombax ceiba* speices was not found in recently managed community forest i.e (SCF)as this species might have been destroyed by CFUGs at its sapling stage. Pandit (2014) reported vegetation types, age of the stand, the surrounding environment, management activities and other human induced disturbances are the key factors in variation of carbon stock and carbon sequestration in forests. Hence, poor management practices and human disturbance may also be one of the reason for having less carbon stock in SCF.

The above ground biomass was 122.46 t/ha in LCF and 104.89t/ha in SCF. In LCF highest biomass was contributed by *Bombax ceiba* (41.5%), *Acacia catechu* (37.82%) and *Adina cordifolia* (14.56%). In SCF highest biomass was contributed by *Acacia catechu* (46.95%) and *Holoptelea integrifolia* (20.49%). Similar findings was obtained by Sejuwal (1994) in the riverine forest of Chitwan National Park (CNP).Tree characteristics like DBH and height directly influence biomass production. Lower value of DBH and height results into lower biomass and Carbon stocks (Feldpausch *et al*., 2012). Similarly, in SCF trees with lower DBH has resulted in lower biomass. Insignificant difference at p=0.05 was obtained from the Duncans muntiple range test followed after one way ANOVA for biomass and carbon stock of trees at LCF and SCF. But previously managed forest GCF showed significantly (p=0.05) high biomass and carbon stockthan other two forest (Figure 4.6 & figure

4.7). This could be due to various reasons like species composition, age of the forest, canopy cover, stand structure (Pandey *et al*., 2014; Karki *et al*., 2016; Dar *et al*., 2017). As GCF forest has more trees with greater basal area and DBH. CFUGS of this forest get more timber seasonally in comparison to other two forests.As grazing has been banned in all three forests but cattles which were left unnecessarily haddestroyed the SCF forest. This condition was not found in GCF as this forest has fencing. Forbs and grasses were allowed to collect round the year in all community forests. Harvesting of grass, fodder from woody species, fuel wood from dry and deadbranches, and leaf litter were allowed to collect for free in all CF. The user group hadestablished two system of pricing for timber harvesting; one was based on cubic feet.(Rs. 40 for one cubic feet.), and other was based on pole size (Rs. 150 to Rs. 500 depending on the pole size) in all CF. Community Forest User's Groups(CFUGS) ofShiva Parbati Community Forest collect timber products from their forests because itis degraded forest and has lower density of trees.Similarly SCF was highly dominated by *Holoptelea integrifolia* its leaves fall at greater amount during winter and litter collection was highest in this forest.

CHAPTER 6: CONCLUSION AND RECOMMENDATION

6.1 Conclusion

From this study it can be concluded that plant diversity is higher at the Gwasisamaigi Community Forest(old forest) than the other two Laxmi Community Forest (mid aged) and Shiva Parbati Community Forest (recently managed). This clearly shows that the plant diversity increases with forest management duration. Similarly Carbon stock and biomass increased with the increase in duration of management period. In Shiva Parbati community forest regeneration was favouredbecause of open canopy.In GCF *Bombax ceiba* was highest contributor to carbon stock as it was a tree with more basal area and DBH. But in SCF *Acacia catechu* and *Holoptelea integrifolia* were highest contributor for carbon stock. From this study it can also be concluded that plant diversity and carbon stock of forest increases with increase in management duration of forest.As management period among three community forests varied, biomass of forest also varied. Gwasisamaigi Community Forest (old forest) showed highest mean biomass than other two forests.

6.2 Recommendation

i. As age of the forest management promotes the diversity,regeneration and carbon stock of plant species, therefore, management committee of forest need tobe strict inorder to protect forest from unnecessary use of forest products.

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APPENDICES

APPENDIX I

Data sheet used in field sampling

Date: District:

Locality: Altitude:

Slope: Latitude:

Longitude: Plot size:

Quadrat no: Quadrat size:

Canopy cover (%): Ground vegetation cover

Litter cover (%):

S.N	**Plant species**	**Local name**	**DBH(cm)**	**Height(m)**	**Remarks**

APPENDIX II

Geographical position of plots with different variables measured in these plots. Where, plot number 1-30; for GCF, 31-60; for LCF and 61-90 for SCF(Alt-altimeter).

Plot no.	Alt(m)	Longitude	Latitude	Slope(˚)
1	221	80˚38' 33"E	28˚46' 45"N	0˚
2	220	80˚38'31"E	28˚46'46"N	0˚
3	223	80˚38'27"E	28˚46'48"N	0˚
4	223	80˚38'25"E	28˚46'49"N	0˚
5	222	80˚38'14"E	28˚46'56"N	0˚
6	222	80˚38'14"E	28˚46'57"N	0˚
7	220	80˚38'15"E	28˚46'56"N	0˚
8	222	80˚38'17"E	28˚46'54"N	0˚
9	225	80˚38'7"E	28˚47'19"N	0˚
10	226	80˚38'5"E	28˚47'14"N	0˚
11	226	80˚38'5"E	28˚47'12"N	0˚
12	225	80˚38'8"E	28˚47'10"N	1˚
13	225	80˚38'9"E	28˚47'8"N	0˚
14	222	80˚38'14"E	28˚46'57"N	0˚
15	224	80˚38'11"E	28˚47'4"N	0˚
16	225	80˚38'11"E	28˚47'5"N	0˚
17	222	80˚38'18"E	28˚46'52"N	0˚
18	222	80˚38'21"E	28˚46'50"N	0˚
19	223	80˚38'24"E	28˚46'49"N	0˚
20	223	80˚38'25"E	28˚46'49"N	0˚
21	200	80˚39'5"E	28˚46'33"N	0˚
22	222	80˚38'30"E	28˚46'46"N	1˚
23	223	80˚38'29"E	28˚46'47"N	0˚
24	222	80˚38'17"E	28˚46'53"N	0˚
25	197	80˚38'21"E	28˚46'41"N	0˚
26	223	80˚38'14"E	28˚47'0"N	0˚

27	224	80˚38'13"E	28˚47'1"N	0˚
28	224	80˚38'15"E	28˚47'9"N	0˚
29	225	80˚38'11"E	28˚47'6"N	0˚
30	225	80˚38'11"E	28˚47'7"N	0˚
31	240	80˚39'2"E	28˚46'38"N	0˚
32	236	80˚39'3"E	28˚46'37"N	0˚
33	236	80˚39'3"E	28˚46'35"N	0˚
34	242	80˚39'10"E	28˚46'33"N	1˚
35	231	80˚39'11"E	28˚46'33"N	0˚
36	231	80˚39'9"E	28˚46'35"N	0˚
37	237	80˚39'8"E	28˚46'35"N	0˚
38	242	80˚39'7"E	28˚46'31"N	0˚
39	237	80˚39'8"E	28˚46'29"N	0˚
40	219	80˚38'56"E	28˚46'34"N	0˚
41	217	80˚38'57"E	28˚46'39"N	0˚
42	220	80˚38'47"E	28˚46'47"N	0˚
43	219	80˚38'47"E	28˚46'48"N	0˚
44	231	80˚38'44"E	28˚46'52"N	0˚
45	236	80˚39'5"E	28˚46'35"N	0˚
46	234	80˚39'6"E	28˚46'34"N	0˚
47	238	80˚39'9"E	28˚46'33"N	0˚
48	242	80˚39'7"E	28˚46'33"N	0˚
49	242	80˚39'7"E	28˚46'32"N	0˚
50	237	80˚39'7"E	28˚46'30"N	0˚
51	238	80˚39'9"E	28˚46'29"N	0˚
52	238	80˚39'8"E	28˚46'28"N	0˚
53	239	80˚39'7"E	28˚46'27"N	0˚
54	233	80˚39'8"E	28˚46'27"N	0˚
55	220	80˚38'55'E	28˚46'31"N	0˚
56	239	80˚39'11'E	28˚46"30"N	0˚
57	220	80˚38'55'E	28˚46'33"N	0˚
58	242	80˚39'9"E	28˚46'35"N	0˚

59	231	80˚39'15"E	28˚46'32"N	0˚
60	240	80˚39'4"E	28˚46'36"N	0˚
61	242	80˚38'23"E	28˚48'24"N	0˚
62	242	80˚38'24"E	28˚48'32"N	0˚
63	242	80˚38'23"E	28˚48'28"N	0˚
64	233	80˚38'22"E	28˚48'25"N	0˚
65	231	80˚38'23"E	28˚48'23"N	0˚
66	236	80˚38'24"E	28˚48'23"N	0˚
67	235	80˚38'25"E	28˚48'21"N	0˚
68	252	80˚38'26"E	28˚48'19"N	0˚
69	249	80˚38'28"E	28˚48'17"N	0˚
70	248	80˚38'27"E	28˚48'13"N	0˚
71	254	80˚38'25"E	28˚48'14"N	0˚
72	227	80˚38'26"E	28˚48'12"N	0˚
73	236	80˚38'23"E	28˚48'12"N	0˚
74	236	80˚38'24"E	28˚48'10"N	0˚
75	243	80˚38'24"E	28˚48'8"N	0˚
76	243	80˚38'24"E	28˚48'7"N	0˚
77	244	80˚38'22"E	28˚48'6"N	0˚
78	244	80˚38'22"E	28˚48'4"N	0˚
79	227	80˚38'26"E	28˚48'6"N	0˚
80	227	80˚38'25"E	28˚48'4"N	0˚
81	239	80˚38'26"E	28˚48'4"N	0˚
82	240	80˚38'27"E	28˚48'4"N	0˚
83	240	80˚38'27"E	28˚48'7"N	0˚
84	240	80˚38'29"E	28˚48'8"N	0˚
85	245	80˚38'28"E	28˚48'11"N	0˚
86	239	80˚38'29"E	28˚48'15"N	0˚
87	241	80˚38'31"E	28˚48'14"N	0˚
88	241	80˚38'32"E	28˚48'16"N	0˚
89	241	80˚38'35"E	28˚48'14"N	1˚
90	241	80˚38'37"E	28˚48"15"N	0˚

APPENDIX III

Wood density of tree species used to estimate carbon stock using equation Chave *et al*., (2005)

Species name	**Wood density (g/cm^3)**
Acacia catechu	0.801
Adina cordifolia	0.48
Alstonia scholaris	0.35
Bombax ceiba	0.35
Trewia nudiflora	0.44
Mallotus philippensis	0.64
Dalbergia Sisoo	0.76
Aegle marmelos	0.77
Holoptelea integrifolia	0.5
Salix plectilis	0.28
Terminalia alata	0.75
Terminalia chebula	0.88
Syzygium cumini	0.76
Garuga pinnata	0.64

APPENDIX IV

Herbs, shrubs and trees species found in Gwasisamaigi Community Forest, Laxmi Community Forest and Shiva Parbati Community Forest.

S.N.	**Scientific name of herbs**	**Scientific name of shrubs**	**Scientific names of trees**
1	*Cynodon dactylon* (L.) Pers.	*Ziziphus nummularia* (Burm)	*Acacia catechu* (L.F.) Willd.
2	*Ageratum houstonianum* mill	*Sida cordifolia* (Linn)	*Haldina cordifolia* Roxb
3	*Senna tora* (L.)Roxb.	*Pogosteremon benghalensis*(Burn.F.)	*Alstonia scholaris*(L.)R.Br
4	*Hyptis suoveolens* (L.)Poit	*Urena lobata* L.	*Bombax ceiba* L.
5	*Barleria cristata* L.	*Chlerodendrum viscosum* L.	*Trewia nudiflora* L.
6	*Oplismenus brumanii* (Retz.) P.Beauv	*Alstonia scholaris*(L.)R.Br.	*Mallotus philippensis* (Lam.)
7	*Hemarthrua compressa* (L.f.)	*Colaebrockia oppositifolia* Sm.	*Dalbergia sisoo* Roxb.
8	*Justicia* L.	*Tinospora sinensis* (Lour.)	*Aegle marmelos* L.
9	*Sonchus asper* (L.)	*Ichnocarpus frutescens* L.	*Holoptelea integrifolia*
10	*Imperata cylindrica* L.	*Aegle marmelos* L.	*Garuga pinnata* Roxb.
11	*Cyperus compressus* (L.)	*Mallotus philippensis* (Lam.)	*Salix pectalis*
12	*Marselia*(L.)	*Syzygium cumini* L.	Terminalia alata B. Heyne Ex Roth
13	*Mimullus tinellus* (L.)	*Holoptelea integrifolia*	*Terminalia chebula* Retz.
14	*Evolvulus nummularies* (L.)	*Acacia catechu* (L.F.) Willd.	*Syzygium cumini* L

15	*Trifolium repens* (L.)	*Haldina cordifolia* Roxb.	
16	*Oxalis corniculata* (L.)	*Trewia nudiflora* L.	
17	*Colocasia esculenta* (L.) Schott	*Bombax ceiba* L.	
18	*Dioscorea bulbifera* (L.)	*Garuga pinnata* Roxb.	
19	*Elephantopus Scaber* Linn	*Murrya koeginii* L.	
20	*Bombax ceiba* L.	*Calotropis gigantea* (Linn.)	
21	*Mallotus philippensis* (Lam.)	*Bidens pilosa L.*	
22	*Acacia catechu* (L.F.) Willd.	*Solanum viarum* (Dunal.)	
23	*Cissampelos pareira* L.	*Bambusa vulgaris* ex. J.C. Wendl.	
24	*Equisetum arvense* L.	*Ficus religosa* L.	
25	*Sapindus mukorossi* Gaertn.		
26	*Syzygium cumini* L.		
27	*Aegle marmelos* L.		
28	*Saccharum spontaneum* L.		
29	*Dryopteris filix* Adans		
30	*Euphorbia hirta* L.		
31	*Xanthium strumarium* Linn		
32	*Holoptelea integrifolia*		

APPENDIX V

Frequency, density and abundance values of herbs in Gwasisamaigi Community Forest

Plant name	Total number of individual in 90 plot (Q)	F	RF%	D	RD%	A	RA%	IVI
Cynodon dactylon	1305	98.89	6.73	362.50	16.24	14.66	13.50	36.46
Ageratum houstorium	603	87.78	5.97	167.50	7.50	7.63	7.03	20.50
Senna tora	461	92.22	6.27	128.06	5.74	5.55	5.11	17.12
Hyptis suoveolens	74	26.67	1.81	20.56	0.92	3.08	2.84	5.57
Barleria cristata	1078	96.67	6.58	299.44	13.41	12.39	11.41	31.40
Oplismenus brumanii	1584	100.00	6.80	440.00	19.71	17.60	16.20	42.71
Hemarthrua compressa	334	100.00	6.80	92.78	4.16	3.71	3.42	14.37
Justicia species	258	83.33	5.67	71.67	3.21	3.44	3.17	12.05
Sonchus asper	60	42.22	2.87	16.67	0.75	1.58	1.45	5.07
Imperata cylindrical	105	45.56	3.10	29.17	1.31	2.56	2.36	6.76
Cyperus compressus	89	36.67	2.49	24.72	1.11	2.70	2.48	6.08
Marselia	477	83.33	5.67	132.50	5.94	6.36	5.85	17.46
Mimullus tinellus	187	73.33	4.99	51.94	2.33	2.83	2.61	9.92
Evolvulus nummularies	25	17.78	1.21	6.94	0.31	1.56	1.44	2.96
Trifolium	139	47.78	3.25	38.61	1.73	3.23	2.98	7.96
Oxalis	257	61.11	4.16	71.39	3.20	4.67	4.30	11.66
Colocasia esculenta	17	13.33	0.91	4.72	0.21	1.42	1.30	2.42
Dioscorea bulbifera	49	27.78	1.89	13.61	0.61	1.96	1.80	4.30
Elephantopus scaber	73	41.11	2.80	20.28	0.91	1.97	1.82	5.52
Bombax ceiba	221	95.56	6.50	61.39	2.75	2.57	2.37	11.62
Mallotus philippensis	301	98.89	6.73	83.61	3.75	3.38	3.11	13.59
Acacia catechu	339	100.00	6.80	94.17	4.22	3.77	3.47	14.49

Frequency, density and abundance values of herbs in Laxmi Community Forest

Plant name	**Total number of individual in 90 plot (Q)**	**F**	**RF%**	**D**	**RD%**	**A**	**RA%**	**IVI**
Cynodon dactylon	1232	98.89	5.79	54.76	14.51	13.84	10.58	30.88
Ageratum houstorium	1123	95.56	5.60	49.91	13.22	13.06	9.98	28.80
Senna tora	612	92.22	5.40	27.20	7.21	7.37	5.63	18.24
Hyptis suoveolens	437	85.56	5.01	19.42	5.15	5.68	4.34	14.49
Barleria cristata	953	92.22	5.40	42.36	11.22	11.48	8.77	25.40
Oplismenus brumanii	638	90.00	5.27	28.36	7.51	7.88	6.02	18.80
Hemarthrua compressa	267	77.78	4.56	11.87	3.14	3.81	2.91	10.62
Justicia species	221	83.33	4.88	9.82	2.60	2.95	2.25	9.74
Sonchus asper	87	53.33	3.13	3.87	1.02	1.81	1.38	5.53
Imperata cylindrical	190	55.56	3.26	8.44	2.24	3.80	2.90	8.40
Cyperus compressus	164	53.33	3.13	7.29	1.93	3.42	2.61	7.67
Achyranthes	94	46.67	2.73	4.18	1.11	2.24	1.71	5.55
Marselia	243	51.11	2.99	10.80	2.86	5.28	4.04	9.89
Mimullus tinellus	117	52.22	3.06	5.20	1.38	2.49	1.90	6.34
Evolvulus nummularies	88	46.67	2.73	3.91	1.04	2.10	1.60	5.37
Trifolium	258	63.33	3.71	11.47	3.04	4.53	3.46	10.21
Saccharum	153	33.33	1.95	6.80	1.80	5.10	3.90	7.65

spontaneum								
Oxalis	127	43.33	2.54	5.64	1.50	3.26	2.49	6.52
Cissampelos pareira	119	55.56	3.26	5.29	1.40	2.38	1.82	6.47
Colocasia esculenta	45	32.22	1.89	2.00	0.53	1.55	1.19	3.60
Equistem arvense	33	15.56	0.91	1.47	0.39	2.36	1.80	3.10
Dioscorea bulbifera	52	28.89	1.69	2.31	0.61	2.00	1.53	3.83
Elephantopus scaber	115	52.22	3.06	5.11	1.35	2.45	1.87	6.28
Aegle mamelos	93	24.44	1.43	4.13	1.10	4.23	3.23	5.76
Syzygium cumini	423	100.00	5.86	18.80	4.98	4.70	3.59	14.43
Mallotus philippensis	339	96.67	5.66	15.07	3.99	3.90	2.98	12.63
Acacia catechu	178	61.11	3.58	7.91	2.10	3.24	2.47	8.15
Sapindus mukorossi	92	25.56	1.50	4.09	1.08	4.00	3.06	5.64

Frequency, density and abundance values of herbs in Shiva Parbati Community Forest

Plant name	**Total number of individual in 90 plot (Q)**	**F**	**RF%**	**D**	**RD%**	**A**	**RA%**	**IVI**
cynodon dactylon	1017	82.22	5.58	45.20	10.73	13.74	6.93	23.24
Ageratum houstorium	923	86.67	5.89	41.02	9.73	11.83	5.97	21.59
Senna tora	801	78.89	5.36	35.60	8.45	11.28	5.69	19.50
Hyptis	669	77.78	5.28	29.73	7.06	9.56	4.82	17.16

suoveolens								
Barleria cristata	721	80.00	5.43	32.04	7.60	10.01	5.05	18.09
Oplismenus brumanii	832	71.11	4.83	36.98	8.77	13.00	6.56	20.16
Hemarthrua compressa	262	64.44	4.38	11.64	2.76	4.52	2.28	9.42
Justicia species	192	50.00	3.40	8.53	2.02	4.27	2.15	7.57
Sonchus asper	119	31.11	2.11	5.29	1.26	4.25	2.14	5.51
Imperata cylindrical	497	42.22	2.87	22.09	5.24	13.08	6.60	14.71
Cyperus compressus	199	31.11	2.11	8.84	2.10	7.11	3.58	7.80
Achyranthes	135	40.00	2.72	6.00	1.42	3.75	1.89	6.03
Marselia	299	46.67	3.17	13.29	3.15	7.12	3.59	9.91
Mimullus tinellus	419	42.22	2.87	18.62	4.42	11.03	5.56	12.85
Evolvulus nummularies	102	31.11	2.11	4.53	1.08	3.64	1.84	5.03
Trifolium	127	32.22	2.19	5.64	1.34	4.38	2.21	5.74
Saccharum spontaneum	70	10.00	0.68	3.11	0.74	7.78	3.92	5.34
Oxalis	56	8.89	0.60	2.49	0.59	7.00	3.53	4.72
Cissampelos pareira	74	15.56	1.06	3.29	0.78	5.29	2.67	4.50
Equistem arvense	73	14.44	0.98	3.24	0.77	5.62	2.83	4.58
Gettha bela	50	15.56	1.06	2.22	0.53	3.57	1.80	3.39
Dryopteris filix	43	13.33	0.91	1.91	0.45	3.58	1.81	3.17
Euphorbia hirta	37	12.22	0.83	1.64	0.39	3.36	1.70	2.92
Xanthium strumarium	52	24.44	1.66	2.31	0.55	2.36	1.19	3.40
Elephantopus scaber	49	14.44	0.98	2.18	0.52	3.77	1.90	3.40

Aegle mamelos	130	48.89	3.32	5.78	1.37	2.95	1.49	6.18
Syzygium cumini	333	97.78	6.64	14.80	3.51	3.78	1.91	12.06
Mallotus philippensis	413	100.00	6.79	18.36	4.36	4.59	2.31	13.46
Acacia catechu	400	93.33	6.34	17.78	4.22	4.76	2.40	12.96
Sapindus mukorossi	91	28.89	1.96	4.04	0.96	3.50	1.77	4.69
Holoptelea integrifolia	297	86.67	5.89	13.20	3.13	3.81	1.92	10.94

APPENDIX VI

Frequency, density and abundance values of shrubs in Gwasisamaigi Community Forest

Plant species	Total number of individual in 90 plots	F	RF%	D	RD%	A	RA%	IVI
Ziziphus nummularia	320	83.33	7.69	88.89	10.21	5.08	9.29	27.19
Sida cardifolia	173	70.00	6.46	48.06	5.52	2.75	5.02	17.00
Pogostermon benghalensis	150	64.44	5.95	41.67	4.78	2.59	4.73	15.46
Urena lobata	303	84.44	7.79	84.17	9.67	3.99	7.29	24.75
Chlerodendrum viscosum	114	54.44	5.03	31.67	3.64	2.33	4.26	12.92
Alstonia scholaris	62	40.00	3.69	17.22	1.98	1.72	3.15	8.82
Colaebrockia oppositifolia	40	31.11	2.87	11.11	1.28	1.43	2.61	6.76
Tinospora sinensis	17	16.67	1.54	4.72	0.54	1.13	2.07	4.15
Ichnocarpus frutescens	188	61.11	5.64	52.22	6.00	3.42	6.25	17.89
Aegle marmelos	112	46.67	4.31	31.11	3.57	2.67	4.88	12.76
Mallotus philippensis	337	98.89	9.13	93.61	10.75	3.79	6.93	26.80
Syzygium cumini	283	96.67	8.92	78.61	9.03	3.25	5.95	23.90

Holoptelea integrifolia	88	25.56	2.36	24.44	2.81	3.83	7.00	12.17
Acacia catechu	300	100.00	9.23	83.33	9.57	3.33	6.10	24.90
Adina cordifolia	194	48.89	4.51	53.89	6.19	4.41	8.07	18.77
Trewia nudiflora	90	32.22	2.97	25.00	2.87	3.10	5.68	11.52
Bombax ceiba	287	94.44	8.72	79.72	9.15	3.38	6.18	24.05
Garuga pinnata	77	34.44	3.18	21.39	2.46	2.48	4.54	10.18

Frequency, density and abundance values of shrubs in Laxmi Community Forest

Plant name	**Toal number of individual in 90 Q**	**F**	**RF%**	**D**	**RD%**	**A**	**RA%**	**IVI**
Ziziphus nummularia	576	94.44	7.69	160.00	14.13	1.88	9.623	31.44
Murrya koeginii	228	91.11	7.41	63.33	5.60	0.77	3.949	16.96
Sida cardifolia	190	72.22	5.88	52.78	4.66	0.81	4.151	14.69
Urena lobata	608	86.67	7.05	168.89	14.92	2.17	11.070	33.04
Chlerodendrum viscosum	61	32.22	2.62	16.94	1.50	0.58	2.987	7.11
Colaebrockia oppositifolia	71	41.11	3.35	19.72	1.74	0.53	2.725	7.81
Calotropis gigantean	20	16.67	1.36	5.56	0.49	0.37	1.894	3.74
Bidens pilosa	399	88.89	7.23	110.83	9.79	1.39	7.083	24.11
Solanum viarum	213	96.67	7.87	59.17	5.23	0.68	3.477	16.57
Tinospora sinensis	305	90.00	7.32	84.72	7.48	1.05	5.347	20.16
Bumbusa vularis	173	81.11	6.60	48.06	4.25	0.66	3.366	14.21

Aegle marmelos	93	18.89	1.54	25.83	2.28	1.52	7.769	11.59
Mallotus philippensis	294	93.33	7.59	81.67	7.21	0.97	4.970	19.78
Syzygium cumini	187	84.44	6.87	51.94	4.59	0.68	3.494	14.95
Holoptelea integrifolia	76	24.44	1.99	21.11	1.87	0.96	4.906	8.76
Acacia catechu	222	88.89	7.23	61.67	5.45	0.77	3.941	16.62
Adina cordifolia	174	73.33	5.97	48.33	4.27	0.73	3.744	13.98
Trewia nudiflora	90	23.33	1.90	25.00	2.21	1.19	6.086	10.19
Bombax ceiba	62	18.89	1.54	17.22	1.52	1.01	5.179	8.24
Ficus religosa	33	12.22	0.99	9.17	0.81	0.83	4.260	6.06

Frequency, density and abundance values of shrubs in Shiva Parbati Community Fores**t**

Name of plants	**Total number of individual in 90 Q**	**F**	**RF%**	**D**	**RD%**	**A**	**RA%**	**IVI**
Ziziphus nummularia	349	51.11	5.09	96.94	8.18	7.59	11.63	24.90
Murrya koeginii	880	82.22	8.19	244.44	20.63	11.89	18.23	47.05
Sida cardifolia	684	83.33	8.30	190.00	16.04	9.12	13.98	38.31
Pogostermon benghalensis	292	91.11	9.07	81.11	6.85	3.56	5.46	21.38
Urena lobata	431	85.56	8.52	119.72	10.11	5.60	8.58	27.20
Colaebrockia oppositifolia	196	71.11	7.08	54.44	4.60	3.06	4.69	16.37
Calotropis gigantean	51	33.33	3.32	14.17	1.20	1.70	2.61	7.12
Tinospora sinensis	22	18.89	1.88	6.11	0.52	1.29	1.98	4.38
Ichnocarpus frutescens	270	61.11	6.08	75.00	6.33	4.91	7.53	19.94

Aegle marmelos	76	24.44	2.43	21.11	1.78	3.45	5.30	9.51
Mallotus philippensis	178	86.67	8.63	49.44	4.17	2.28	3.50	16.30
Syzygium cumini	199	91.11	9.07	55.28	4.67	2.43	3.72	17.46
Holoptelea integrifolia	373	100.00	9.96	103.61	8.75	4.14	6.35	25.05
Acacia catechu	223	96.67	9.62	61.94	5.23	2.56	3.93	18.78
Adina cordifolia	41	27.78	2.77	11.39	0.96	1.64	2.51	6.24

APPENDIX VII

Trees in Gwasisamaigi Community Forest

Name of plants	Total number of species in 30 Q	F	RF%	D	RD%	A	RA%	IVI
Acacia catechu	68	93.33	17.83	0.0227	29.825	2.429	14.30	61.96
Adina codifolia	43	86.67	16.56	0.0143	18.860	1.654	9.74	45.16
Alstonia scholaris	28	73.33	14.01	0.0093	12.281	1.273	7.49	33.79
Bombax ceiba	17	46.67	8.92	0.0057	7.456	1.214	7.15	23.52
Trewia nudiflora	16	36.67	7.01	0.0053	7.018	1.455	8.57	22.59
Mallotus philipensis	13	40.00	7.64	0.0043	5.702	1.083	6.38	19.72
Dalbergia sisoo	5	16.67	3.18	0.0017	2.193	1.000	5.89	11.27
Aegle marmelos	4	13.33	2.55	0.0013	1.754	1.000	5.89	10.19
Holoptelea integrifolia	10	33.33	6.37	0.0033	4.386	1.000	5.89	16.64
Garuga pinnata	5	16.67	3.18	0.0017	2.193	1.000	5.89	11.27
Salix pectalis	3	10.00	1.91	0.0010	1.316	1.000	5.89	9.12
Terminalia alata	4	13.33	2.55	0.0013	1.754	1.000	5.89	10.19
Terminalia chebula	5	16.67	3.18	0.0017	2.193	1.000	5.89	11.27
Syzygium cumini	7	26.67	5.10	0.0023	3.070	0.875	5.15	13.32

Trees in Laxmi Community Forest

Name of plants	**Total number of species in 30 Q**	**F**	**RF%**	**D**	**RD%**	**A**	**RA%**	**IVI**
Acacia catechu	48	96.67	16.76	0.016	22.64	1.655	12.02	51.42
Adina cordifolia	29	73.33	12.72	0.010	13.68	1.318	9.57	35.97
Alstonia scholaris	23	63.33	10.98	0.008	10.85	1.211	8.79	30.62
Bombax ceiba	15	50.00	8.67	0.005	7.08	1.000	7.26	23.01
Trewia nudiflora	22	56.67	9.83	0.007	10.38	1.294	9.40	29.60
Mallotus philipensis	12	36.67	6.36	0.004	5.66	1.091	7.92	19.94
Dalbergia sisoo	15	43.33	7.51	0.005	7.08	1.154	8.38	22.97
Aegle marmelos	6	20.00	3.47	0.002	2.83	1.000	7.26	13.56
Holoptelea integrifolia	22	70.00	12.14	0.007	10.38	1.048	7.61	30.12
Garuga pinnata	5	16.67	2.89	0.002	2.36	1.000	7.26	12.51
Syzygium cumini	11	36.67	6.36	0.004	5.19	1.000	7.26	18.81
Salix pectalis	4	13.33	2.31	0.001	1.89	1.000	7.26	11.46

Trees in Shiva Parbati Community Forest

Name of plants	**Total number of species in 30 Q**	**F**	**RF%**	**D**	**RD%**	**A**	**RA%**	**IVI**
Holoptelea integrifolia	43	73.33	16.06	0.0143	19.91	1.95	13.69	49.66
Acacia catechu	59	93.33	20.44	0.0197	27.31	2.11	14.76	62.51
Adina cordifolia	16	40.00	8.76	0.0053	7.41	1.33	9.34	25.51
Trewia nudiflora	20	50.00	10.95	0.0067	9.26	1.33	9.34	29.55
Alstonia scholaris	13	30.00	6.57	0.0043	6.02	1.44	10.12	22.70
Dalbergia sisso	22	43.33	9.49	0.0073	10.19	1.69	11.85	31.53
Terminalia chebula	6	20.00	4.38	0.0020	2.78	1.00	7.00	14.16
Salix pectalis	13	36.67	8.03	0.0043	6.02	1.18	8.28	22.33
Garuga pinnata	8	26.67	5.84	0.0027	3.70	1.00	7.00	16.55
Mallotus philipensis	16	43.33	9.49	0.0053	7.41	1.23	8.62	25.52

APPENDIX VIII

Regeneration status of all tree species in Gwasisamaigi Community Forest, Laxmi Community Forest and Shiva Parbati Community Forest.

In Gwasisamaigi Community Forest

S.N	Plant species	Forest regeneration stem/ha		
		Seedling	**Sapling**	**Trees**
1	*Acacia catechu*	1130	1000	226.33
2	*Adina codifolia*	_	646.66	142
3	*Alstonia scholaris*	_	_	93
4	*Bombax ceiba*	736.66	956.66	56
5	*Trewia nudiflora*	_	300	53
6	*Mallotus philipensis*	1003.33	1123.33	43
7	*Dalbergia sisoo*	_	_	16
8	*Aegle marmelos*	_	373.33	13
9	*Holoptelea integrifolia*	_	293.33	33
10	*Garuga pinnata*	_	256.66	16
11	*Salix pectalis*	_	_	10
12	*Terminalia alata*	_	_	13
13	*Terminalia chebula*	_	_	16
14	*Syzygium cumini*	_	943.33	23
	Total	2869.99	5893.3	753.33

In Laxmi Community Forest

S.N	Plant name	Regenration in stem/ha		
		Seedling	Sapling	Trees
1	*Acacia catechu*	593.33	740	160
2	*Adina cordifolia*	-	580	96.66
3	*Alstonia scholaris*	-	--	76.66
4	*Bombax ceiba*	-	206.66	50
5	*Trewia nudiflora*	-	300	73.33

6	*Mallotus philipensis*	1130	980	40
7	*Dalbergia sisoo*	-	-	50
8	*Aegle marmelos*	310	310	20
9	*Holoptelea integrifolia*	-	253.33	73.33
10	*Garuga pinnata*	-	-	16.66
11	*syzygium cumini*	1410	623.33	36.66
12	*Salix pectalis*	-	-	13.33
13	*Sapindus mukorossi*	306.66	-	-
14	*Ficus religiosa*	-	110	-
	Total	3749.99	4103.32	703.32

In Shiva Parbati Community Forest

S.N	**Name of plants**	**Regeneration in stem/ha**		
		Seedling	Sapling	Trees
1	*Holoptelea integrifolia*	990	1243.33	143.33
2	*Acacia catechu*	1333.33	743.33	196.66
3	*Adina cordifolia*	-	136.66	53.33
4	*Trewia nudiflora*	-	-	66.66
5	*Alstonia scholaris*	-	--	43.33
6	*Dalbergia sisso*	-	--	53.33
7	*Terminalia chebula*	-	-	20
8	*Salix pectalis*	-	-	43.33
9	*Garuga pinnata*	-	-	26.66
10	*Mallotus philipensis*	1376.66	593.33	53.33
11	*Syzygium cumini*	1110	663.33	-
12	*Aegle marmelos*	433.33	253.33	-
13	*Sapindus mukorossi*	303.33	3633.31	-
	Total	5546.65	3633.31	699.96

APPENDIX IX

Basal area, Density stem/ha of each species, Density stem/ha and DBH class and carbon stock (%) of each tree species in Gwasisamaigi community forest, Laxmi community forest and Shiva Parbati community forest.

In Gwasisamaigi Community Forest

S.N	**Plant species**	**Carbon stock (%)**	**Basal area** m²/ha	**Density stem/ha**
1	*Acacia catechu*	19.31	13.33	226.33
2	*Adina codifolia*	5.80	7.09	142
3	*Alstonia scholaris*	3.83	7.55	93
4	*Bombax ceiba*	65.90	24.21	56
5	*Trewia nudiflora*	0.36	0.77	53
6	*Mallotus philipensis*	0.30	0.4	43
7	*Dalbergia sisoo*	0.09	0.13	16
8	*Aegle marmelos*	0.11	0.13	13
9	*Holoptelea integrifolia*	1.28	1.46	33
10	*Garuga pinnata*	1.02	1	16
11	*Salix pectalis*	0.36	1.02	10
12	*Terminalia alata*	1.21	1.01	13
13	*Terminalia chebula*	0.21	0.21	16
14	*Syzygium cumini*	0.22	0.32	23

In Laxmi Community Forest

S.N	Plant name	Carbon stock (%)	Basal area m²/ha	Density (stem/ha)
1	*Acacia catechu*	30.87	9.81	160
2	*Adina cordifolia*	11.89	5.61	96.66
3	*Alstonia scholaris*	6.29	5.81	76.66
4	*Bombax ceiba*	33.87	23.49	50

5	*Trewia nudiflora*	1.55	1.58	73.33
6	*Mallotus philipensis*	1.17	0.9	40
7	*Dalbergia sisoo*	1.96	1.12	50
8	*Aegle marmelos*	0.74	0.47	20
9	*Holoptelea integrifolia*	8.08	4.28	73.33
10	*Garuga pinnata*	2.04	1.07	16.66
11	*Syzygium cumini*	1.40	0.86	36.66
12	*Salix pectalis*	0.13	0.2	13.33

In Shiva Parbati Community Forest

S.N	**Name of plants**	**Carbon stock (%)**	**Basal area (m^2/ha)**	**Density (stem/ha)**
1	*Holoptelea integrifolia*	19.52	8.01	143.33
2	*Acacia catechu*	44.74	11.67	196.66
3	*Adina cordifolia*	10.33	3.93	53.33
4	*Trewia nudiflora*	2.88	2.21	66.66
5	*Alstonia scholaris*	6.50	4.62	43.33
6	*Dalbergia sisso*	6.67	2.45	53.33
7	*Terminalia chebula*	1.46	0.55	20
8	*Salix pectalis*	1.72	1.57	43.33
9	*Garuga pinnata*	4.89	1.89	26.66
10	*Mallotus philipensis*	1.30	0.74	53.33

APPENDIX X

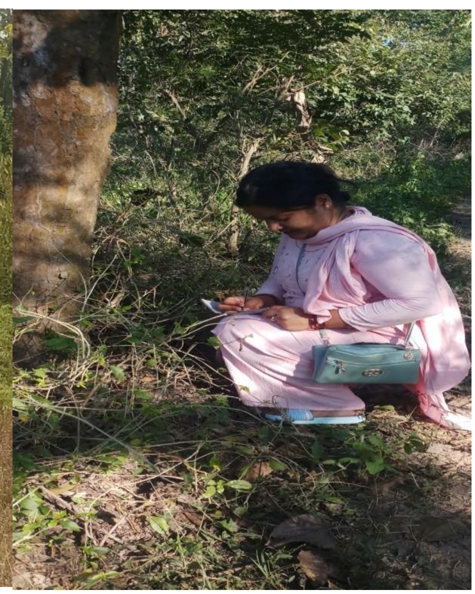
Density (stem/ha) and DBH class for three forest

S.N	DBH clas	Gwasisamaiji CF	Laxmi CF	Shiva Parbati CF
1	10-20	43.33	16.66	20
2	20-30	113.33	96.67	73.33
3	30-40	53.33	123.33	136.66
4	40-50	213.33	166.67	160
5	50-60	230.00	213.33	193.33
6	60-70	36.67	26.67	63.33
7	70-80	10.00	3.33	33.33
8	80-90	3.33	6.67	13.33
9	90-100	6.67	3.33	6.66
10	100 above	43.33	46.67	0

APPENDIX XI

Photo plates


Riverine forest   Measuring DBH

Collecting data