PLANT DIVERSITY AND CARBON STOCK OF TWO COMMUNITY MANAGED FORESTS, KAILALI, WESTERN NEPAL

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

BY

KESHAVI KUMARI MAHARA

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DEPARTMENT OF BOTANY

AMRIT CAMPUS

INSTITUTE OF SCIENCE AND TECHNOLOGY

TRIBHUVAN UNIVERSITY

KATHMANDU, NEPAL

MAY 2, 2022

DECLARATION

I, Keshavi Kumari Mahara, 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.

Keshavi Kumari Mahara

Department of Botany

Amrit Campus

Kathmandu, Nepal

Date: May, 2022

Tribhuvan University

Institute of Science & Technology

AMRIT CAMPUS

P.O. Box No. 192, Thamel, Kathmandu, Nepal

Tel: 4411637,
4410408

E-mail: amritcampus@ntc.net.np

Institute of Science & Technology
Amrit Campus

RECOMMENDATION LETTER

This is to certify that Mrs. Keshavi Kumari Mahara has completed the dissertation work entitled "**Plant diversity and carbon stock of two community managed forests, Kailali, Western Nepal " under** our supervision and co-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.

Supervisor
Dr. Laxmi Joshi Shrestha
Department of Botany
Amrit Campus
Tribhuvan University
Thamel, Kathmandu, Nepal
May, 2022

Co-supervisor
Krishna Prasad Sharma (Lecturer)
Department of Botany
~~Amrit Campus~~ Trichandra campus
Tribhuvan University
~~Thamel~~, Kathmandu, Nepal
May, 2022

Tribhuvan University
Institute of Science & Technology
AMRIT CAMPUS
P.O. Box No. 102, Thamel, Kathmandu, Nepal
E-mail: amritcampus@nte.net.np
Tel: 4411637,
4410408

Ref. No.:

Date: 2nd May, 2022

LETTER OF APPROVAL

The M.Sc. dissertation entitled "**Plant diversity and carbon stock of two community managed forests, Kailali, Western Nepal**" Submitted by Mrs. Keshavi Kumari Mahara 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.

Expert Committee

External Examiner
Asst. Prof. Dr. Narayan Prasad Ghimire
Central Department of Botany
T.U., Kirtipur

Internal examiner
Prof. Dr. Mukesh Kumar Chettri
Department of Botany
Amrit Campus

Supervisor and coordinator
Dr. Laxmi Joshi Shrestha
Department of Botany
Amrit Campus

Co-supervisor
Krishna Prasad Sharma (Lecturer)
Department of Botany
~~Amrit Campus~~ Trichandra campus

Head of Department
Associate Prof. Dr. Shila Shingh
Department of Botany
Amrit Campus

Date of Examination: 2nd May 2022

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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

DCF – Durgalaxmi community forest

DFRS – Department of Forest Research and Survey Ha – hectare

IVI – Importance Value Index

No. – Number

Q – Quadrat

REDD – Reducing emission from deforestation and degradation

SOC – Soil Organic Carbon

TCF – Teghari community forest

ABSTRACT

Vegetation study is crucial for the biophysical environment and ecosystem balance. Carbon stock and biodiversity have an intricate relationship. Community forests were functioning to upscale the carbon sequestration as well as the biodiversity. This study is intended to assess the plant diversity and carbon stock of two different types of community forests, Kailali, Western Nepal. Teghari community forest was riverine forest and Durgalaxmi community forest was Sal forest. To assess IVI, species diversity, regeneration and carbon stock altogether 40 sample plots (20 plots in each forest) of 20m radii were studied for trees applying stratified random sampling. Within the 20m radii plots, 3 subplots of 5m radii for shrubs and 3 subplots of 1m radii for herbs were laid. Tree biomass was estimated and regeneration was estimated by calculating the density of each species in seedling, sapling and tree phases. Soil samples were collected from the surface up to 20cm depth. Carbon stock of DCF was found higher 148.75 t/ ha in DCF than 39.30 t/ ha in TCF. The diversity of herbs and shrubs was higher in riverine forest (Teghari community forest) than Sal forest (Durgalaxmi community forest) due to the presence of more open canopy which facilitates understory vegetation like *Murraya koenigii* and *Lantana camara* were most common shrub species. Similarly, total species diversity was found higher in riverine Teghari community forest. The index of similarity between two different forests was found to be quite low. The mean value of basal area, DBH, carbon stock was higher in Durgalaxmi community forest compared to Teghari community forest. These results revealed that the ground vegetation and regeneration was high in less dense canopy forest and Sal forest had higher carbon stock than riverine forest.

Keywords: Riverine forest, Sal forest, carbon stock, diversity, regeneration

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CHAPTER 1: INTRODUCTION

1.1. Background

Community forestry program in Nepal was introduced in 1978, after the failure of controlling deforestation and forest degradation by the centralized forest management systems, realizing that without involvement of the local community's forest cannot be saved. Community forestry program proved this, as it becomes successful in protection, conservation and management of forest thus, in-spite of having debate on the contribution of it to biodiversity conservation (Shrestha *et al*., 2010), it is considered as one of the most successful natural resource management practice (Acharya, 2004) and which significantly contributes to the reversal of deforestation and forest degradation (Nagendra *et al*., 2008).

Species diversity is the measure of diversity within an ecological community that incorporates both species richness and the evenness of species abundances. Diversity is measured for three main reasons: to measure stability to determine if an environment is degrading, to compare two or more environments and to eliminate the need for extensive lists. Diversity indices provide important information about the composition of a community. Species diversity can be expressed in a single index number. Ecologists have developed many indices of species diversity among which Simpson's index (Simpsons, 1949) and Shannon-wiener Index, H_1 (Shannon and Weaver, 1949) are the most commonly used indices. Simpson's index (C) reflects dominance while Shannon-Wiener Index (H_1) 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. Species richness is currently the most widely used measure of diversity (Stirling and Wilsey, 2001). It is a simple and easily interpretable indicator of biological diversity (Whittaker, 1977). A complex of various factors determines species richness (Schuster and Diekmann, 2005). Numerous studies have examined the relationships between plant species richness, climate and spatial variables.

Natural regeneration is the process of re-growing or reproduction of plants through their juvenile (Acharya and Shrestha, 2011). The regeneration status of a forest indicates its health and vitality while a healthy forest ensures good future regeneration (Awasthi *et*

al., 2015). Regeneration is measured 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 *et tal*., 2004).

The sustainable forest must have good regeneration, proper age class (age-gradation), normal increment and normal growing stock (Subedi, 2011). The regeneration and productive character of forest is determined by the presence of different age groups of seedlings and saplings and trees (Chauhan *et al*., 2008). Deforestation, overexploitation of resources, grazing, fragmentation, industrialization and many other factors are responsible for the depletion and degradation of forest and regeneration. Regeneration is said to be good if forests have seedling >5000 and sapling >2000 per hectare (HMG, 2004) (cited in Pandey *et al*., 2012). Regeneration of Sal was higher than other associated species in Terai and Churia forest of Nepal (DFRS, 2014).

Carbon stock is the quantity of carbon held within a pool at a time. Carbon sequestration is the process of separation of CO_2 from the atmosphere and storing to reservoir (plant biomass and soil). Soil organic carbon stocks display a high spatial variability. In fact, most of the studies concern only the topsoil (e.g. 0-30 cm), although carbon sequestration or loss may also occur in deeper soil layers (Bird *et al*., 2002; Fontaine *et al*., 2007). SOC is an important index of soil quality because of its relationship to large amounts of CO_2 being transferred between the atmosphere and terrestrial ecosystems. 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). They play a critical role in reducing ambient CO_2 levels, by sequestering atmospheric C into the growth of woody biomass through the process of photosynthesis and also by increasing the soil organic carbon content. Tropical forests hold large storage of carbon. Carbon is held in the terrestrial system in vegetation and soils. Trees act as a major source of sink as it captures atmospheric CO_2. Carbon sequestration from the atmosphere can be advantageous from both environmental and socio-economic perspectives. The rate of C sequestration 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). Climate is changing. Removal of greenhouse gases from the atmosphere into sinks (i.e. soil and forest vegetation) is one way of addressing climate change (Bajracharya *et al*., 1998). The major cause of the climate change is the emission of anthropogenic greenhouse gases (GHGs),

particularly of carbon dioxide (CO_2). Burning of fossil fuels, clearing of forests, and the industrial revolution are the major human activities responsible for the increment of greenhouse gases in the atmosphere. Carbon dioxide (CO_2) makes its position on the top, accounting for 76% of total anthropogenic GHG emissions (IPCC, 2014). As deforestation is currently a common phenomenon of the developing countries, planting 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 an important strategy for dealing with climate change. Forest plays an important role in mitigating global climate change (Kaul *et al*., 2010) through carbon-dioxide sequestration. Carbon sequestration is considered as an important means to mitigate the impacts of greenhouse gases on climate change. In Nepal, through pilot projects few CFUG's have got support and assistance from the government for carbon enhancement to mitigate and adapt against climate change and also to make carbon trade, a great hope in a country like Nepal (Chand *et al*. 2018; Adhikari, 2016). The flow of financial benefit under REDD carbon financing depends on the national-level carbon balance rather than an individual project or management system within the country. Managed forests offer the opportunity for influencing forest rates and providing for full stocking, of which allow for more carbon sequestration and bio-diversity.

This research work was conducted in Far Western, Nepal to know the diversity and carbon stock status of two community forests of Kailali district which are different in vegetation type. To assess regeneration and carbon stock altogether 40 sample plots (20 plots in each forest) of 20m radii were studied for trees applying stratified random sampling.

1.2 Justification

There are large number of research works related to plant diversity and C-stock estimation in CF in various parts of Nepal. But, there are very few research work related to plant diversity and variation of C-stock estimation having two different types of CF in Far Western region of Nepal. It is not clear if difference in forest types and had some co-dominant species will have impacts on species richness, carbon stock and regeneration in tropical community forest dominated by *Shorea robusta, Acacia catechu, Syzygium cumini and Mallotus philippensis*. So similarly, information

obtained will be helpful in planning and implementing the forest restoration, management and conservation strategies at community, regional or national level.

1.3 Research questions

1. How does vegetation composition and regeneration change between different forest types?
2. Does carbon stock vary with different forest types?
3. How do Physico-chemical properties of soil change in different forest types?
4. How does vegetation composition and carbon stocks are dependent on soil characteristics?

1.4 Objectives

The general objective is to access the Vegetation composition, regeneration and carbon stock among different forest types and the specific objectives are

i) To study plant diversity among two forest types.

ii) To estimate the total carbon stocks of two forest types.

iii) To study regeneration patterns of two forest types.

iv) To analyze Physico-chemical properties of soil.

1.5 Limitations

i. Due to lack of instrument, canopy cover was estimated by visual method.

ii. Only tree carbon stock was calculated.

iii. Soil parameters such as soil moisture and bulk density were not estimated due to lack of time.

CHAPTER 2: LITERATURE REVIEW

2.1. Plant diversity

In Nepal floral diversity, it comprises 3.2% of world's known flora with 2.5% (1001 species) of algae, 5.1% (534 species) of pteridophytes, 5.1% (26 species) of gymnosperms and 3.2% (6973 species) of angiosperms (MoFSC, 2014). Altogether 2,467 species of fungi, 792 species of lichens and 1,213species of bryophytes are reported from different parts of the country were recorded and also revealed that decline and 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). Bio-resources are essential to maintain the ecological process and life support system and to sustain and improve agricultural, forestry and presence of suitable habitats for the survival of species but the biodiversity is under threat due to high pressure by the growth of population (Joshi and Joshi, 1998). Biodiversity plays a fundamental role as an ecosystem services to maintain ecological processes. Community forestry program is considered as one of the most successful natural resource management programs in terms of restoring degraded land and habitats, conserving biodiversity, increasing supply of forest products, generating rural income and developing human resources (Acharya, 2003). Community forestry has been the most effective means of managing common forest resources in Nepal. Besides this, community forestry improves the environment, contributes to the rural livelihood and is a major means of biodiversity conservation (Acharya *et al*., 2007).

Community forestry is successful in decreasing resource degradation and helpful in the conservation of biodiversity (Adhikari, 2004). Implementation of community forest management has improved the forest condition and biodiversity in the hills of Nepal as compared to degraded forest in the past. It could be a suitable option to conserve biodiversity, but it focuses on sustainable forest products and keeping biodiversity conservation in less priority. Its aim is to supply forest products to local users rather than to conserve biodiversity. There is a considerable role of community forestry in biodiversity conservation of Nepal. For the conservation of forest and its biodiversity, CFUGs are voluntarily involved in fencing, planting and meetings. It is helping in

carbon sequestration and increasing the forest cover by controlling deforestation and forest degradation (Anup *et al.*, 2015).

Various studies have demonstrated a significant increase in forest condition under community forestry showing that it is a proven model for controlling deforestation and forest degradation. There is a growing concern that community forest is prioritizing only towards sustainable management of forest resources and less towards biodiversity conservation. The aim of community forestry is to supply forest products to local users rather than to conserve biodiversity. Currently, there is evidence that CFUGs are slowly moving towards active forest management. Effective management of community forest leads to sustainable production and sustainable harvest of forest resources.

2.2. Regeneration and carbon stock

Regeneration is a vital process for the existence of species in a community. It not only presents the recent status, health, and vitality of the forest but also showcases the future forest composition. It can be further used to determine whether forest management leads to productive capacity as well as biological diversity of forests was maintained (Awasthi *et al*. 2015; Bhatta *et al*., 2020).Community forest resource inventory guideline (2004) suggested criteria based on number of seedling and sapling in forest for evaluating regeneration condition of the forest. Regeneration is said to be good if forests have seedling > 5000 and sapling > 2000 per hectare (HMG, 2004) (cited in Pandey *et al*., 2012).

Successful regeneration requires adequate seedlings and their survival, which was controlled by the microclimate of the site and anthropogenic stimuli (Chikanbanjar, 2020). Indeed, even high starting seedling densities can't ensure successful regenerations in the zones with higher interference levels like grazing and tree felling (Rooney and Waller 1998). A reverse J-shaped size class distribution was attributed to undisturbed old-growth forest with sustainable regeneration (West *et al*., 1981) whereas disturbed forest shows a bell-shaped size class distribution (Saxena *et al*., 1984).

Study of regeneration pattern in Sal forests from various parts of Nepal has found that regeneration status of Sal was higher than the other associated species. 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. The overall stand density changed quadratically along the disturbance gradient. Aryal *et al.,* (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.

In Nepal, most studies have been conducted in forests for their tangible economic benefit. Information on vegetation and carbon stocks at different forests is generally insufficient in Nepal. Forests play important repositories of terrestrial biodiversity and play a key role in influencing socio-ecological and cultural attributes of human societies including livelihood activities of traditional societies living in these areas (Joshi *et al*., 2021). Biodiversity is needed for human survival, economic well-being, and ecosystem function and stability (Singh, 2002). Globally, habitat destruction, overexploitation, pollution, and species introduction are identified as major causes of biodiversity loss (Mourya *et al.,* 2019).Forest help in the global C cycle through exchange of C between the land and the atmosphere (Dixon *et al*., 1994; Pan *et al*., 2011) and acts as sink or source of C (Kohl *et al*., 2015). The amount of C sequestered in a forest is constantly changing with growth, death, and decomposition of vegetation (Kaul *et al*., 2010). The biomass and C-stock of forest increases with increasing forest age (Luyssaert *et al*., 2008), tree density and area (Sedjo, 2001). The rate of C sequestration 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; Nair *et al*., 2009). The C-stock in forest vegetation varies according to geographical location, life zone, forest type, forest structure, plant species, age of the stand and degree of disturbances (Brown *et al*., 1989; Dixon *et al*., 1994). Nepal forest contributes approximately 176.95 t/ha carbon stock where tree component contributes 61.53%, forest soil contributes 37.80%, and litter and debris contributes 0.67% (DFRS, 2015). Carbon stock did not vary significantly with species richness and litter cover, but is usually increased with the management duration (Thapa magar and Shrestha, 2015).A ton of C sequestered in the forest biomass reduces 3.67 tons of CO_2 from atmosphere (van Kooten, 2000) and world's forest sink holds more C than the atmosphere (Stern, 2007). Joshi *et al.,* (2021) studied vegetation structure and carbon Stock of two community managed *Shorea robusta* Forests of

Dhangadhi, Nepal and concluded that the carbon stock of moist forest (92.99t/ha) was higher than dry forest (51.94 t/ha). Forest types play an important role in total carbon sequestration. Estimation of total biomass and carbon sequestration in any forest was crucial as it gave ecological and economic benefits through various environmental services. Pandey and Bhusal, (2016) studied the total carbon stock in the two different ecological regions the hills and the terai, two Community Forests having the dominance of *Shorea robusta* from Gorkha and Chitwan would found to be 234.54 t ha-1 and 479.29 t ha-1, respectively. The Carbon Stock of Hill Sal forest was 97.86 ton per hectare and the Carbon sequestration rate was1.30 ton per hectare per year (Baral *et al*., 2009). The carbon stock in living biomass of the forest managed for more than 20 years in Dadheldhura district was 199 Mg/ha which was significantly higher than the forest managed for less than 11 years was 151 Mg/ha (Bhatta *et al*., 2020).

2.3. Soil organic carbon

Soil organic carbon (SOC) stock is an important part of the global carbon cycle involving the cycling of carbon through the soil, plants, ocean, and atmosphere. Factors that may be important for increasing SOC storage include litter production (both above and below ground); litter quality; placing organic matter deeper in the soil either directly by increasing below-ground inputs or indirectly by improving surface mixing by soil organisms; and increasing physical protection through either intraaggregate or organic mineral complexes and microclimate change. Das and Mondal (2016) found that litter production was continuous, but the quantity of litter produced varied by season and dry winter period showed maximum litterfall of the studied species at Ramna forest. Nutrients of N, K, and P were the primary limiting nutrients returned to soil through litterfall with important roles in soil fertility and forest productivity of *Shorea robusta* and *Tectona grandis* in a subtropical forest of West Bengal, Eastern India. In high mountain and high himal areas, the largest SOC stock (114.0 t/ha), the lowest in the Churia region with an average of 31.4 t/ha, Middle mountain area showed an average SOC stock of 54.3 t/ha. SOC stocks in the Terai forests were found to be slightly higher than those in Churia (Morales-Ruiz *et al*., 2021) has been estimated region. With increased soil depths, SOC and nitrogen were found to decrease, with a statistically significant difference in values across various soil layers (Shapkota and Kafle, 2021). Since there have been no more such study done in this site. Hence this

study will help as to find out the vegetation and carbon stock of two different types of community forest types in far western Attariya kailali, Nepal.

CHAPTER 3: MATERIALS AND METHODS

3.1. Study area

Study area is located in far-western Nepal. The study was carried out in two different forest, Sal forest and tropical deciduous riverine forest within Godawari VDC-2 Attariya,Kailali (Fig.3.1). The studies lies over latitude from 28˚51' N and longitude 80˚33' E. The altitude of the study area ranges from 155m to 254m above sea level (Asl).

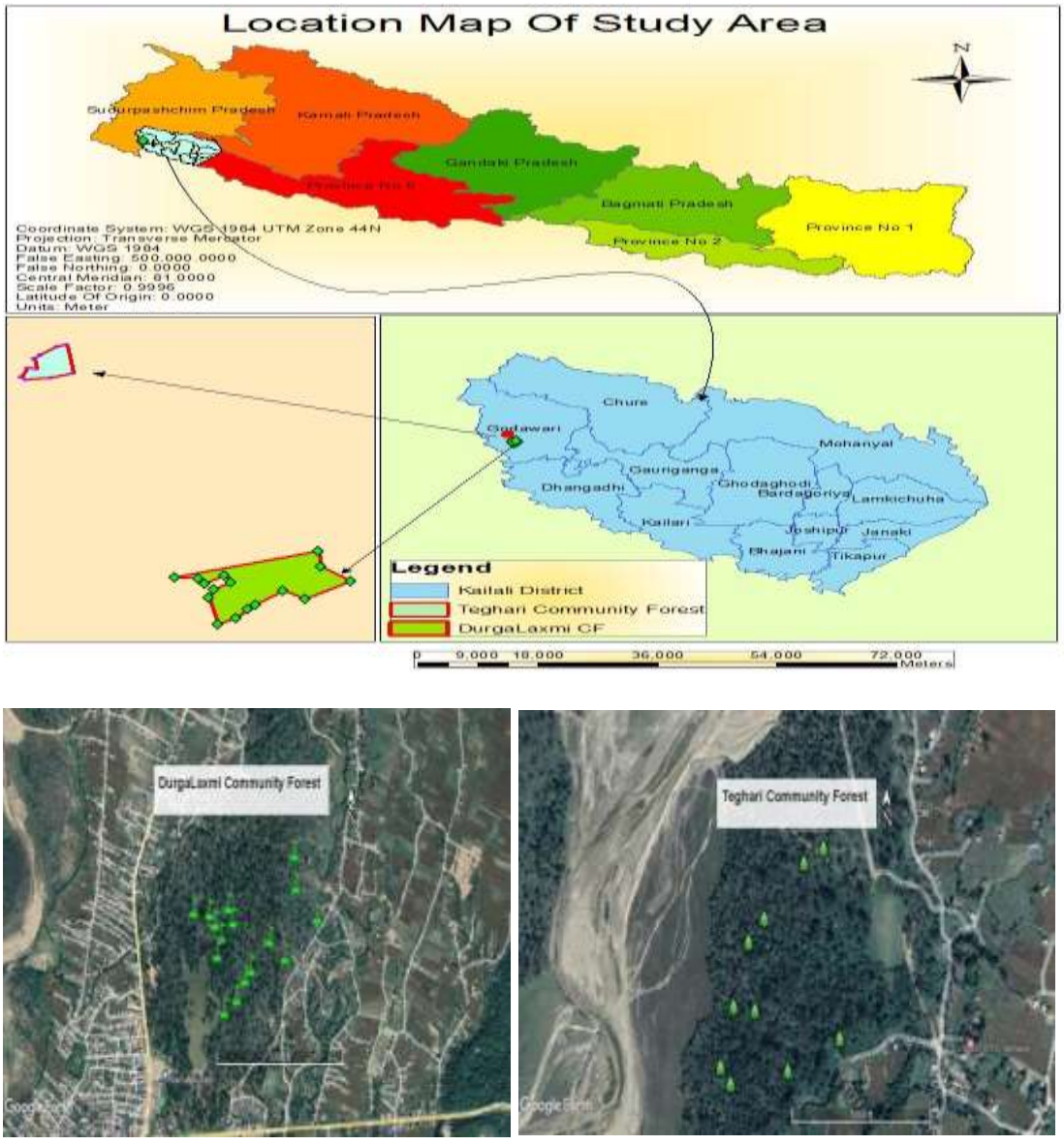


Figure 3. 1. Map of the study area; (a), Location of study community forests (Durgalaxmi and Teghari) in attariya ,kailali (b), Map of Durgalaxmi community forest showing sampling plots (c) and Map of Teghari community forest showing sampling plots (d).

3.1.1 Climate

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%.

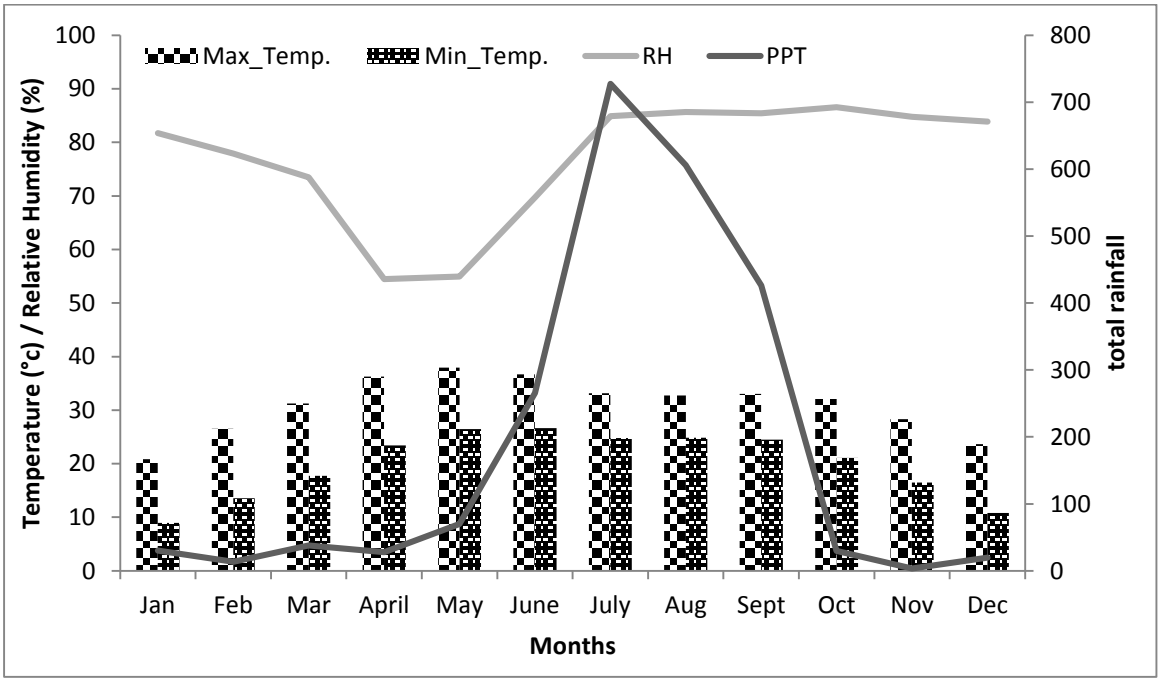


Figure 3. 2: Five years (2015-2019) climatic graph showing Average monthly temperature, Humidity and Rainfall of Kailali – Godawari station. (Source: DHM, 2019).

3.1.2 Study forest

The study was conducted in Durgalaxmi community forest (DCF) and Teghari community forest (TCF) (Figure 3.1). DCF is located between 28° 49' 0 "N to 28°49’28’’N and 80° 33 '33" E to 80°33’52’’E and TCF is located between 28°50’39’’to 28°50’36’’N and 80°33’9’’to 80°33’12’’E with the altitude ranging from 147 to 233 m asl (Figure 3.1) in Godawari-2 respectively in Attariya, Kailali. The study area consists of plane slopes 0° to gentle slope 1°.

Vegetation type of study area is a tropical zone principally including Terai, Bhabar, and Dun valleys. The major vegetation types are Sal forest, and tropical deciduous riverine forest. Sal forest is dominated by *Shorea robusta* (Sal) and tropical deciduous riverine forest with dominance of *Acacia catechu* and *Dalbergia sissoo* along with *Bombax ceiba* and *Syzygium cumini*. Other common associated species in both forests were *Trewia nudiflora, Adina cordifolia, Murraya koenigii, Aegle marmelos, Semecarpus anacardium, Terminalia bellirica Ficus* Species, *Schleichera oleosa, Cassia fistula, Mallotus philippensis, Terminalia chebula, Terminalia tomentosa* (Saj), *Syzygium cumini* (Jamun), etc. Both the forest was different in vegetation type. DCF was handed over to the community in 2062 B.S. It covers an area 257 hectares and 987 house's member take membership of this forest whereas TCF was handed over to the community in 2065 B.S. It covers an area of 341 hectares and 1077 house's member take membership of this forest.

3.2. Field Sampling

Field sampling was done from May to June 2019.The stratified random sampling method was used for locating the sampling plots, the forest blocks designated by the 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 20 circular plots (CCSPs) of 20m radii were laid in each forest. Each tree species enrooted inside the plots were recorded. Trees on the border were also included if ≥50% of their basal area fell within the plot. Tree height > 1.37m with diameter ≥ 10cm at breast height of all individuals of tree species was measured. 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 20m radii plot (quadrat) was divided into 3 sub plots of 5m radii for shrub and 3 plots with radii 1m for herbs to estimate biodiversity. Similarly, for 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.

Geographical location (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. From each quadrat, during May to June soil sample was collected using a steel ring with height 20 cm and internal diameter 3.4 cm from the center of the plot. Collected soil sample was packed in airtight plastic bags wrapped in aluminum foil until laboratory analysis. Most of the specimens were identified at the time of sampling measurement with the help of field guides (members of CFUGS) and consulting with local experts. Unidentified species were 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. Lab Work

The physiochemical parameter of soil such as soil pH, soil organic carbon, Nitrogen, and Phosphorus was assessed using a standard protocol in Soil and Fertilizer Testing Laboratory, Sundarpur, Kanchanpur, Nepal. For this a soil sample was given to the laboratory.

3.3.1. Preparation of Soil Sample

The soil sample arrived at the laboratory was first labeled in the laboratory number and registered on the laboratory register book. The sample containers, usually plastic bags, were also marked as the same number. The soil sample was then spread on a tray and the stones and undecomposed materials were discarded and large are broken. Labeled tags should have the sample and plastic bag underneath the tray to ensure the identification of the sample after drying. Sample trays were left in the room or shade to air dry the soil.

3.3.2. Soil organic Carbon

Organic carbon content in the soil was calculated by Walkey and Black's rapid titration method (1934). Soil sample (0.5 g) was passed through fine sieve (0.2 mm) was taken in a 500 mL conical flask and added 10 mL of 1N $K_2Cr_2O_7$ and 20 mL of conc. H_2SO_4 with gentle swirling. The digestion reaction being exothermic, the flask was left for about 30 minutes to cool down at room temperature. A standard solution was also

prepared in the same way. After half an hour 200 mL distilled water, 10 drops of ferroin indicator and about 0.2gm of sodium fluoride were added and shaken.

Ferrous ammonium sulphate solution (0.5 N) was run from burette, with constant stirring until the color changed from violet to bright green through blue. The volume of ferrous ammonium sulphate solution used for titration was noted. A blank titration (without soil) was carried out at every lot of 15 samples in a similar manner.

$$\text{Organic Matter of the soil (\%)} = \frac{(B-S)N}{Wt.of\ Soil(gm)}\ x\ 0.67$$

Where,

B= Volume of 0.5N Ferrous ammonium sulphate solution used for blank titration.

S= Volume of 0.5N Ferrous ammonium sulphate solution used for soil sample titration.

N= Normality of Ferrous ammonium sulphate from blank titration.

3.3.3. Soil Nitrogen

Kjeldahl Method was used for the determination of the total nitrogen available in soil in which organic nitrogen compounds are converted into ammonium sulphate by digestion with concentrated sulphuric acid.

For the determination of soil nitrogen 1gm soil in a 50ml Kjeldhal digestion flask and 2gm catalyst digestion mixture followed by 10ml conc. Sulphuric acid and few pieces of broken porcelain was taken. For a fine textured soil 10ml of distilled water was added and the mixture was left for 30 minute.

After that digestion mixture and sulphuric acid was added and mixed with soil by swirling the flask and heating the solution till frothing stops. Gradually increase the heat until the acid boils. Swirling the flask at intervals and digested till the color of the mixture was turned into green blue or grey color.

For Block Digester Décor, about 10ml of sulphuric acid was added in a 1gm soil and 2gm digestion mixture in a 250ml digestion tube. Then the mixture was heated in the preheated Block Digester at 410˚C for 45minutes. In the exhaust system the rate of the

digestion was increased at the beginning and after 10 minute it was reduced so the acid fume was condensed around two thirds of the digestion tube. After that the flask was cooled and 20ml of distilled water was added before the solution started crystallization. The solution was transferred in the 100ml volumetric flask and 20ml aliquot was taken and 20ml of 40% NaOH was added and distilled it. Liberated NH_3 was collected and 10ml of 4% boric acid along with 2 drops of mixed indicator was taken in a 125ml conical flask. The solution was titrated with 0.01N HCl and reading was noted.

Total Soil Nitrogen (%) =7×n× (T-B)/S

Where, n= Normality of the solution

T= volume of acid used during titration.

B= Volume of acid used in blank

S= Weight of the soil samples

3.3.4. Soil Phosphorus

Modified Olsen's Bicarbonate Method was used for the determination of phosphorus present in the soil. First of all a 100ml polyethylene bottle was taken along with 2gm soil sample. One teaspoon of activated charcoal and 40ml of 0.5 $NaHCO_3$ was added to make extracted solution. The solution was shaken for 30 minutes and filtered by using Whatman no 42 filter paper and 10ml of aliquot was taken in a 50ml flask. Then the solution was acidified by using 5N sulphuric acid of pH 5.0 and p-nitrophenol indicator was used till the yellow color disappeared. The acid was kept drop wise. The process of addition of acid and shaking was continued till the yellow colored solution become colorless. After that 40ml of distilled water and 8ml of reagent (ammonium molybdate) was added. Maximum intensity of blue color was obtained in 10 minutes and remains stable up to 24 hours. The color intensity was measured by using a colorimeter after 10 min using a red filter (660nm). The standard curve was prepared by taking 0, 0.5, 1, 2, 4, 6 and 10 ml of 5ppm standard solution and extracting solution of $NaHCO_3$ and proceeds the solution.

P_2O_5 (Kg/ha) =ppm P in Solution × 2.29×100×2**9

Where,

100= dilution factor

2= conversion factor for ppm in soil to kg/ha in soil.

2.29= conversion factor for P to P_2O_5.

3.3.7. Soil potassium

Potassium content in soil was determined by using the Flame Photometer method. For this method the 2gm of air dried soil was taken in a 125ml conical flask. After that 20ml of normal neutral ammonium acetate was added and shaken for 5minute by using a mechanical shaker. The solution was then filtered through Whatman no 42, 12.5cm filter paper. A standard curve of K was prepared by aspiring 0, 5, 10, 15, 20 and 25ppm K after adjusting the full scale deflection of the flame photometer with 25ppm K. The reading was noted and a graph was drawn. By using this graph potassium content in soil was determined.

K_2O (kg/ha) = R×22/2×1.2×2**^{i0}

Where,

R = potassium of soil extract in ppm, from the standard curve

1.2 = conversion factor for K to K_2O

2 = Conversion factor for ppm to kg/ha

20/2 = Dilution factor

3.4. Quantitative 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).

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

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

Frequency = $\frac{No.of\ quadrat\ in\ which\ species\ occurred}{Total\ no.of\ quadrat\ studied}$ x 100%

Relative Frequency (%) = $\frac{Frequency\ of\ individual\ species}{Total\ frequency\ of\ all\ species}$ x 100

Abundance = $\frac{Total\ no\ of\ individual\ of\ a\ species\ in\ all\ quadrat}{Number\ of quadrat\ in\ which\ the\ species\ occurred}$

Relative Abundance (%) = $\frac{abundance\ of\ individual\ species}{Total\ abundance\ all\ species}$ x 100

3.4.1. 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

3.4.2. 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.

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

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) = $\Sigma\ (n-1)\ N\ (N-1)$

N = total number of individual species (all species)

n = number of individuals of a particular species

3.4.3. 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

3.4.4. 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) = $\frac{\pi D2}{4}$

Where,

π = 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 m2 /ha.

3.5. Estimation of Biomass and Carbon Stock of trees

3.5.1. Estimation of Above and Below Ground Biomass

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

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

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).

3.5.2. Wood Density

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

3.5.3. 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 the total plot 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.

3.5.4. 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:

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

3.6. 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;

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

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

3.7. Statistical Analysis

All statistical analysis were performed using SPSS 16.0 and excel 2016. Correlation and regression analysis were used to show the relationship of basal area, density, carbon stock and soil properties. Descriptive statistics was applied to generate means. The mean values of total carbon stock in living biomass of trees were compared between two community forests. Most of the specimens were identified at the time of sampling measurement 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: RESULTS

4.1. Vegetation structure

4.1.1. Species richness

Altogether 37 plant species were recorded in Durgalaxmi community forest and 47 in Teghari community forest. Species richness in the riverine forest of TCF was found to be higher than Sal forest of DCF. Species richness of trees were found to be higher in Durgalaxmi community forest (Sal forest 17) than Teghari community forest (riverine forest 16) but the species richness of shrubs and herbs were found higher in riverine forest TCF (figure 4.1).

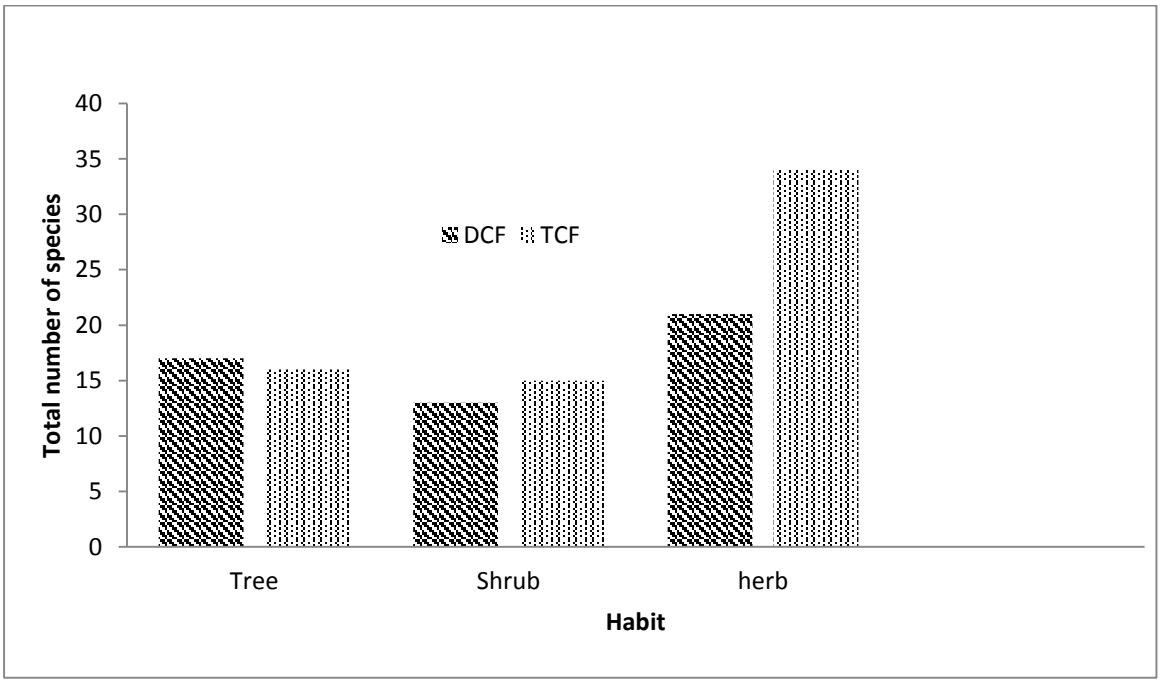


Figure 4. 1: Species richness in Durgalaxmi community and Teghari community forest

4.1.2. Importance value index (IVI)

In the DCF and TCF altogether 15 and 26 species of herbs were recorded respectively. Among them herb *Ageratum houstonianum* had highest IVI i.e. 35.93 and fern had lowest IVI i.e. 2.22 in DCF and in TCF *Eragrostis tenella* had highest IVI i.e. 22.82 and *Acorus calamus* had lowest IVI i.e. 2.33. (Table 4.1 and 4.2).

Table 4. 1: Relative frequency, Relative density, Relative abundance and IVI of herbs in Durgalaxmi community forest (DCF).

Plant name	**RF (%)**	**RD (%)**	**RA (%)**	**IVI**
Ageratum conyzoides	1.85	0.82	1.53	4.82
Ageratum houstonianum	1.85	16.54	5.49	35.93
Artemisia indica	9.25	1.23	2.04	6.05
Curcuma zedoaria	0.92	0.51	2.56	3.99
Cynodon dactylon	0.925	8.94	4.45	22.65
Cyperus procerus	0.925	3.08	15.36	19.37
Eragrostis tenella	1.85	6.37	3.17	18.80
Eupatorium adenophorum	7.40	1.02	2.56	5.43
Fern	0.92	0.20	1.02	2.15
Imperata cylindrica	9.25	10.68	6.65	24.75
Ipomoea carnea	0.925	2.56	12.80	16.29
Marsdenia roylei	2.46	1.74	4.35	7.95
Parthenium hysterophorus	2.77	1.33	3.32	6.51
Saccharum spontaneum	2.77	1.54	7.68	10.14
Senna tora	13.88	2.46	4.09	9.34

Table 4. 2: Relative frequency, Relative density, Relative abundance and IVI of herbs in Teghari community forest (TCF).

Plant species	RF (%)	RD (%)	RA (%)	IVI
Acorus calamus	0.53	0.3	1.49	2.33
Ageratum conyzoides	1.07	2.35	5.86	9.29
Ageratum houstonianum	1.6	0.7	1.16	3.475
Artemisia indica	1.07	0.6	1.49	3.17
Asparagus racemosus	2.14	3.65	4.55	10.36
Bidens pilosa	1.07	1.25	3.12	5.44
Caryopteris foetida	0.80	0.75	2.49	4.05
Curcuma zedoaria	0.80	0.90	2.99	4.7
Cynodon dactylon	4.28	1.35	0.84	6.48

Cyperus compressus	3.75	7.36	5.24	16.36
Desmostachya bipinnata	0.8	1	3.32	5.135
Dioscorea bulbifera	8.04	10.72	3.56	22.33
Dryopteris filix	1.07	0.5	1.24	2.82
Equisetum arvense	0.53	0.35	1.74	2.63
Eragrostis tenella	6.7	11.52	4.59	22.82
Eulaliopsis binata	0.53	0.8	3.99	5.33
Euphorbia hirta	4.8	1.4	0.77	7
Hemarthria compressa	1.07	1.7	4.24	7.02
Imperata cylindrica	2.14	8.32	10.36	20.82
Marsdenia roylei	1.07	0.95	2.37	4.39
Ocimum basilicum	2.14	0.55	0.68	3.38
Ophioglossum reticulatum	0.53	0.35	1.74	2.6
Oxalis corniculata	0.80	2.25	7.48	10.55
Saccharum spontaneum	2.68	4.61	4.59	11.89
Thysanolaena maxima	0.80	0.65	2.16	3.61
Xanthium strumarium	0.53	1.35	6.74	8.62

Altogether 11 and 15 species of shrubs were recorded respectively. In DCF, shrub *Murraya koenigii* and *Mallotus philippensis* had highest IVI i.e. 62.24 and 68.31 and *Psidium guajava* had lowest IVI i.e. 5.5 and whereas in TCF *Dalbergia sissoo* had highest IVI i.e. 33.66 and *Bombax ceiba* had recorded lowest IVI i.e. 5.5 respectively (Table 4.3 and 4.4).

Table 4. 3: Relative frequency, Relative density, Relative abundance and IVI of shrubs in Durgalaxmi community forest (DCF).

Plant species	RF (%)	RD (%)	RA (%)	IVI
Alstonia scholaris	4.79	0.93	2.32	8.05
Bauhinia vahlii	3.59	1.14	3.79	8.5
Cassia fistula	4.79	1.04	2.58	8.41
Garuga pinnata	2.99	1.66	6.62	11.28
Mallotus philippensis	17.96	30.28	2.07	68.31
Murraya koenigii	14.97	26.33	20.94	62.24

Psidium guajava	2.39	0.52	2.58	5.5
Schleichera oleosa	5.98	1.56	3.10	10.65
Semecarpus anacardium	7.18	2.39	3.96	13.54
Shorea robusta	14.97	25.6	20.36	60.93
Syzygium cumini	11.98	5.82	5.79	23.6
Terminalia chebula	3.59	1.35	4.48	9.42
Xeromphis spinosa	4.79	1.35	3.36	7.56

Table 4. 4: Relative frequency, Relative density, Relative abundance and IVI of shrubs in Teghari community forest (TCF).

Plant species	RF (%)	RD (%)	RA (%)	IVI
Acacia catechu	15.87	12.2	4.8	32.87
Aegle marmelos	3.17	2	4.11	9.38
Alstonia scholaris	2.11	1.22	3.6	6.93
Bambusa vulgaris	3.7	2.61	4.4	10.73
Bombax ceiba	2.64	1.74	4.11	5.5
Dalbergia sissoo	18.52	11.32	3.82	33.66
Ficus racemosa	2.11	1.22	3.6	6.93
Holoptelea integrifolia	7.93	5.22	4.11	17.28
Lantana camara	2.64	6.79	16	25.49
Mallotus philippensis	13.23	8.53	4	25.8
Murraya Koenigii	8.46	24.91	18.39	51.77
Solanum viarum	1.58	1.56	6.17	9.32
Syzygium cumini	4.76	8	10.51	23.29
Trewia nudiflora	7.93	6.44	5	19.46
Ziziphus mauritiana	5.2	6	7.2	18.59

In the DCF and TCF, altogether 17 and 16 species of trees were recorded respectively. Among them *Shorea robusta* had highest IVI i.e. 67.93 and *Sapium insigne* had lowest IVI i.e. 2.89 in DCF and *Acacia catechu* had highest IVI i.e. 57.09 and *Terminalia belerica* had lowest IVI i.e. 3.57 in TCF (Table 4.5 and 4.6).

Table 4. 5: Relative frequency, Relative density, Relative abundance and IVI of tree species in Durgalaxmi community forest (DCF)

Plant species	RF (%)	RD (%)	RA (%)	IVI
Aegle marmelos	1.92	0.52	1.67	4.11
Alstonia scholaris	4.80	0.78	1	6.59
Careya herbacea	0.96	0.52	3.34	4.83
Dalbergia sissoo	0.96	1.04	6.69	8.70
Garuga pinnata	18.26	7.57	2.55	27.36
Haldina cordifolia	2.88	6.26	13.39	22.54
Mallotus philippensis	5.76	10.96	11.7	28.45
Miliusa velutina	0.96	0.52	3.34	4.83
Sapium insigne	0.96	0.26	1.67	2.89
Schleichera oleosa	10.6	2.08	1.21	13.88
Semecarpus anacardium	1.92	0.26	0.83	3.02
Shorea robusta	12.5	42.81	2121	67.9
Syzygium cumini	3.8	9.66	15.48	28.99
Terminalia bellirica	0.96	1.3	8.37	10.63
Terminalia chebula	1.92	0.26	0.83	3.02
Terminalia tomentosa	13.46	12.79	5.86	32.11
Trewia nudiflora	17.3	2.3	0.83	20.49

Table 4. 6: Relative frequency, Relative density, Relative abundance and IVI of tree species in Teghari community forest (TCF).

Plant species	RF (%)	RD (%)	RA (%)	IVI
Acacia catechu	18	26.3	12.69	57
Aegle marmelos	3	2.39	6.92	12.32
Bombax ceiba	3	1.86	5.38	10.25
Butea monosperma	1	0.53	4.6	6.15
Dalbergia sissoo	13	18.6	12.43	44
Ficus semicordata	2	0.8	3.46	6.26
Haldina cordifolia	7	4.79	5.93	17.7

Holoptelea integrifolia	6	7.73	11.1	24.89
Madhuca longifolia	3	1.06	3	7.14
Mallotus philippensis	13	15.2	10.12	38.32
Mangifera indica	2	0.53	2.3	4.84
Semecarpus anacardium	3	1.06	3.07	7.14
Syzygium cumini	15	12.53	7.23	34.76
Terminalia bellirica	1	0.26	2.3	3.57
Terminalia tomentosa	2	0.8	3.46	6.26
Trewia nudiflora	8	5.33	5.77	19.1

4.1.3 Diversity indices

Diversity indices, Shannon Wiener (H) and Simpson diversity (Ds) values for herbs, shrubs and trees were found higher in TCF than in DCF (Table 4.7).

Table 4. 7: Shannon Wiener index (and evenness) and Simpson index of herbs, shrubs and trees in Durgalaxmi community forest (DCF) and Teghari community forest (TCF).

Species form	**Shannon's diversity index (H)**	**Simpson' diversity index (Ds)**	**Forest**
Herbs	2.97	0.92	TCF
	2.45	0.126	DCF
Shrubs	2.36	0.88	TCF
	1.74	0.77	DCF
Trees	2.12	0.84	TCF
	1.9	0.76	DCF

DCF and TCF had a large number of different herbs, shrubs and tree species, hence the index of similarity between these two forests was also found to be quite low (Table 4.8).

Table 4. 8. Similarity index between Durgalaxmi community forest (DCF) and Teghari community forest (TCF).

Habit	**Index of similarity (%)**
Herbs	47%
Shrubs	21%
Trees	48%

4.2. Forest Regeneration

The total density of seedling, sapling and tree of all species in TCF were 112000 stem/ha, 3480 stem/ha and 468 stem/ha, respectively whereas in DCF seedling, sapling and tree were found to be 6633 stem/ha, 6840 stem/ha and 478 stem/ha, respectively. Density of seedling was higher in TCF than DCF and density of saplings was higher in DCF than TCF, but density of tree was found to be less in both TCF and DCF respectively (Fig4.2).

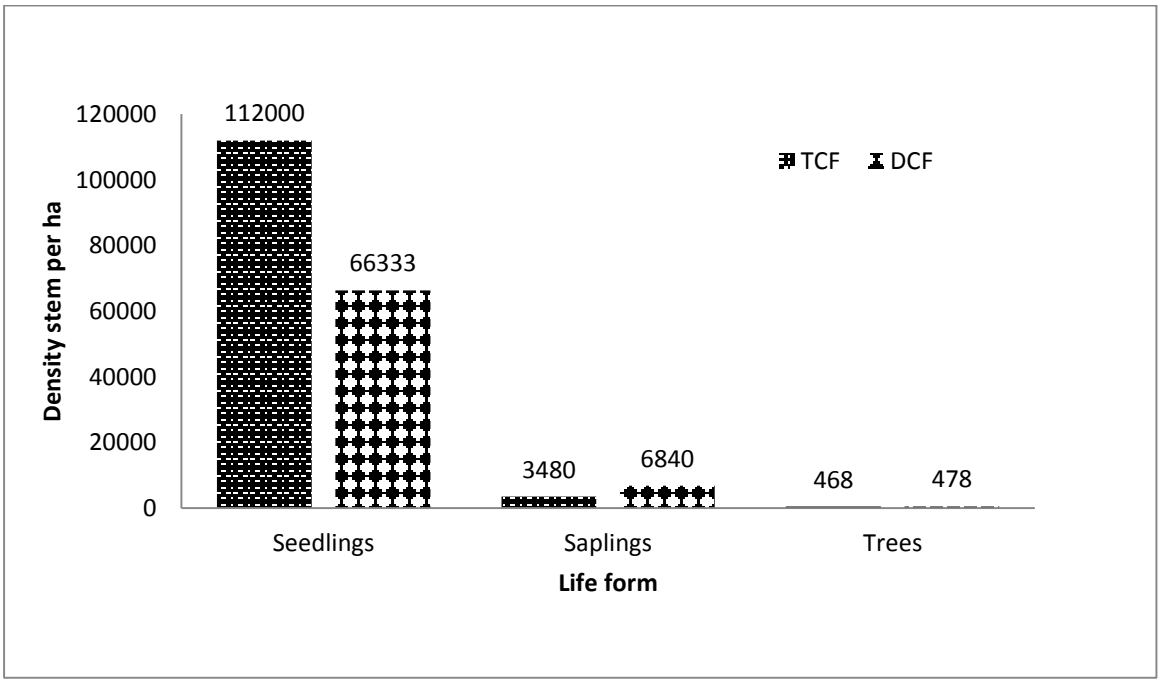


Figure 4. 2: Life form diagram to show the regeneration status of all species in Durgalaxmi community forest and Teghari community forest

Seedlings of co-dominant species Syzygium *cumini* were recorded higher in DCF than in TCF but seedlings of *Mallotus philippensis* were higher in TCF than DCF and

Alstonia scholaris were not found in both community forests. Similarly, sapling of *Syzygium cumini*, *Mallotus philippensis* and *Alstonia scholaris* were recorded higher in DCF than in TCF. Tree density of *Syzygium cumini* and *Mallotus philippensis* were also recorded higher in TCF than in DCF but *Alstonia scholaris* were not found in both forests. (Figure 4.3)

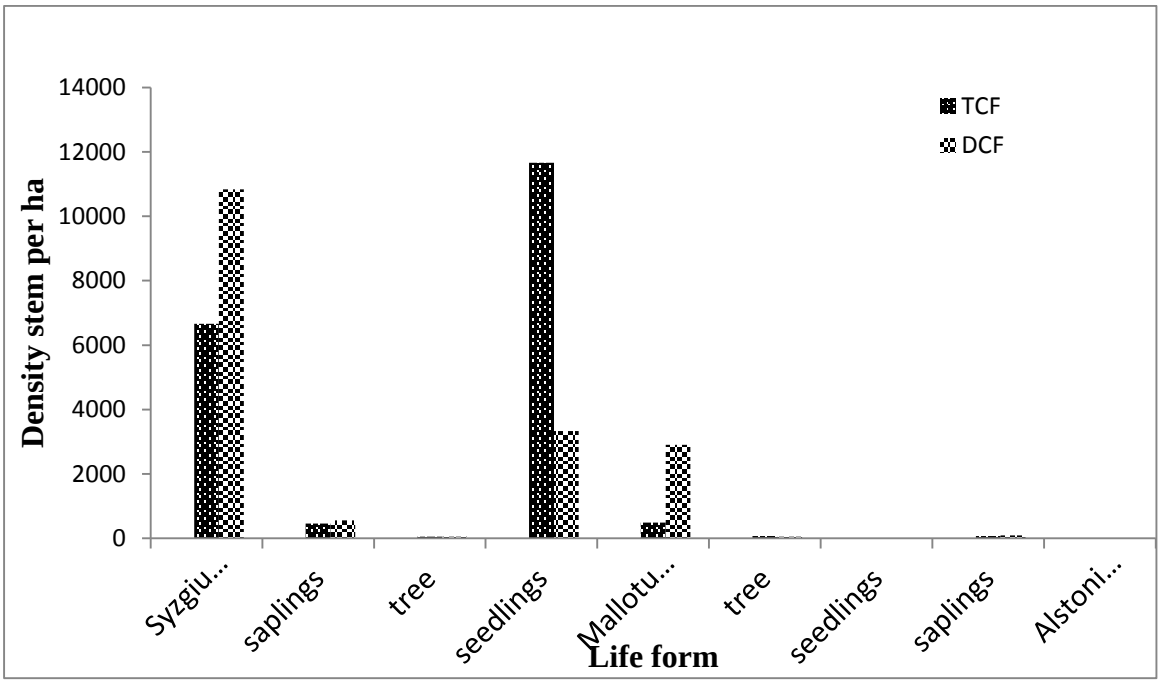


Figure 4.3: Life form diagram to show the regeneration status of three co-dominant species *Syzygium cumini, Mallotus philippensis* and *Alstonia scholaris* in Durgalaxmi community forest and Teghari community forest

4.2.1. Density Diameter Relationship of tree.

Tree density (per ha) was highest in density class 70-85(98stem/ha) followed by 55-70 (90stem/ha) in DCF (Figure 4.4) where as in TCF tree density (per/ha) was highest in density class 10-25 (150stem/ha) followed by 25-40 (141 stem/ha) (Figure 4.5). This showed that most of the stands were at an intermediate stage of growth. Trend line indicates that there is rapid decrease in density with increase in DBH of trees in TCF but it is with gentle slope because of more or less hump shaped density with DBH class (maximum density at 70-85 cm DBH class) in DCF.

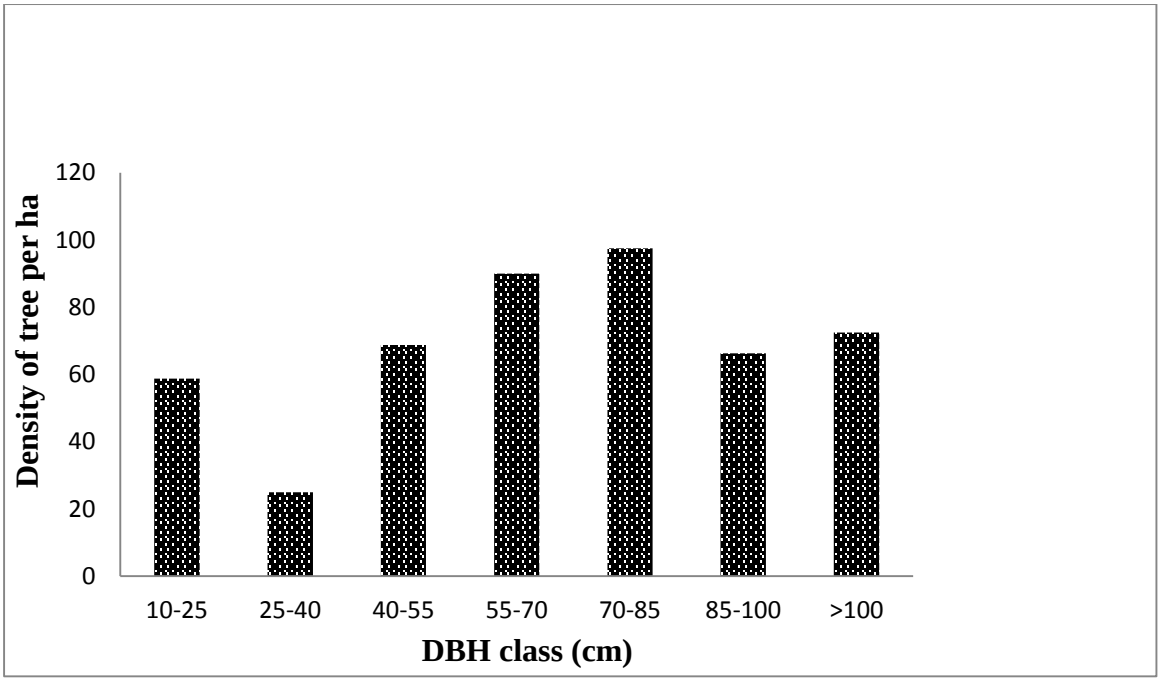


Figure 4. 4: Density diameter relationship of trees in Durgalaxmi community forest

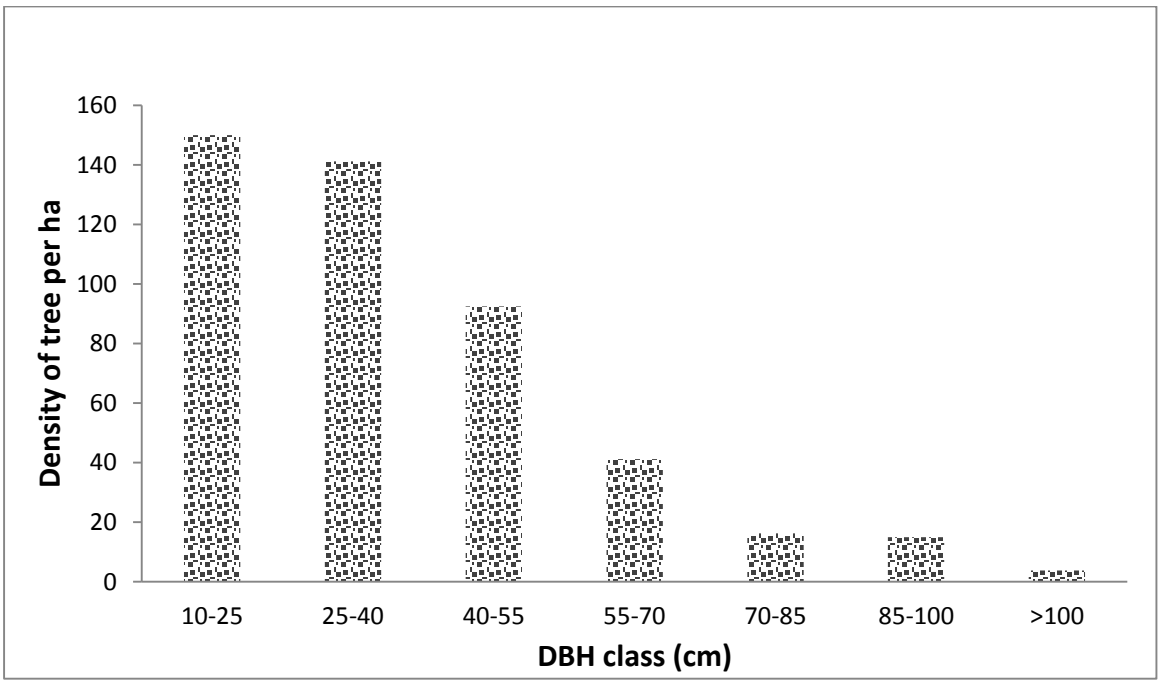
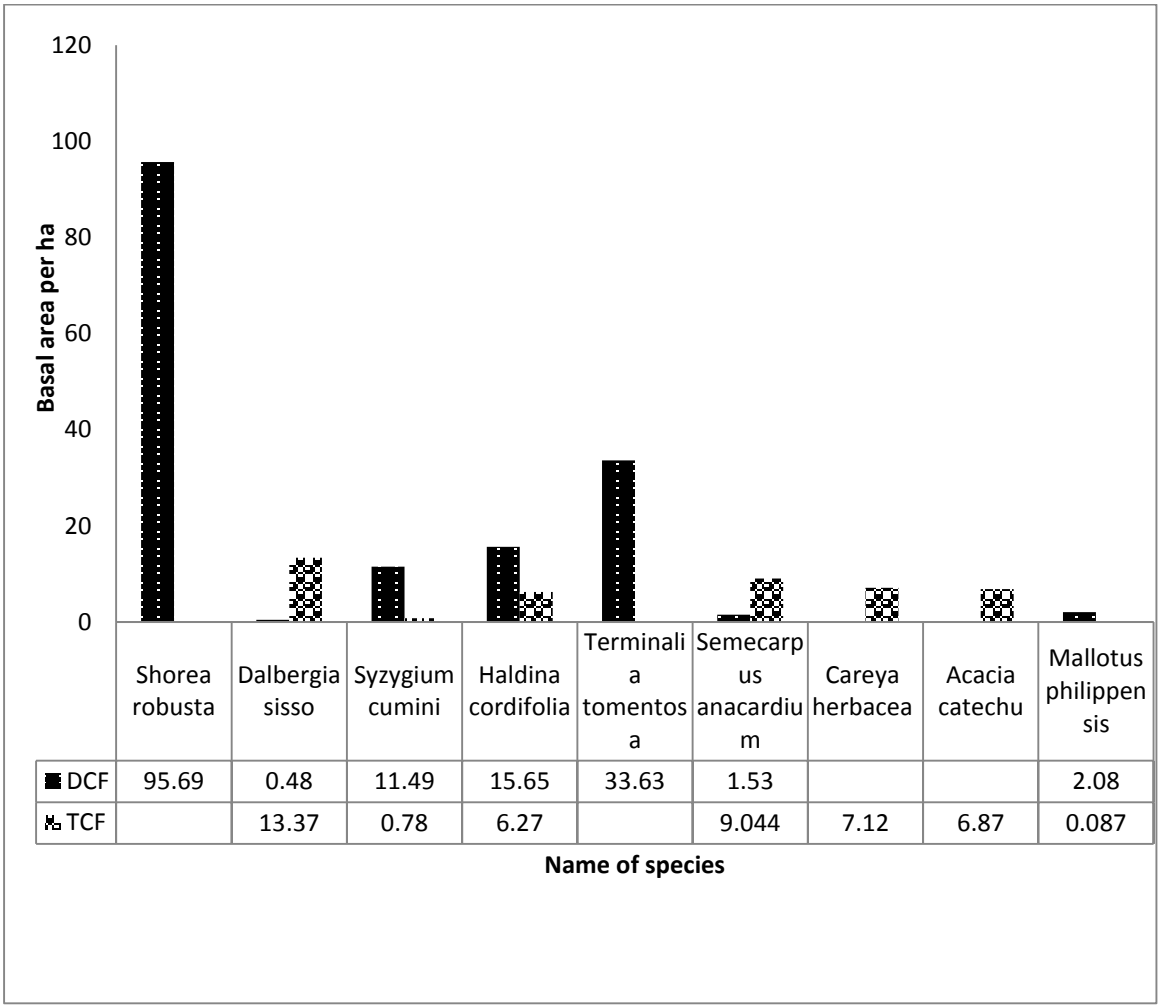


Figure 4. 5: Density diameter relationship of trees in Teghari community forest

4.2.2 Basal Area of Species

In Durga Laxmi CF, basal area of *Shorea robusta* (95.69m^2/ha), *Terminalia tomentosa* (33.63m^2/ha) and *Haldina cordifolia* (15.65 m^2/ha) respectively (Fig 4.6). While in Teghari CF, basal area of *Dalbergia sissoo* (13.37 m^2/ha), *Acacia catechu* (6.87 m^2/ha),

and *Semecarpus anacardium* (9.044 m^2/ha) measured respectively. Other major associated species were *Syzygium cumini*, *Mallotus philippensis*, *Careya herbacea*. Highest value of basal area of *Shorea robusta* in DCF and *Dalbergia sissoo* in TCF indicated the forests were dominated by *Shorea robusta* and *Dalbergia sissoo* species.



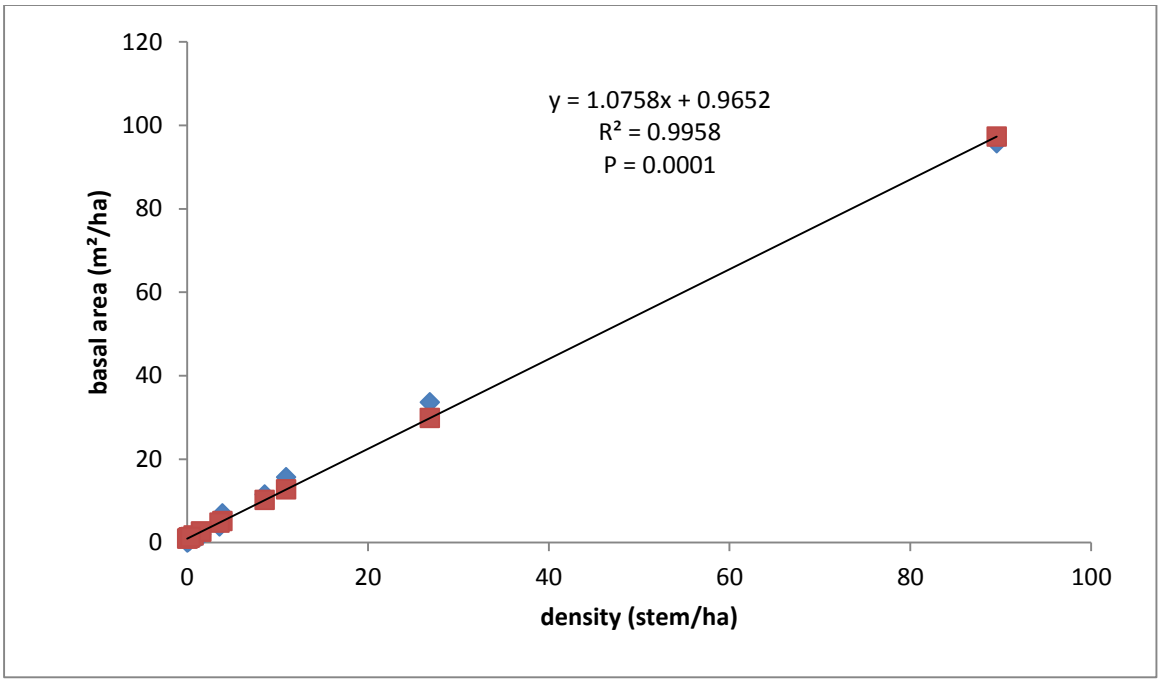
	Shorea robusta	Dalbergia sisso	Syzygium cumini	Haldina cordifolia	Terminalia tomentosa	Semecarpus anacardium	Careya herbacea	Acacia catechu	Mallotus philippensis
DCF	95.69	0.48	11.49	15.65	33.63	1.53			2.08
TCF		13.37	0.78	6.27		9.044	7.12	6.87	0.087

Figure 4. 6: Basal area of trees in DCF and TCF

Relation of basal area and density

In both DCF and TCF, Basal area increased with increase in density. Regression analysis showed that there was strong significant positive relationship between basal area and density in DCF (i.e. P =0.0001) but weak relationship in TCF (P =0.018). R^2 Value was higher in DCF than in TCF Figure 4.7 (a) and (b).

a)



(b)

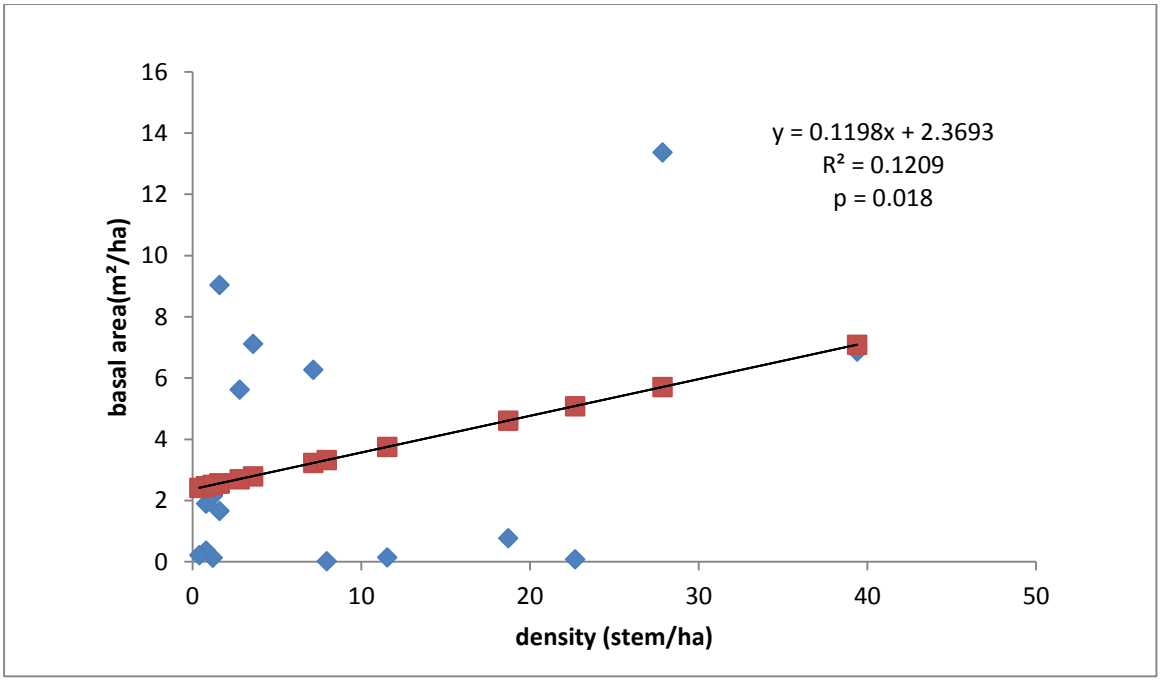


Figure 4. 7: Regression analysis showing relationship between basal area and density of Durgalaxmi community forest (a) and Teghari community forest (b)

4.3. Carbon Stock

4.3.1. Tree carbon stock

Among the two forests, above ground biomass contains higher carbon than below ground biomass (Table 4.9). Among plant tree species *Shorea robusta* had highest carbon in both above and below ground in DCF i.e. 158.79t/ha in above ground and 31.75 t/ha in below ground and *Alstonia scholaris* had lowest carbon in both above and below ground in DCF i.e. 0.01t/ha in above ground and 0.002 in below ground. *Syzygium cumini* had highest carbon i.e. 24.74t/ha in above ground and 4.94t/hac in below ground whereas *Butea monosperma* had lowest carbon i.e. 0.013 in above ground and 0.002t/hac in below ground in TCF respectively (Table 4.9.)

Table 4. 9. Above ground and below ground carbon stock of tree species in Durgalaxmi community forest (DCF) and Teghari community forest (TCF).

Tree species	**Above ground biomass(t/ha) of TCF**	**Below ground biomass(t/ha) of TCF**	**Above ground biomass(t/ha) of DCF**	**Below ground biomass(t/ha) of DCF**
Acacia catechu	10.028	2.0057	–	–
Aegle marmelos	2.3838	0.476	0.17	0.033
Alstonia scholaris	–	–	0.01	0.002
Bombax ceiba	0.048	0.0097	–	–
Butea monosperma	0.013	0.002	–	–
Careya herbacea	–	–	0.33	0.065
Dalbergia sissoo	7.187	1.43	0.45	0.091
Ficus semicordata	0.085	0.01	–	–
Garuga pinnata	–	–	6.93	1.38

Holoptelea integrifolia	8.6	1.70	–	–
Madhuca longifolia	1.938	0.38	–	–
Mangifera indica	0.05	0.011	–	–
Mallotus philippensis	4.81	0.96	1.23	0.24
Miliusa velutina	–	–	0.5	0.10
Sapium insigne	–	–	0.34	0.068
Schleichera oleosa	–	–	6.34	1.26
Semecarpus anacardium	0.25	0.051	2.7	0.54
Shorea robusta	–	–	158.79	31.75
Syzygium cumini	24.74	4.94	15.20	3.04
Terminalia bellirica	0.15	0.03	2.79	0.55
Terminalia chebula	–	–	0.126	0.025
Terminalia elliptica	0.5	0.1	–	–
Terminalia tomentosa	–	–	47.57	9.51
Trewia nudiflora	1.15	0.231	0.64	0.12
Total	**69.68**	**13.93**	**263.61**	**52.72**

Among both forests DCF had the highest carbon stock (148.75ton/ha) than TCF (39.3 ton/ha). In DCF *Shorea robusta* had the highest carbon stock i.e. 89.56 ton/ha followed by *Terminalia tomentosa* (26.83 ton/ha), *Haldina cordifolia* and (10.96 ton/ha) and so on. *Syzygium cumini* (13.95ton/ha) and *Acacia catechu* (5.65 ton/ha) had highest carbon

stock followed by *Haldina cordifolia* (4.38 ton/ha), *Dalbergia sissoo* (4.05 ton/ha), *Holoptelea integrifolia* (4.8ton/ha) and so on which are given in table 4.10.

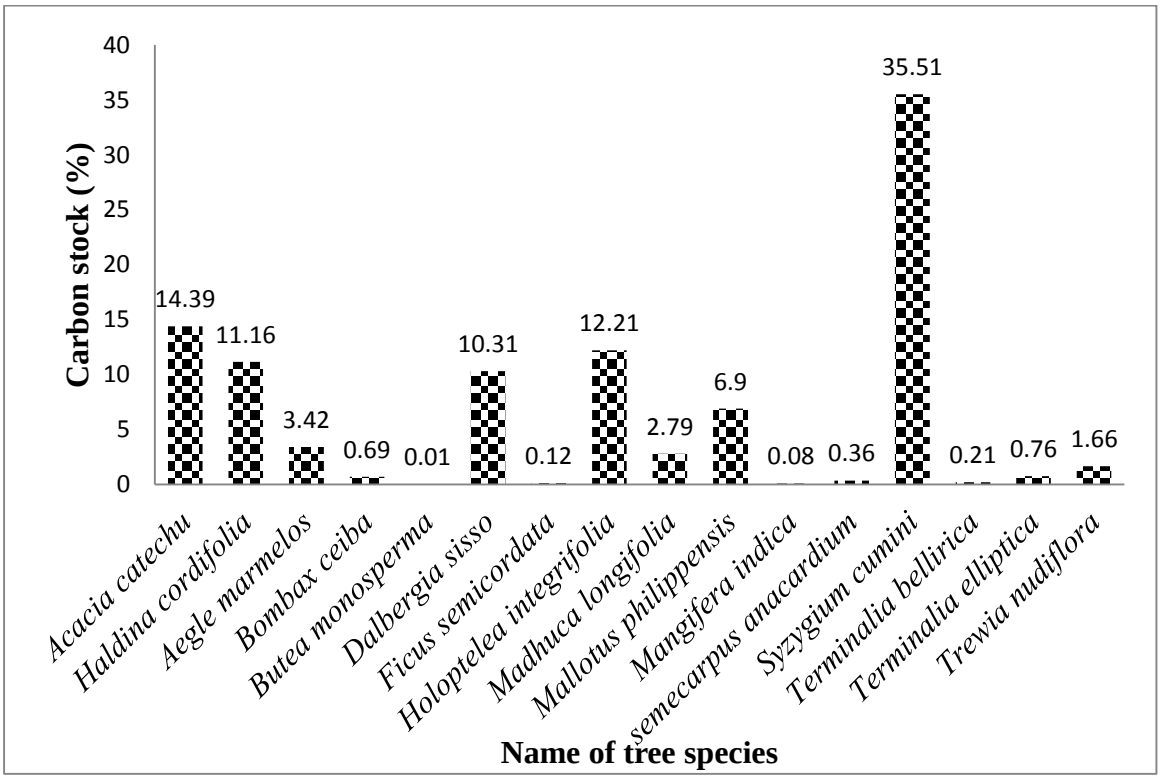
Table 4. 10. Species wise carbon stock in Durgalaxmi community forest (DCF) and Teghari community forest (TCF).

Name of species	**DCF carbon stock (t/ha)**	**TCF carbon stock (t/ha)**
Acacia catechu	–	5.65
Haldina cordifolia	10.96	4.38
Aegle marmelos	0.094	1.34
Bombax ceiba	–	0.027
Butea monosperma	–	0.0076
Dalbergia sissoo	0.25	4.05
Ficus semicordata	–	0.047
Holoptelea integrifolia	–	4.8
Madhuca longifolia	–	1.08
Mallotus philippensis	0.69	2.71
Mangifera indica	–	0.031
Semecarpus anacardium	1.52	0.14
Syzygium cumini	8.57	13.95
Terminalia bellirica	1.57	0.085
Terminalia elliptica	–	0.3
Trewia nudiflora	0.36	0.65
Alstonia scholaris	0.006	–
Garuga pinnata	3.91	–
Miliusa velutina	0.28	–
Sapium insigne	0.19	–
Schleichera oleosa	3.57	–
Shorea robusta	89.56	–
Careya herbacea	0.18	–
Terminalia chebula	0.071	–
Terminalia tomentosa	26.8	–
Total	**148.75**	**39.30**

4.3.2. Contribution of Species in Tree Carbon Stock

The value of Carbon stock was measured 148.75 t/ ha in DCF and 39.30 t/ ha in TCF. Average contributions were highly skewed in DCF with maximum carbon stock (60.24%) on *Shorea robusta* and relatively low percentage of carbon stock on *Alstonia scholaris* (0.004%) and other species (fig 4.8 b) but in TCF, carbon stock of *Syzygium cumini* (35.51%) *Acacia catechu*, (14.39%) *Holoptelea integrifolia* (12.21%) and *Dalbergia sissoo* (10.31%) were almost proportional (Fig 4.8 a).

TCF (a)



DCF(b)

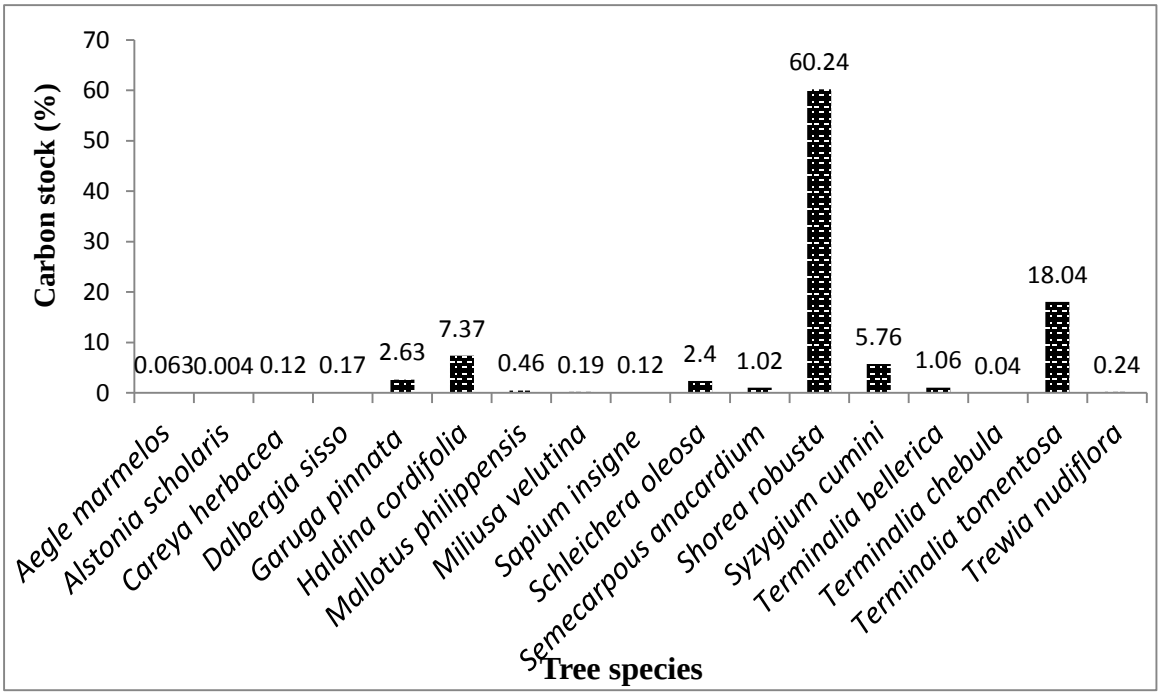
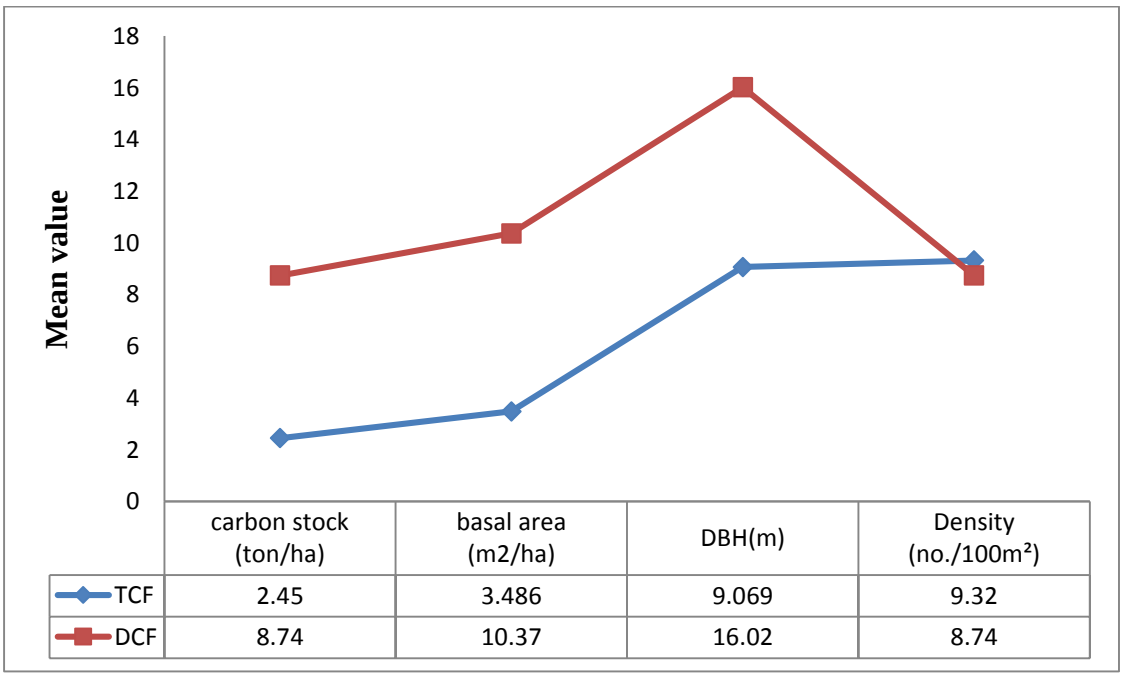


Figure 4. 8: Species contribution on carbon stock (a) TCF (b) DCF.

4.3.3. Comparison between Forest Types

Between the two community forest types, the mean values of carbon stock, DBH and basal area were higher in DCF than TCF (Fig 4.9). However there was a higher value of density in TCF than DCF.



	carbon stock (ton/ha)	basal area (m2/ha)	DBH(m)	Density (no./100m²)
TCF	2.45	3.486	9.069	9.32
DCF	8.74	10.37	16.02	8.74

Figure 4. 9: Mean values of Carbon stock, basal area, density and DBH.

4.3.4. Soil parameters

Organic carbon and nitrogen were found to be quite low whereas Phosphorus was found to be low and some sample medium and value of pH was basic and neutral in Durgalaxmi community forest. (Figure 4.11).

Table 4.11. Total organic carbon, pH, nitrogen and phosphorous in Durgalaxmi community forest

S.N.	Organic carbon	pH	Nitrogen	Phosphorous
1	0.74	6.91	0.02	0.18
2	0.46	7.69	0.08	1.19
3	0.98	6.57	0.09	3.21
4	1.19	6.68	0.06	0.18
5	2.02	6.43	0.15	3.21
6	2.06	6.71	0.24	11.27
7	2.04	6.67	0.16	30.43
8	0.76	7.57	0.06	13.29
9	0.95	7.38	0.11	5.22
10	2.23	7.46	0.16	18.33
11	1.50	6.58	0.13	18.33
12	1.32	6.99	0.10	4.22
13	1.69	7.43	0.18	10.26
14	1.76	7.36	0.15	4.22
15	2.08	6.42	0.06	0.18
16	1.35	6.80	0.05	4.22
17	0.74	7.50	0.08	2.20

Organic carbon and nitrogen were found to be quite low and medium whereas Phosphorous was found to be low and some sample medium and value of pH was acidic and neutral in Teghari community forest (figure 4.12).

Table 4.12. Total organic carbon, pH, nitrogen and phosphorous in Teghari community forest

S.N.	pH	Organic carbon	Nitrogen	Phosphorous
1	7.35	3.15	0.18	14.30
2	5.49	0.89	0.20	2.20
3	5.95	0.96	0.23	7.24
4	6.55	1.34	0.05	9.26
5	5.92	1.06	0.15	7.24
6	6.10	0.96	0.14	8.25
7	6.51	0.56	0.22	4.22
89	6.04	0.70	0.13	13.29
10	6.13	0.61	0.06	2.20
11	5.94	1.30	0.03	5.22
12	6.95	1.95	0.19	16.31
13	5.57	2.23	0.15	13.29
14	6.96	1.19	0.22	22.36
15	5.95	0.74	0.05	10.26
16	5.45	0.91	0.18	1.19
17	5.38	1.11	0.24	1.19

4.3.5. Correlation between the soil parameters and carbon stock

Pearson's correlation coefficient (r) of correlation analysis was calculated between the soil parameters and carbon stock of both forests. Insignificant correlation was observed between the soil parameters (pH, OM, N and P) and tree carbon stock in all studied Forest (Table 4.13 and 4.14).

Table 4. 13. Pearson correlation coefficients between forest composition and soil properties in TCF

Parameters	CS	OM	pH	N	P
CS	1	-	-	-	-
OM	0.12	1	-	-	-
pH	0.46	0.48	1	-	-
N	0.25	0.09	0.03	1	-
P	**0.58**	0.48	**0.68**	0.08	1

Table 4.14. Pearson correlation coefficients between forest composition and soil properties in DCF

Parameters	**CS**	**OM**	**pH**	**N**	**P**
CS	1	-	-	-	-
OM	-0.13	1	-	-	-
pH	0.19	-0.46	1	-	-
N	-0.24	**0.69**	-0.11	1	-
P	**0.67**	0.14	0.20	0.09	1

Note: CS: Carbon stock, pH: Power of hydrogen, OM: Organic matter, N-Nitrogen, P-Phosphorus.

CHAPTER 5: DISCUSSION

5.1 Plant Diversity

Species diversity is the measure of diversity within an ecological community that incorporates both species richness and the evenness of species abundances. Plant diversity was found to be higher in riverine forest (TCF) than Sal forest (DCF). The diversity of herbs and shrubs were higher in riverine forest (TCF) than Sal forest (DCF) due to the presence of more open canopy which facilitates understory vegetation like *Murraya koenigii*, and *Lantana camara* were most common shrub species. Also, the *Dioscorea* species was the most frequent climber. Similarly, diversity indices, Shannon Wiener (H) and Simpson diversity (Ds) value for herbs, shrubs and trees were found higher in TCF than in DCF. Riverine forest had over twice the density of trees per ha (many small trees), and higher tree species richness than Sal forest. Sal forest had more large trees than riverine forest.

Besides, *Shorea robusta, Garuga pinnata, Syzygium cumini, Terminalia tomentosa* species were found with higher IVI in DCF which are the indicator of dryness favor plant and in TCF, *Dalbergia sissoo, Syzygium cumini, Mallotus philippensis, Holoptelea integrifolia* and *Acacia catechu* were found with higher IVI which are the indicator of riverine forest. High IVI of a species indicates its dominance and ecological success, its good power of regeneration and greater ecological amplitude (Shameem and Kangroo, 2011).

Total tree basal area was higher in DCF due to the presence of species Like *Shorea robusta, Terminalia tomentosa, Haldina cordifolia,* and *Syzygium cumini* attaining thick trunk (Giri *et al.*, 2001). Similarly *Acacia catechu* and *Dalbergia sissoo* are more frequent in TCF. Overall, the index of diversity is highest in TCF and least in DCF. High value of species diversity in TCF was due to the presence of extensive stands of understory species like *Murraya koenigii*. These species are not affected by forest fires and seasonal floods. Similar findings have been reported in India (Rodger *et al*. 1986; Maithani *et al*., 1986). Diversity of ground vegetation varied in two different forest communities and also exhibited seasonal variations. High herb diversity in the areas with less shrub cover might be due to the response of herbs to the removal of shrubs or the low availability of shrubs (Joshi, 2021). Generally, the diversity of herb species is

greater in the rainy season. In summer the low moisture content in the soil as well as the fire affected the diversity of herb species.

5.2 Regeneration

Natural regeneration of plant species was crucial to the sustainable management of tropical forests (Medjibe *et al*., 2014).Seedling density was higher in TCF than in DCF and sapling density was higher in DCF than TCF but density of tree was found to less in both community forest. It might be due to more plants with minimum basal area and open canopy in TCF than in DCF and due to differences in ecosystems. Opening of the canopy in a forest stand promotes regeneration and the growth of understory seedlings and saplings 37 (Troup, 1986; Gautam, 1990).In both forests, regeneration is proceeding well, as evidenced by the high population density of seedlings followed by saplings and adult trees. However, the population density of seedlings was twice as high in TCF as in DCF. It might be due to faster nutrient cycling and plenty of light availability on the forest floor in the warmer climate (Aiba and Kitayama, 1999). A strong positive relationship between individuals at seedling and advanced regeneration stages was found. This implies that such a high rate of early establishment could lead to higher recruitment of adults if disturbance is precluded (Sagar and Singh, 2005). Seth and Bhatnagar (1959) reported that poor soil aeration and high organic matter in the soil are related to poor regeneration which is generally encountered in moist and very moist Sal forests. Sal has dominated seedlings and saplings layers. The higher density of Sal species (seedlings and saplings) might be due to the presence of low canopy cover in community forests which allowed the required amount of sunlight to reach the understory of community forests and made the environment favorable for abundant growth of seedlings and saplings of Sal species (Joshi *et al.*, 2020). The abundance and density of seedlings and saplings indicate the regeneration potential of a community forest (Joshi *et al*., 2021).

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 112000 seedlings and 3480 saplings stem/ha in TCF and 66333 and 6840 stem/ha in DCF which were higher than the above mentioned values. Hence, the regeneration status in both TCF and DCF were in good condition. Regeneration is the determinant factor for the sustainability of forests.

Cutting down of trees must have led to open canopy and this must have favored good regeneration. Natural regeneration is essential for preservation and maintenance of biodiversity.

5.3 Carbon stock

The value of Carbon stock was measured 148.75 t/ ha in DCF and 39.30 t/ ha in TCF. Average contributions were highly skewed in DCF with maximum carbon stock (60.24%) on *Shorea robusta* and relatively low percentage of carbon stock on *Alstonia scholaris* (0.004%) and other species. *Shorea robusta* was the highest contributor of C-stock in durgalaxmi community forest (i.e. 60.24% in Sal forest) this could be due to the highest basal area of *Shorea robusta* in Sal forest than other species (i.e. 95.69m²/ha in DCF). This value was less than the value obtained for *Shorea robusta* dominated two CFS of Gorkha where *Shorea robusta* contributed 95% and 86% in C-stock (Neupane and Sharma, 2014). Similar result has been shown *Shorea robusta* dominated two CFS of Kanchanpur where Sal was the highest contributor of C-stock in the tree layer with 50.17% (38.5 t ha-1) and 87.73% (143.10 t ha-1) in both Ganesh and Ramnagar community forests, respectively (Joshi *et al*. 2021). In contrast to this, Gairhe, (2015) found sal contributed 64.5% & 44.7% in C-stock in two community managed forests of Tanahun district. IVI value of *Shorea robusta* was higher in DCF forest than other associated species. The above ground biomass was 263.61t/ha in DCF. *Shorea robusta* accounted for a greater amount of TAGB in DCF forest similar to the findings of Singh and Singh, (1992) in Central Himalayas with *Shorea robusta* accounting for 87-94% of total tree biomass. Sejuwal, (1994) reported 1038.16 ton/ha aboveground biomass in the Sal forest of Chitwan National Park, Central Nepal, in which Sal covered 96.7% of total species. Similarly, Baral *et al*., (2009) reported that the total above ground carbon stock was higher in the tropical forests of Nepal than subtropical forests.

The above ground biomass was 69.68t/ha in TCF. The highest biomass was contributed by *Syzygium cumini* (35.51%) *Acacia catechu*, (14.39%) *Holoptelea integrifolia* (12.21%) and *Dalbergia sisso* (10.31%). Sejuwal (1994) also obtained similar findings in the riverine forest of Chitwan National Park (CNP). Tropical riverine forests are fast growing species thus had higher carbon sequestration rates while *Shorea robusta* were slow growing species thus had low carbon sequestration rates (Baral *et al*., 2009).

Similarly, Baral *et al*., (2009) reported that the total above ground carbon stock was higher in the tropical forests of Nepal than subtropical forests.

In the present study, canopy cover and basal area of species were found higher in DCF than in TCF. The relationship between basal area and density was found to be statistically significant in DCF but showed weak relationship in TCF which is similar to Thapa Magar and Shrestha, (2015). High density of tree individuals with 10-25cm diameter at breast height was observed in TCF. The result showed more trees individual with minimum diameter because TCF was regenerating forest. But in DCF more tree individuals with 70-85cm diameter at breast height were observed indicating it to be older than the TCF. Basal area was a good predictor for biomass (Gebrewahid and Meressa, 2020). Sahoo *et al*., (2021) basal area was strongly correlated with tree density. Carbon sequestration depends on the rate of annual growth of forests, positively correlated with age. The rate of carbon sequestration is much faster in young and regenerating forest but C-stock is more in old and mature forest (Joshi *et al*., 2021).

Insignificant Pearson's correlation was observed between the soil parameters and tree carbon stocks in DCF and TCF in the present study. The possible reason behind the insignificant relationship between soil parameters and tree carbon stock might be due to regular extraction of biomass (for firewood and fodder) and litter collection (from the forest floor). These human activities transfer the carbon and other nutrients from forest to farmland and interfere with the natural biogeochemical cycle.

CHAPTER 6: CONCLUSION AND RECOMMENDATION

6.1 Conclusion

From this study it can be concluded that plant diversity is higher in Teghari community forest (riverine forest) than Durgalaxmi community forest due to presence of less dense canopy forest. Diversity of ground vegetation varied in two different forest communities and also exhibited seasonal variations. The carbon stock increased with the increase in sustainable management duration of forests while the density of seedlings, saplings, and trees in studied CFs were in the following order: seedlings > saplings > trees. The study revealed that the contribution of seedlings to the total population was highest followed. In Teghari community forest *Acacia catechu* and *Dalbergia sissoo* were dominant species and in Durgalaxmi forest *Shorea robusta* was dominant species with higher total number of seedlings and saplings/ha. It illustrates that the regeneration of tree species in the forest is good and the future communities may be sustained unless there is any major environmental stress or interference exerted by human activities. As studied the total mean values of carbon stock, DBH and basal area was favored in DCF than TCF. *Shorea robusta* was the most dominant species and showed a significant contribution to the carbon stock between both community forests. Relationship between soil parameters and carbon stock showed insignificant relation. Hence this study showed Sal forest was important for carbon stock and tropical riverine forest species richness.

6.2 Recommendation

i. People should be aware about situation of the forest and economic importance plant should be plant.

ii. Illegal logging and grazing should be strictly prohibited for regeneration of the forest.

iii. Fast regeneration is essential near the roadsides and settlements proximity in DCF.

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APPENDICES

APPENDIX I

Data sheet used in field sampling

Date: District:

Locality: Altitude:

Slope Latitude:

Longitude: Plot no:

Quadrat no: Quadrat size:

Canopy cover (%): Ground vegetation cover:

Litter cover (%):

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

APPENDIX II

Geographical position of plots with different variables measured in these plots. Where, plot number 1-20; for DCF and 21 - 40 TCF (Alt- altimeter).

Plot no	Alt(m)	Longitude	Latitude	Slope(°)
1	189	80° 33 '33" E	28° 49' 0 "N	0
2	186	80 33 36 E	28 49 6 N	0
3	193	79 33 24 E	27 46 12 N	1
4	180	80 33 25 E	28 49 14 N	0
5	187	80 33 21 E	28 49 14 N	0
6	240	80 33 24 E	28 49 9 N	0
7	186	80 33 47 E	28 15 2 N	0
8	207	80 33 43 E	28 49 55 N	0
9	204	80 33 46 E	28 49 51 N	0
10	147	80 33 34 E	28 49 31 N	1
11	222	80 33 38 E	28 49 30 N	0
12	229	80 33 42 E	28 49 29 N	0
13	227	80 33 45 E	28 49 26 N	0
14	233	80 33 28 E	28 49 22 N	0
15	230	80 33 37 E	28 49 27 N	0
16	225	80 33 47 E	28 49 31 N	0
17	206	80 33 51 E	28 49 36 N	0
18	215	80 33 50 E	28 49 14 N	0
19	197	80 33 40 E	28 47 8 N	0

20	187	80 33 52 E	28 49 28 N	0
21	197	80 33 9 E	28 50 39 N	0
22	209	80 33 8 E	28 50 45 N	0
23	211	80 33 3 E	28 50 42 N	0
24	209	80 32 59 E	28 50 44 N	0
25	185	80 32 38 E	28 50 36 N	0
26	171	80 32 59 E	28 50 32 N	1
27	172	80 32 57 E	28 50 28 N	0
28	179	80 32 57 E	28 50 17 N	0
29	187	80 32 38 E	28 50 16 N	0
30	190	80 32 44 E	28 50 11 N	0
31	191	80 32 44 E	28 50 9 N	0
32	195	80 32 41 E	28 50 7 N	0
33	171	80 32 37 E	28 50 7 N	0
34	190	80 32 35 E	28 56 4 N	0
35	139	80 32 35 E	28 50 12 N	0
36	177	80 32 37 E	28 49 60 N	0
37	195	80 32 40 E	28 47 45 N	0
38	200	80 33 5 E	28 50 44 N	0
39	204	80 33 7 E	28 50 45 N	0
40	198	80 33 12 E	28 50 36 E	0

APPENDIX III

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

Species name	**Wood density (g/cm3)**
Acacia catechu	0.801
Aegle marmelos	0.77
Alstonia scholaris	0.35
Bombax ceiba	0.35
Butea monosperma	0.12
Careya herbacea	0.67
Dalbergia sissoo	0.76
Ficus semicordata	0.39
Garuga pinnata	0.64
Haldina cordifolia	0.48
Holoptelea integrifolia	0.5
Madhuca longifolia	0.74
Mallotus philippensis	0.64
Mangifera indica	0.68
Miliusa velutina	0.46
Sapium insigne	0.37
Schleichera oleosa	0.108
Semecarpus anacardium	0.64
Shorea robusta	0.73
Syzygium cumini	0.76
Terminalia chebula	0.88
Terminalia bellirica	0.76
Terminalia tomentosa	0.73

APPENDIX IV

Herbs, shrubs and trees species found in Durgalaxmi community forest and Teghari community forest

S.N.	Scientific name of herbs	Scientific name of shrubs	Scientific name of trees
1	*Acacia catechu* (L.F.) Willd.	*Aegle marmelos* L.	*Acacia catechu* (L.F.) Willd
2	*Acorus calamus* Spreng.	*Acacia catechu*	*Aegle marmelos* L.
3	*Aegle marmelos* L.	*Alstonia scholaris* L.	*Alstonia scholaris* L
4	*Ageratum conyzoides* L.	*Bauhinia vahlii* (Wight.) Arn.	*Butea monosperma* (Lam.)
5	*Ageratum houstonianum* mill	*Bombax ceiba* L.	*Bombax ceiba* L.
6	*Artemisia indica* Willd.	*Bambusa vulgaris* ex. J.C. Wendl.	*Careya herbacea* Roxb.
7	*Asparagus racemosus* Willd.	*Cassia fistula*	*Dalbergia sisso* Roxb.
8	*Bidens pilosa* L.	*Dalbergia sissoo*	*Garuga pinnata* Roxb.
9	*Bombax ceiba* L.	*Ficus racemosa* L.	*Holoptelea integrifolia* Roxb.
10	*Caryopteris foetida* (D.Don)	*Garuga pinnata* Roxb.	*Haldina cordifolia* Roxb.
11	*Curcuma zedoaria* Rosc.	*Holoptelea integrifolia*	*Mallotus philippensis* (Lam.)
12	*Cynodon dactylon* (L.) Pers.	*Lantana camara* L.	*Madhuca longifolia* J. Konig
13	*Cyperus procerus* Rottb.	*Mallotus philippensis* (Lam.)	*Mangifera indica* L.
14	*Dalbergia sisso* Roxb.	*Murraya Koenigii* L.	*Miliusa velutina* Hook. F.
15	*Desmostachya bipinnata* Miers.	*Psidium guajava* L.	*Syzygium cumini* L.
16	*Dioscorea bulbifera* L.	*Solanum viarum* (Dunal.)	*Shorea robusta* Gaertn.
17	*Dryopteris filix* Adans.	*Shorea robusta* Gaertn.	*Schleichera oleosa* (Llour.)Merr.
18	*Equisetum arvense* L.	*Syzygium cumini* L.	*Sapium insigne* benth
19	*Eragrostis tenella* (Retz) C.E Hubb.	*Schleichera oleosa* (Llour.)Merr.	*Semecarpus anacardium* L.
20	*Eulaliopsis binata* (Retz.) C.E. Hubb.	*Semecarpus anacardium*	*Ficus semicordata* Ham. ex Sm.

21	*Eupatorium adenophorum*	*Terminalia Chebula* Retz.	*Terminalia chebula* Retz.
22	*Euphorbia hirta* L.	*Trewia nudiflora* L.	*Terminalia tomentosa* Roxb.
23	Fern	*Xeromphis spinosa* keay	*Terminalia bellirica* Roxb
24	*Garuga pinnata* Roxb.	*Ziziphus mauritiana* Lam.	*Trewia nudiflora* L.
25	*Haldina cordifolia* Roxb.		
26	*Hemarthria compressa* (L.F.)		
27	*Holoptelea integrifolia*		
28	*Imperata cylindrica* L.		
29	*Ipomoea carnea* Jacq.		
30	*Mallotus philippensis* (Lam.)		
31	*Marsdenia roylei* wight		
32	*Ocimum basilicum* L.		
33	*Ophioglossum reticulatum* Linn.		
34	*Oxalis corniculata* L.		
35	*Parthenium hysterophorus* L.		
36	*Psidium guajava L.*		
37	*Saccharum spontaneum* L.		
38	*Senna tora* (L.) Roxb.		
39	*Shorea robusta* Gaertn.		
40	*Syzygium cumini* L.		
41	*Thysanolaena maxima* (Roxb) Kuntze		
42	*Trewia nudiflora* L.		
43	*Xanthium strumarium* Linn.		

APPENDIX V

Frequency, density and abundance values of herbs in Durgalaxmi community forest.

Plant name	**Total number of individual in 60 plot (Q)**	**F**	**D**	**A**
Ageratum conyzoides	8	10	424.41	1
Ageratum houstonianum	161	10	8541.32	3.57
Artemisia indica	12	50	636.62	1.33
Curcuma zedoaria	5	5	265.25	1.67
Cynodon dactylon	87	5	4615.49	2.9
Cyperus procerus	30	5	1591.55	10
Eragrostis tenella	62	10	3289.20	2.06
Eupatorium adenophorum	10	40	530.51	1.67
Fern	2	5	106.1	0.67
Garuga pinnata	25	21.66	1326.29	2.77
Haldina cordifolia	18	16.66	954.93	2.57
Imperata cylindrica	104	50	5517.37	4.33
Ipomoea carnea	25	5	1326.29	8.33
Mallotus philippensis	20	11.66	1061.03	1.53
Marsdenia roylei	17	13.33	901.87	2.83
Parthenium hysterophorus	13	15	689.67	2.16
Psidium guajava	20	66.66	1061.03	2
Saccharum spontaneum	15	15	795.77	5
Senna tora	24	75	1273.24	2.67
Shorea robusta	250	5	13262.92	4.38
Syzygium cumini	65	95	3448.36	1.625

Frequency, density and abundance values of shrubs in Durgalaxmi community forest.

S.N.	Plant species	Total number of individual in 40 plot (Q)	F	D	A
1	*Alstonia scholaris*	9	20	28.65	1.12
2	*Bauhinia vahlii*	11	15	35.01	1.83
3	*Cassia fistula*	10	20	31.38	1.25
4	*Garuga pinnata*	16	12.5	50.93	3.2
5	*Mallotus philippensis*	291	75	926.3	9.7
6	*Murraya koenigii*	253	62.5	805.3	10.12
7	*Psidium guajava*	5	10	15.92	1.25
8	*Schleichera oleosa*	15	25	47.7	1.5
9	*Semecarpus anacardium*	23	30	73.21	1.91
10	*Shorea robusta*	246	62.5	783	9.84
11	*Syzygium cumini*	56	50	178.3	2.8
12	*Terminalia chebula*	13	15	41.38	2.16
13	*Xeromphis spinosa*	13	20	41.38	1.62

Frequency, density and abundance values of tree in Durgalaxmi community forest

Plant species	Total number of individual in 20 plot (Q)	F	D	A
Aegle marmelos	2	10	0.79	1
Alstonia scholaris	3	25	1.19	0.6
Careya herbacea	2	5	0.79	2
Dalbergia sissoo	4	5	1.59	4
Garuga pinnata	29	95	11.53	1.52
Haldina cordifolia	24	15	9.5	8
Mallotus philippensis	42	30	16.71	7
Miliusa velutina	2	5	0.79	2
Sapium insigne	1	5	0.39	1
Schleichera oleosa	8	55	3.18	0.72
Semecarpus anacardium	1	10	0.39	0.5
Shorea robusta	164	65	65.25	12.61
Syzygium cumini	37	20	14.72	9.25
Terminalia bellirica	5	5	1.98	5
Terminalia chebula	1	10	0.39	0.5
Terminalia tomentosa	49	70	19.49	3.5
Trewia nudiflora	9	90	3.58	0.5

Frequency, density and abundance values of herbs in teghari community forest

Plant species	**Total number of individual in 60 plot (Q)**	**F**	**D**	**A**
Acacia catechu	250	83.33	13262.92	5
Acorus calamus	6	3.33	318.31	3
Aegle marmelos	15	13.33	795.77	1.87
Ageratum conyzoides	47	6.67	2493.43	11.75
Ageratum houstonianum	14	10	742.72	2.33
Artemisia indica	12	6.67	636.62	3
Asparagus racemosus	73	13.33	3872.77	9.12
Bidens pilosa	25	6.67	1326.29	6.25
Bombax ceiba	3	3.33	159.15	1.5
Caryopteris foetida	15	5	795.77	5
Curcuma zedoaria	18	5	954.93	6
Cynodon dactylon	27	26.67	1432.3	1.68
Cyperus compressus	147	23.33	7798.59	10.5
Dalbergia sissoo	235	75	12467.15	5.22
Desmostachya bipinnata	20	5	1061	6.67
Dioscorea bulbifera	214	50	11353	7.13
Dryopteris filix	10	6.67	530.51	2.5
Equisetum arvense	7	3.33	371.36	3.5
Eragrostis tenella	230	41.6	12201.8	9.2
Eulaliopsis binate	16	3.33	848.82	8
Euphorbia hirta	28	30	1485.44	1.55
Hemarthria compressa	34	6.67	1808.75	8.57
Holoptelea integrifolia	25	25	1326.29	1.67
Imperata cylindrica	166	13.33	8806.5	20.75
Mallotus philippensis	70	38.33	3713.61	3.04
Marsdenia roylei	19	6.67	1007.98	4.75
Ocimum basilicum	11	13.33	583.56	1.37
Ophioglossum reticulatum.	7	3.33	371.36	3.5
Oxalis corniculata	45	5	2387.32	15
Saccharum spontaneum	92	16.67	4880.75	9.2
Syzygium cumini	40	33.33	2122.06	2
Thysanolaena maxima	13	5	689.67	4.33
Trewia nudiflora	34	30	1803.75	1.88
Xanthium strumarium	27	3.33	1432.39	13.5

Frequency, density and abundance values of shrubs in teghari community forest

Plant species	**Total number of individual in 40 plot (Q)**	**F**	**D**	**A**
Murraya Koenigii	143	40	455.2	8.93
Ziziphus mauritiana	35	25	11.4	3.5
Lantana camara	39	12.5	124.1	7.8
Holoptelea integrifolia	30	37.5	95.49	2
Syzygium cumini	46	22.5	146.4	5.11
Mallotus philippensis	49	62.5	156	1.96
Acacia catechu	70	75	222.8	2.33
Trewia nudiflora	37	37.5	117.8	2.46
Aegle marmelos	12	*15*	38.2	2
Bombax ceiba L.	10	12.5	31.83	2
Bambusa vulgaris	15	17.5	47.75	2.14
Ficus racemosa	7	10	22.28	1.75
Dalbergia sissoo	65	87.5	206.9	1.85
Solanum viarum	9	7.5	28.65	3
Alstonia scholaris	7	10	22.28	1.75

Frequency, density and abundance values of trees in teghari community forest

Plant species	**Total number of individual in 20 plot (Q)**	**F**	**D**	**A**
Haldina cordifolia	18	35	7.16	2.57
Aegle marmelos	9	15	3.58	3
Acacia catechu	99	90	39.39	5.5
Trewia nudiflora	20	40	7.95	2.5
Mallotus philippensis	57	65	22.6	4.38
Mangifera indica	2	10	0.79	1
Semecarpus anacardium	4	15	1.59	1.33
Terminalia tomentosa	3	10	1.19	1.5
Madhuca longifolia	4	15	1.59	1.33
Bombax ceiba	7	15	2.78	2.33
Holoptelea integrifolia	29	30	111.53	4.83
Butea monosperma	2	5	0.79	2
Ficus semicordata	3	10	1.19	1.5
Syzygium cumini	47	75	18.7	3.13
Dalbergia sissoo	70	65	27.8	5.38
Terminalia bellirica	1	5	0.39	1

APPENDIX VI

Regeneration status of all tree species in Durgalaxmi community forest and Teghari community forest.

Regeneration status of Tree species in Durgalaxmi community forest

S.N	Plant species	Forest regeneration stem/ha		
		seedlings	Saplings	Trees
1	*Bombax ceiba*	500	100	8.75
2	*Dalbergia sissoo*	39166.67	650	70
3	*Syzygium cumini*	6666.667	460	58.75
4	*Holoptelea integrifolia*	4166.66	300	36.25
5	*Acacia catechu*	41666.67	700	123.75
6	*Mallotus philippensis*	11666.67	490	71.25
7	*Trewia nudiflora*	5666.67	370	25
8	*Aegle marmelos*	2500	120	11.25
9	*Haldina cordifolia*	-	-	22.5
10	*Alstonia scholaris*	-	70	-
11	*Holoptelea integrifolia*	-	300	-
12	*Bambusa vulgaris*	-	150	-
13	*Ficus racemosa*	-	70	-
14	*Mangifera indica*	-	-	2.5
15	*Semecarpus anacardium*	-	-	5
16	*Terminalia tomentosa*	-	-	3.75
17	*Madhuca longifolia*	-	-	5
18	*Butea monosperma*	-	-	2.5
19	*Ficus semicordata*	-	-	3.75
20	*Terminalia bellirica*	-	-	1.25

Regeneration status of Tree species in Teghari community forest

S.N	Plant species	Forest regeneration stem/ha		
		Seedlings	Saplings	Trees
1	*Psidium guajava*	3333.33	-	-
2	*Garuga pinnata*	4166.66	-	36.25
3	*Cassia fistula*	-	100	-
4	*Terminalia chebula*	-	130	1.25
5	*Careya herbacea*	-	-	2.5
6	*Sapium insigne*	-	-	1.25
7	*Miliusa velutina*	-	-	2.5
8	*Shorea robusta*	-	-	-
9	*Schleichera oleosa*	-	150	10
10	*Dalbergia sissoo*	-	-	5
11	*Syzygium cumini*	10833.3	560	46.25
12	*Mallotus philippensis*	3333.33	2910	52.5
13	*Trewia nudiflora*	-	-	-
14	*Aegle marmelos*	-	-	2.5
15	*Haldina cordifolia*	3000	-	-
16	*Alstonia scholaris*	-	-	3.75
17	*Semecarpus anacardium*	-	230	1.25
18	*Terminalia tomentosa*	-	-	61.25
19	*Terminalia bellirica*	-	-	6.25

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

S.N	DBH class	DCF	TCF
1.	10-25	58.75	150
2.	25-40	25	141.25
3.	40-55	68.75	92.5
4.	55-70	90	41.25
5.	70-85	97.5	16.25
6.	85-100	66.25	15
7.	100<	72.5	3.75

APPENDIX VII

Basal area, Density stem/ha of each species, and Carbon stock (%) of each tree species in Teghari community forest.

S.N	Plant species	Carbon stock (%)	Basal area (m^2/ha)	Density (stem/ha)
1	*Acacia catechu*	14.39	6.87	123.75
2	*Haldina cordifolia*	11.16	6.27	22.5
3	*Aegle marmelos*	3.42	7.12	11.25
4	*Bombax ceiba*	0.06	5.63	8.25
5	*Butea monosperma*	0.01	1.9	2.5
6	*Dalbergia sissoo*	10.31	13.37	87.5
7	*Ficus semicordata*	0.12	2.16	3.75
8	*Holoptelea integrifolia*	12.21	0.15	36.25
9	*Madhuca longifolia*	2.76	1.66	5
10	*Mallotus philippensis*	6.90	0.087	71.25
11	*Mangifera indica*	0.08	0.366	2.5
12	*Semecarpus anacardium*	0.36	9.044	5
13	*Syzygium cumini*	35.5	0.78	58.75
14	*Terminalia bellirica*	0.21	0.22	1.25
15	*Terminalia tomentosa*	0.76	0.14	3.75
16	*Trewia nudiflora*	1.66	0.02	25

Basal area, Density stem/ha of each species, and Carbon stock (%) of each tree species in Durgalaxmi community forest

S.N	Plant species	Carbon stock (%	Basal area (m^2/ha)	Density (stem/ha)
1	*Aegle marmelos*	0.06	0.21	2.5
2	*Alstonia scholaris*	0.004	0.036	3.75
3	*Careya herbacea*	0.12	0.3	2.5
4	*Dalbergia sissoo*	0.17	0.48	5
5	*Garuga pinnata*	2.63	6.98	36.25
6	*Haldina cordifolia*	7.37	15.65	30
7	*Mallotus philippensis*	0.46	2.08	52.5
8	*Miliusa velutina*	0.19	0.57	2.5
9	*Sapium insigne benth*	0.12	0.56	1.25
10	*Schleichera oleosa*	2.4	3.87	10
11	*Semecarpus anacardium*	1.02	1.53	1.25
12	*Shorea robusta*	60.24	95.69	205
13	*Syzygium cumini*	5.76	11.49	46.25
14	*Terminalia bellirica*	1	2.02	6.25
15	*Terminalia chebula*	0.04	0.12	1.25
16	*Terminalia tomentosa*	18	33.63	61.25
17	*Trewia nudiflora*	0.24	1.09	11.25

PHOTOPLATES

Measuring tree DBH at height 1.37 meter.

With local people

Collecting the data of herbs


Teghari community forest near river


Collecting Soil Samples