Carbon Stock and Regeneration Status of Two Community Forests of Dhangadhi, Nepal

A Dissertation Submitted for the Partial Fulfillment of the Requirements for the Master's degree in Botany

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Submitted by

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DECLARATION

I, Gyanu Joshi, 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.

....Gjoshi........

Dhangadhi-12, Kailali, Nepal

February, 2021

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RECOMMENDATION

This is to certify that **Ms. Gyanu Joshi** has completed the dissertation work entitled **"Carbon Stock and Regeneration Status of Two Community Forests of Dhangadhi, Nepal"** under our supervision and co-supervision. The entire work is based on her own field work 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 dissertation work submitted by Gyanu Joshi entitled **"Carbon Stock and Regeneration Status of Two Community Forests of Dhangadhi, Nepal"** to Department of Botany, Amrit campus, Tribhuvan University by Gyanu Joshi, TU Registration number 5-2-0554-0050-2012 has been accepted for the partial fulfillment of the requirements for Master's degree in Botany (Ecology).

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ABBREVIATIONS AND ACRONYMS

Asl - Above sea level

°C - Celsius

Cm - centimeter

C - Carbon

CF - Community Forest

SCF - Siddhanath community forest

MCF - Manehara community forest

DBH - Diameter at breast height

DFRS - Department of Forest Research and Survey

Ha - hectare

GtC - Gigatonne of carbon

IVI - Importance Value Index

T – Tone

Pls - plants

REDD - Reducing emission from deforestation and degradation

CFUGs - Community Forest Users Groups

UNFCCC – United Nations Framework Convention on Climate Change

Q – Quadrat

No. - Number

ABSTRACT

In Nepal, *Shorea robusta* dominates the vegetation of the Terai region. This species plays an important role in abating global warming and climate change through conserving atmospheric CO_2. Hence, this study is intended to assess the carbon stock and regeneration status of two community forests having different soil moisture condition of Dhangadhi, Nepal. SCF was comparatively dry than MCF. 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, 2 subplots of 5m radii for shrubs and 3 subplots of 2m radii for herbs was laid. 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. Soil samples were collected from the surface up to 20cm depth. Carbon stock of MCF was found higher (92.99t/ha) than in SCF (51.94t/ha) and it increased with increasing soil organic carbon and soil moisture but soil bulk density was found higher in dry SCF (1.43%) than in MCF (1.34%). Similarly, total species diversity was found higher in moist MCF but herbs species diversity was found higher in dry SCF. The index of similarity of shrubs and trees between two forests was found to be quite high. SCF had very good regeneration status with 150625 seedling /ha, 13090 sapling /ha and 649 tree/ha in comparison to MCF. Open canopy of SCF might have favored the regeneration of greater number of seedling, sapling. These result revealed that the ground vegetation and regeneration was high in less dense canopy forest and moist forest had highest carbon stock than dry forest.

Key words: Sequestration, *Shorea robusta*, seedling, sapling, soil moisture

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CHAPTER 1: INTRODUCTION

1.1 Background

Carbon stock is the quantity of carbon contained in a ‘pool’, meaning a reservoir or system which has the capacity to accumulate or release carbon (FAO forestry term and definition). In the context of forest, carbon stock refers to the amount of carbon stored in the world’s forest ecosystem, mainly in living biomass and soil but to a lesser extent also in dead wood and litter. Forest play a profound role in reducing ambient carbon dioxide (CO_2) levels as they sequester 20-100 times more carbon per unit area than croplands (Brown and Pearce, 1994). The rate of C 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 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). In the world’s forest, tropical forest stored 471 Gt C (55%), boreal forest stored 227 Gt C (32%) and temperate forest stored 119 Gt C (13%) (Pan *et al*., 2011).

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). Based on land use pattern, forest and shrub area covers 66.76% of Kailali district (DPR, 2016). Nepal forest contributes approximately 1,054.97 million tons (176.95 t/ha) carbon stock. Tree component constituents 61.53%, forest soil 37.80% and litter and debris constitute 0.67% (DFRS, 2015). Carbon stock did not vary significantly with species richness and litter cover. The carbon stock increased with the management duration (Thapa Magar *et al.,* 2015) but due to the population growth every year 13 million hectares of forest are destroyed or degraded (CBD, 2011). Hence for the conservation and protection of the forest community forestry program was started worldwide.

Community forest is a branch of forestry where local community plays a significant role in forest management. In Nepal, CF program was started in the late 1970s. These forest have multiple environmental and socio-economic function which play a vital part in sustainable development. CF is considered as one of the most successful natural resource management practice (Acharya, 2004) and it significantly contributes to the reversal of deforestation and forest degradation (Nagendra *et al*, 2008). These forest act as a source of C sink storing about

20% of the total carbon stock (Pokharal and Byrne, 2009). With a sequestration rate of 1-5 Mg ha^{-1} (Pokharal *et al*., 2007). CF has found to sequester carbon 1.8ton per ha/year (Baral, 2010). A total of 2237670.5 ha of CF was handed over to 22,266 community forest users group through the country (DOF/CFD., 2018).

The presence of young plants at growing stage in the forest called regeneration. Forest having highest regeneration have highest carbon sequestration. The regeneration status of a forest indicates its health and vitality while healthy forest ensures good futures regeneration. 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). 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 forest 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 a, b).

The soil bulk density (BD), also known as dry bulk density, it is the weight of soil divided by the total soil volume. The total soil volume is the weight of dry soil and pores which may contain air or water or both. It is generally desirable to have soil with a low BD for optimum movement of air and water through the soil (Hunt and Gilkes, 1992). Soil with a bulk density higher than 1.6 g/cm^3 tend to restrict root growth.

Similarly, water contained in a soil is called soil moisture. Soil water is the major content of the soil in relation to plant growth. Soil water dissolves salt and makes up the soil solution which is important as medium for supply of nutrient to growing plants. It also regulate soil temperature.

This research work was conducted in Far Western, Nepal to reveal the carbon stock and regeneration status of two community forests (SCF and MCF) in Dhangadhi which are different in soil moisture condition. 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 numerous research work related to carbon stock and regeneration in CF in various parts of Nepal. But, there are few research work related to carbon stock and regeneration in CF having different soil moisture conditions. It is not clear if difference in soil moisture will have impacts on carbon stock and regeneration in tropical community forest dominated by *Shorea robusta*. So, this work was proposed to conduct at two community forests of Dhangadhi, having different soil moisture, to assess their C-stock and regeneration status. The information obtained from this research will be helpful in planning and implementing the forest management and conservation.

1.3 Hypothesis

- **i.** Ground vegetation and regeneration will be higher in less dense canopy and moist forest than in dry forest.
- **ii.** Carbon stock in moist forest will be higher than in dry forest.

1.4 Research Questions

- **i.** Is there any variation in carbon stock and regeneration between two community forests having different soil moisture condition?
- **ii.** Is there any relationship of carbon stock and plant biodiversity with soil moisture?

1.5 Objectives

The general objective of this research was to know the carbon stock and regeneration of two community forests and the specific objectives were

- **i.** To document and compare the plant diversity of two community forests.
- **ii.** To compare the regeneration status of trees in two community forests.
- **iii.** To compare the carbon stock of two community forests.

1.6 Limitation

- **i.** Due to lack of instrument, canopy cover was estimated by visual method.
- **ii.** Only tree carbon stock was calculated.
- **iii.** Other soil parameters such as nitrogen and pH were not calculated.

CHAPTER 2: LITERATURE REVIEW

2.1 Forest and Carbon stock

Forest play very important role in the global Carbon cycle through exchange of carbon between the land and the atmosphere (Dixon *et al.*, 1994). The rate of carbon sequestration is much faster in young and regenerating forest but carbon stock is more in old and mature forest (Luyssaert *et al*., 2008). The world's forest contain up to 80% of all above ground Carbon and nearly 40% of all belowground (soil, litter and roots) terrestrial carbon (Winjum *et al.*, 1992). In Nepal, forest occupies 40.36% of the total area of the country. Out of the total area 23.04% lie in Churia and 6.90% in Terai. The total above ground air-dried biomass in the forest of Nepal is 1,159.65 million tone (194.51t/ha). The total carbon stock in Nepal's forest has been estimated as 1'054.97 million tone (176.95t/ha). Tree component constituents 61.53%, forest soil 37.80% and litter and debris constitute 0.67% (DFRS, 2015).

The CF of Nepal act as major source of C-stock of CO_2 which will help in minimizing the climate change (Pokharel and Byrne, 2009). The 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 (Pandit, 2014). In collaborative forest there is positive and very weak relationship between carbon stock and species richness (Mandal *et al*., 2016). The standing C-stock of old growth forest is higher than the newly regenerating forest (Singh and Singh 1992).

In Nepal, different researchers have found different amount of C stock in different types of Sal forest (Terai and Hill Sal forest). In nine community managed hill Sal forest using allometric equation of Chave *et al. (*2005) 120 $mgha^{-1}$ mean C-stock was found (Thapa Magar and Shrestha, 2015). 244 and 140 $mgha^{-1}$ C-stock in community managed hill Sal forest and government hill Sal forest of Karyakhola Watershed was found by using "moist forest" allometric equation of Chave *et al*., 2005 (Mbaabu *et al.*, 2014) and 132-202 $Mgha^{-1}$ living biomass C-stock in three Sal dominated collaborative forest was found by using "moist forest" allometric equation of Chaves *et al*., 2005 (Mandal *et al.*, 2015). Similarly, 115$Mgha^{-1}$ C-stock and 0.8 $Mgcha^{-1}yr^{-1}$C sequestration rate in semi natural tropical Sal forest was found (Pathak, 2015). The mean C-stock in Sal dominated forests managed by community and government around Bees Hazaare Lake was found 121.7$Mgha^{-1}$, calculated by using "moist forest" allometric equation of Chave *et al*., 2005 and community managed forest (165.2$Mgha^{-1}$) had higher C-stock than government managed forest (78.2$Mgha^{-1}$) (Sharma, 2016). The mean tree layer C-stock in primary forest was 71Mgha $^{-1}$ whereas C-stock in secondary forest was 110Mgha^{-1} by using the "moist forest" allometric equation of Chave *et al*., 2005 and ANOVA test showed significant difference between mean values of carbon stock and diversity among the strata (log carbon, $p = 0.00$ and log H1, $p = 0.001$) while T- test did not show significant difference in mean values of carbon stock ($p = 0.001$) (Gairhe, 2015). Total carbon stock in the community managed forests (CFs) of the terai and the hills were to be 479.29 t/ha and 234.54 t/ha respectively. The biomass carbon stock density was higher in *Shorea robusta* CFs of terai 384.20 t/ha than of hill forest 123.15t/ha. Carbon densities of different carbon pools such as tree, sapling, leaf litter, grass and herbs were significantly higher ($p < 0.05$) in the Terai than in the hill forest whereas dead wood and stumps and the soil organic carbon density were not found to be significantly different in these regions (Pandey and Bhusal, 2016). In the year 2013, average of 62.34 t/ha of carbon stock was found and in the same place 64.86 t/ha carbon stock was found in year 2014 that is increase in 2.52 t/ha of carbon stock per year. A total of 89 plant species in 39 families and 80 genera were documented. Poaceae was found as the richest family with 13 species followed by family Fabaceae with 9 species. Herb was the dominant life form with 41 species followed by tree (21), shrub (16), climber (9) and Pteridophytes (2) species (Ghimire, 2017).

Soil organic carbon was only significant positively correlated with soil moisture in the 0-10 cm layer and indicating that soil moisture played an important role in soil C sequestration of forest ecosystems because high soil moisture contributed to a high net primary productivity and a high soil organic carbon accumulation (Deng *et al.*, 2016).

2.2 Regeneration Status of Sal Forest in Nepal

In Nepal, regeneration is said to be good if forest 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). Higher Sal density than other associated species in both CF and protected forests in western Nepal (Shrestha, 2009). Similarly, higher sapling and seedling of Sal were found than other associated species in Sal dominated forest in western terai, (Timilsina *et al.,* 2007). In tropical forest regeneration of plants depend mainly upon the seed output, viability of seeds, seed dormancy, seed dispersal, seed growth, vegetation growth, reproductive growth and seedling establishment, (Basyal *et al.,* 2011).

Open canopy favors the regeneration of light demanding species (herbs, shrubs and tree). Presence of sufficient canopy gaps allowed sufficient light to reach the forest understory and made the light and dry environment favorable for abundant growth of *Shorea robusta* seedling and sapling. Thus light is considered very important abiotic factors which played two roles increasing photosynthesis and ground temperature which in turn accelerates litter decomposition (Sapkota *et al*. 2009).

Sal is a light demanding species and complete overhead light is needed in most cases from the earliest stages of its development (Champion and Seth, 1968: Kayastha 1985). Opening of the canopy in a forest stand promotes regeneration, and the growth of understory seedlings and saplings (Troup, 1986; Gautam 1990). Cut wood, lopped tree, human/livestock trails, people number are the significant variables for the impact of sapling and seedling density in the park. The induced human disturbances up to the limit avails the highest regeneration status in the park. These human disturbances might have induced the spatial heterogeneity and internal dynamics which help in the regeneration. The main challenge for the forest managers and scientists is to identify threshold levels at which human disturbances will result in an irreversible decline of the vegetation and its regeneration (Napit and Paudel, 2015).

The lower basal area, biomass and higher density show that the forest are younger and are in state of regeneration (Giri *et al*., 1999). *Shorea robusta* was the dominant species with saplings density of 200.49t/ha and seedlings density of 27153.4t /ha in Banke National Park (Napit, 2015). Regeneration was affected by species richness, canopy cover, soil pH and nitrogen (Bhatta *et al*., 2020). Community forest was dominated by a single species, *Shorea robusta*. However, *Shorea robusta* and *Terminalia myriocarpa* were codominant in the government forest and tree density and basal area were higher in the government forest, but shrub/sapling density and basal area were higher in the community forest, suggesting a positive effect of community management on tree regeneration. From the result, the dominance of *Shorea robusta* trees in the community forest suggests that people involved in managing forest may be more interested in a limited number of economically value able species while removing less important trees (Poudel and Shah 2015).

2.3 Plant diversity

In Nepal, altogether 687 species of algae, 1666 species of fungi, 465 species of lichens, 465 species of liverworts and mosses, 380 species of fern and fern allies, 28 species of gymnosperms, 5160 species of angiosperms 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, over grazing, illegal logging and poaching, unplanned development activities and pollution (HMG/N and Govt. of the Netherlands, 1995).

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 product, 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 improving environment, contributing to the rural livelihood and is a major means of biodiversity conservation (Acharya *et al.*, 2007).

2.4 Soil moisture

Radial growth of Tenasserim pines from northern and northeastern Thailand was mainly limited by moisture availability (Rakthai *et al.*, 2020). In moist forest (alder-ash forests of the alliance *Alno- Ulmion*), species richness has a close positive correlation with soil moisture, whilst light conditions and nutrient supply have in the main no effect on species richness (Hardtle *et al.*, 2003). More species richness of herbs in the areas with less shrub cover. Due to response of herbs to removal of shrubs or low availability of shrubs. Because soil moisture is an importing limiting resource in this system (Berlow *et al*., 2003).

Khair is a primary successional species that usually grows along river courses and other moist areas all over the country (Puneet *et al.* (2006). Sal plant favors dry condition than moisture condition (Jackson, 1994). Large number of plant species were present in the community forest than in the government forest however the number of tree species were found higher in national forest than in community forest. Community forest was highly dominated by *Shorea robusta* whereas the national forest was equally dominated by *Terminalia tomentosa* and *Shorea robusta*. Soil pH ranged from 4.33-5.33, organic matter 1.01% to 2.43%, nitrogen 0.056% to 0.01%, phosphorus 76.64 to 126.81 Kg/ha and potassium 196.80 to 267.73 Kg/ha (Poudel, 2000).

Knowledge on the structure, composition, regeneration and carbon stock on Sal forests from Far western, Nepal is still inadequate except Bhatta *et al*., (2020) in Dadeldhura district but few research works were done in western part of Nepal by Timilsina *et al., (*2007), Napit, (2015), Napit, and Paudel, (2015) and Giri, (1999) in Surkhet, Banke and Bardia district respectively and these studied were done on national park areas not in community forest. Thus to fulfill the research gap, this research work was done. The objective of this research was to study about carbon stock and regeneration status of two community forests of Dhangadhi which were different in soil moisture condition.

CHAPTER 3: MATERIALS AND METHODS

3.1 Study Area

Study area is located in Far Western, Nepal. The study was carried out in the Sal forest of Jugeda-12 and Manehara-7, Dhangadhi, Kailali (Figure 3.1). The Dhangadhi covers an area of 261.75 km^2 and expands between 28°40’60”N to 80°35’60”E. It is placed at an altitude of 180m above the sea level and climatic zone is tropic. Kailali have a total of 215,916 ha forest area (including shrub land). The average annual temperature is 24.6°C and average annual rainfall is 1713mm of Dhangadhi.

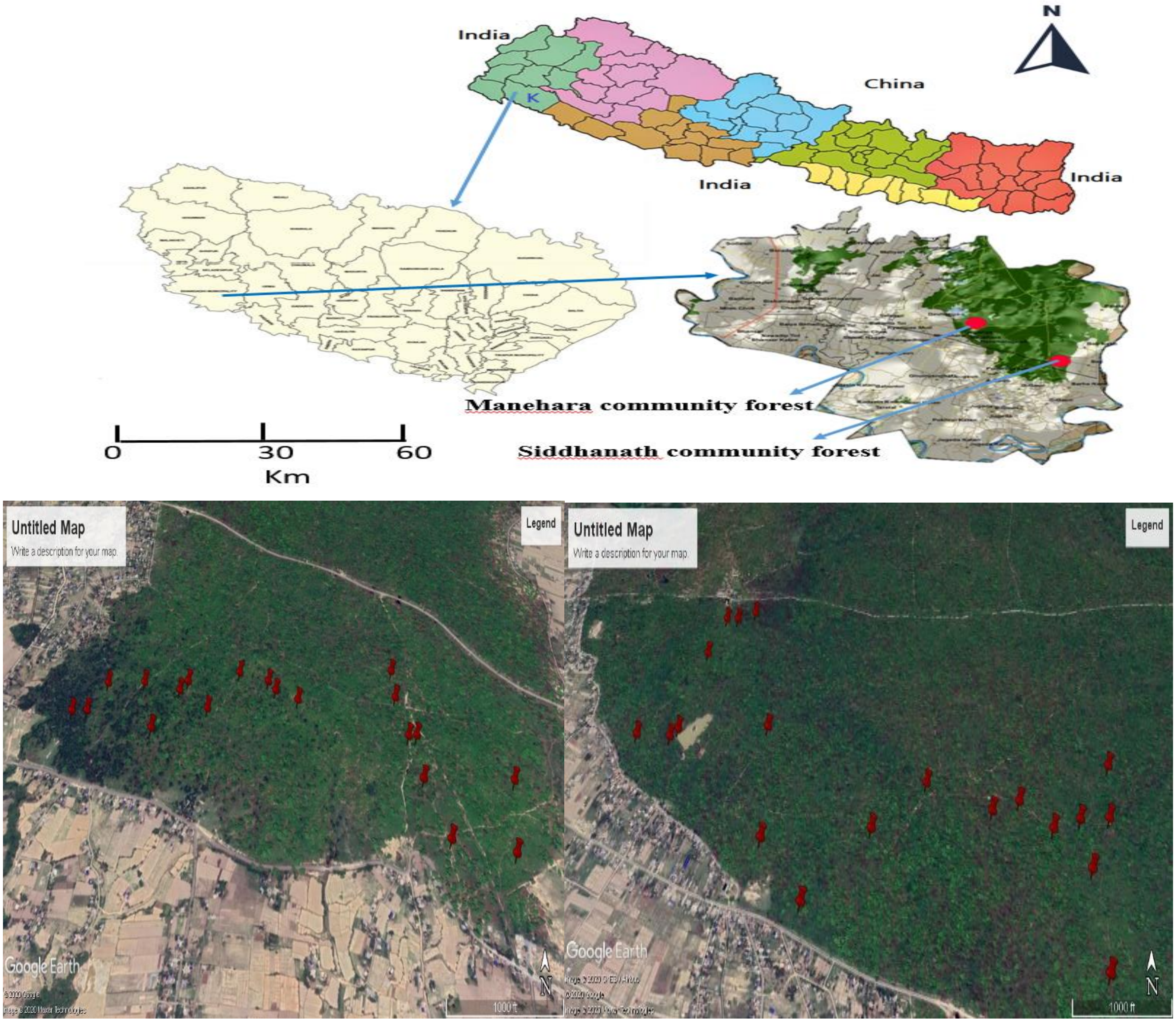


Figure 3.1. Map of the study area; Map of Nepal with provinces and districts (a), Kailali district with local administrative units (b), Location of study community forests (Manehara and Siddhanath) in Dhangadhi sub-metropolitan city **(c),** Map of Siddhanath community forest showing sampling plots (d) and Map of Manehara community forest showing sampling plots (e).

3.1.1 Climate and Hydrology

Dhangadhi located at 180 m above sea level. The summer season of this region is very hot and winter is very cold. In summer the temperature rises up to 46.4°C and in winter the temperature falls below 7°C. The average annual temperature was 24.6°C and average annual rainfall was 1713mm of Dhangadhi. As shown in the figure the average maximum temperature was 37.2 °C in May and minimum temperature was 7.1°C in January. Maximum rainfall was 674.7mm in August and minimum rainfall was 4mm in November (Figure 3.2).

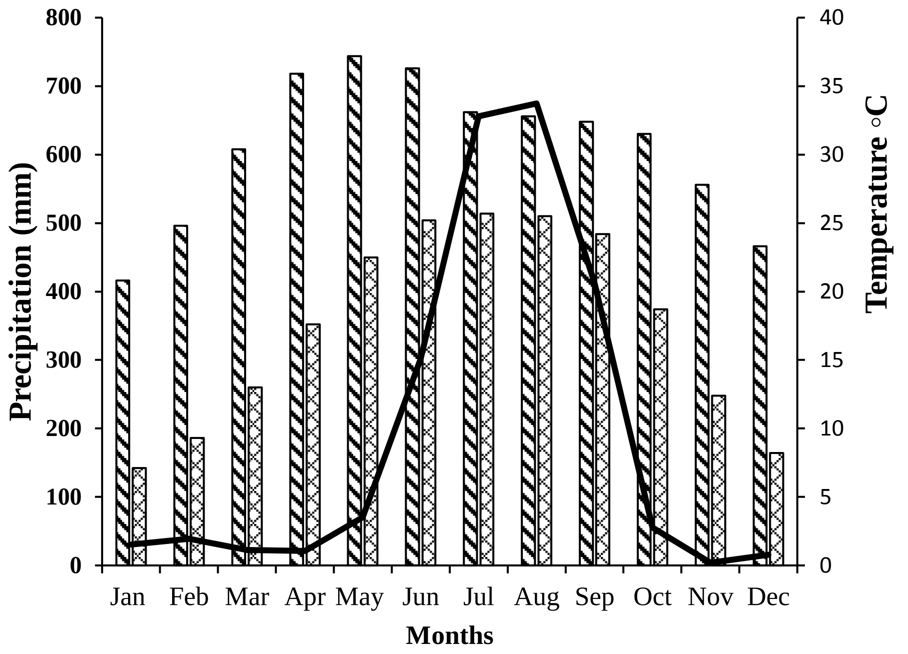


Figure 3.2. Variation in monthly average (minimum and maximum) temperature and precipitation of last 30 years (1990-2019) at Dhangadhi**.**

Source: climatedata.org

3.1.2 Study Forest

The study was conducted in Siddhanath community forest (SCF) and Manehara community forest (MCF) (Figure 3.1). SCF is located between 28°40'30'' to 28°40'54'' N and 80°38'13 to 80°39'7''E and MCF is located between 28°41'1''to 28°41'57''N and 80°37'38''to 80°38'43''E with the altitude ranging from 123 to 191 m asl (Figure.3.1) in Jugeda-12 and Manehara-7 respectively in Dhangadhi, Kailali. The study area consist of plane slopes 0° to gentle slope 1°.

Vegetation type of study area is tropical forest with dominance of *Shorea robusta*. Other common associated species were *Terminalia chebula*, *Terminalia tomentosa* (saj), *Syzygium* *cumini* (Jamun), etc. Both the forest were different in moisture condition. In MCF there were small pond and stream but SCF was comparatively dry, there was no any source of water in the forest. MCF was divided into 3 block whereas SCF was divided into 5 block to prevent forest from fire during summer season. SCF was handed over to community in 2057 B.S. It covers an area 167.25 hector and 1057 house's member takes membership of this forest whereas MCF was handed over to community in 2064 B.S. It covers an area of 285.05 hector and 893 house's member takes membership of this forest.

3.2 Field Sampling

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 plot to be sampled was proportionately distributed among the blocks based on their area. Plots in the CF were located with the help of member of CF. To estimate the carbon stock of tree 20 circular plots (CCSPs) of 20m radii was 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 individual of tree species were 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 clinometers was used to estimate the tree height. The 20 m radii plot (quadrat) was divided into 2 sub plot of 5m radii for shrub and 3 plots with radii 2m for herbs to estimate biodiversity. Similarly, for regeneration sapling were considered with height <1.37m and >15 cm as Thapa Magar and Shrestha (2015) in shrubs plot. Each shrubs species inside the plots and if species ≥ 50% of their basal area fell within the plot were also recorded. Similarly, seedling of tree species were considered with height <15cm in the herbs plot whereas trees were recorded in the main plot.

Geographical location (latitude, longitude and elevation) of each plot (20m radii) was recorded using GPS at the center of the plot. Canopy cover for each plot was estimated by visual estimation method from center of the plot. The sample of field data sheet (Appendix I) used for geographical location had been presented in Appendix II.

From each quadrat, during April to May soil sample was collected using steel ring with height 20 cm and internal diameter 3.4 cm from the center of the plot. The initial weight of soil was taken for soil moisture and bulk density and then packed in air tight plastic bags wrapped in aluminum foil until laboratory analysis but for soil carbon, soil samples were dried in shade for a week and finally packed in air tight plastic bags until laboratory analysis. 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 species were collected tagged and pressed with the help of newspaper and these unidentified herbarium specimens were identified with the help of book "Plant Resources of Kailali, West Nepal" (DPR, 2016).

3.3 Lab Work

The soil physicochemical parameters soil moisture, bulk density and soil carbon were examined. The soil carbon was examined during June, 2019 at Department of Botany, Amrit Science Campus, Kathmandu by using Walkley Black rapid titration method. Soil moisture and bulk density were calculated after drying in hot air oven for 24 hours and by taking final weight of the soil in the laboratory of Aishwarya Multiple Campus, Dhangadhi. Complete procedure is given in Appendix VIII.

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 were carried out by using Zobel *et al*., (1987).

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

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

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

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

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

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

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

Simpson's index of diversity (Ds) = 1-D

Shannon Weiner index (H) = $-\Sigma P_i (L_n P_i)$

Where, P_i=Proportion of individual species

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 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) = $\frac{\Sigma n(n-1)}{N(N-1)}$

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. It was calculated by applying the formula given by Sorenson's index modified by Smith (1964).

IS= $\frac{2C}{A+B} \times 100$

Where,

A=Total number of species in one sample

B=Total number of species in another sample

C=Total number of common species in both the sample

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) =$\frac{\pi D^2}{4}$

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 m^2/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). For name of species and wood density see Annex III.

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 area of 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 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 on 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;

$$\text{Density (stem/ha)} = \frac{\text{Total no.of individual of each species in each life form}}{\text{Total number of plots studied} \times \text{size of plot}(\text{m}^2)} \times 10000$$

Density of individual species was calculated by the following equation;

$$\text{Density (stem/ha)} = \frac{\text{Total no. of individual of each species in each life form}}{\text{total number of plots studied} \times \text{size of plot}(\text{m}^2)} \times 10000$$

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

3.7 Bulk Density

To estimate the bulk density of a forest, bulk density of each plot was determined separately. Then, bulk density was estimated by following equation;

$$\text{Bulk density} = \frac{\text{Dry soil}}{\text{Soil volume}}$$

Soil volume = ring volume

$$\text{Bulk density (g/cm3)} = \frac{\text{Sum of bulk density of each plot}}{\text{Total number of plot studied}}$$

3.8 Soil Moisture

To estimate the soil moisture of a forest, soil moisture of each plot was determined separately. Then, soil moisture was estimated by following equation;

For calculation,

Initial wt. of soil (Wm) = Moist soil weight

Final wt. of soil (WD) = Dry soil weight

Soil water content (Sw) = $\frac{Wm-WD}{WD} \times 100\%$

Soil moisture (%) = $\frac{\text{Sum of soil moisture of each plot}}{\text{Total number of plot studied}}$

3.9 Soil carbon

To estimate the soil carbon of a forest, soil carbon of each plot was determined separately. Then, soil carbon was estimated by following equation;

Soil carbon (%) = $\frac{\text{Sum of soil carbon of each plot}}{\text{Total number of plot studied}}$

3.10. Data analysis method

All statistical analysis were performed using SPSS 16.0 and excel 2016. Correlation and regression analysis were used to show the relationship of carbon stock with other variables like basal area, density, soil carbon, soil moisture and bulk density**.** Descriptive statistics was applied to generate means. The mean values of total C- stock in living biomass of tree were compared between two community forests which were different in moisture condition by Independent sample t-test. Prior to t-test, the data were tested for the normality (Shapiro-Wilk test of normality, $p>0.05$).

CHAPTER 4: RESULTS

4.1 Vegetation structure

4.1.1 Plant diversity

Altogether 53 plant species were recorded in MCF and 47 in SCF. Species diversity in the moist forest MCF were found to be higher than in dry forests SCF. Diversity of herbs were found higher in dry SCF (19) than in moist MCF(13) but the diversity of shrubs and trees were found higher in moist MCF (Figure 4.1). All the names of the plants encountered during the study are given in the Appendix IV.

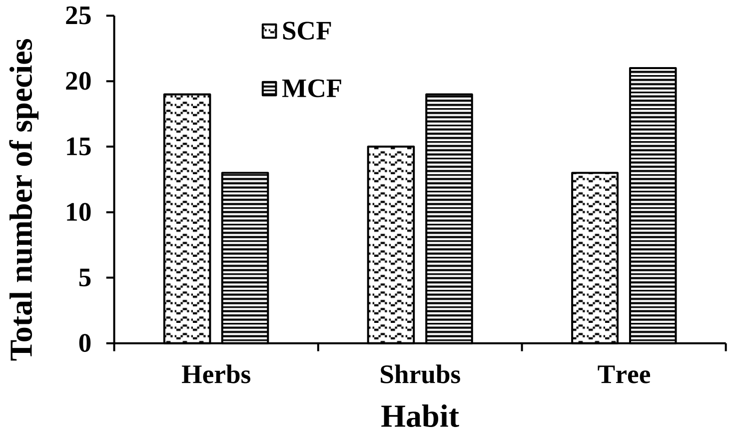


Figure 4.1. Species diversity in Siddhanath community forest and Manehara community forest.

4.1.2 Importance value index (IVI)

In the SCF and MCF, altogether 19 and 13 species of herbs and seedling were recorded respectively. Among them herb *Ageratum conyzoides* had highest IVI i.e. 35.87 and *Chrysopogon aciculatus* had lowest IVI i.e. 2.31 in SCF and in MCF *Imperata cylindrica* had highest IVI i.e. 68.51 and *Cynodon dactylon* had lowest IVI i.e. 5.56. In both SCF and MCF, among seedling *Shorea robusta* had highest IVI value but *Mallotus philippensis* and *Garuga pinnata* recorded lowest IVI in SCF and MCF respectively (Table 4.1). Frequency, relative frequency, density, relative density, abundance and relative abundance are given in Appendix V.

Table 4. 1. IVI of herbs and tree seedling in Siddhanath community forest (SCF) and Manehara community forest (MCF).

Scientific name	IVI	
	SCF	**MCF**
Herbs		
Ageratum conyzoides L.	35.87	39.71
Imperata cylindrical L.	31.72	68.51
Eragostis curvula (Schard.) Nees.	12.94	13.04
Achyranthes bidentate Blume.	10.16	-
Cynodon dactylon L.	9.23	5.56
Cyperus rotundus L.	7.98	-
Oxalis corniculata L.	5.59	-
Chrysopogon aciculatus (Retz.)	2.14	-
Vallaris solanacea Roth.	-	11.08
Phoenix acaulis Roxb.	-	5.56
Tree seedling		
Syzygium cumini (L.) Skeels.	19.46	15.96
Haldina cordifolia Roxb.	11.51	12.37
Dalbergia sissoo Roxb. exDc.	4.73	-
Shorea robusta Gaertn.	122.69	94.09
Schelichera oleosa (Llour.)Merr.	5.01	13.07
Ficus benghalensis L.	4.48	-
Cassia fistula L.	2.32	-
Morus nigra L.	2.32	-
Psidium guajava L.	5.18	7.65
Terminalia tomentosa Roxb. exDc	3.33	-
Mallotus phillippensis (Lam.) Mull.Arg.	3.04	-
Acacia catechu L.f	-	5.56
Garuga pinnata Roxb.	-	2.33

In the SCF and MCF, altogether 15and 19 species of shrubs and sapling were recorded respectively. Among them shrubs *Ziziphus incurva* had highest IVI i.e. 15.56 and *Asparagus racemose* had lowest IVI in SCF and *Solanum viarum* had highest IVI i.e. 31.52 and *Bambusoideae* had lowest IVI in MCF. In both SCF and MCF, among sapling *Shorea robusta* and *Mallotus philippensis* had highest IVI value but *Schleichera oleosa* and *Garuga pinnata* recorded lowest IVI in SCF and MCF respectively (Table 4.2). Frequency, relative frequency, density, relative density, abundance and relative abundance are given in Appendix V.

Table 4. 2. IVI of shrubs and tree sapling in Siddhanath community forest (SCF) and Manehara community forest (MCF).

Scientific name	**IVI**	
	SCF	**MCF**
Shrubs		
Solanum viarum Dunal.	14.03	31.52
Phoenix acaulis Roxb.	-	14.15
Clerodendrum viscosum Vent.	7.53	5.13
Ziziphus incurve Roxb.	15.56	5.13
Lantana camera L.	5.19	7.4
Asparagus racemose Willd.	2.84	-
Bambusoideae	4.02	4.37
Bauhinia *vahlii* (Wight.) Arn.	-	6.94
Tree sapling		
Mallotus philippensis	31.42	74.59
Shorea robusta	103.71	53.52
Syzygium cumini	19.65	38.05
Myrsine semiserrata Wall.	12.03	10.1
Madhuca longifolia J. Konig	-	4.08
Psidium guajava	1.64	6.94
Aegle marmelos L.	8.23	4.08
Dalbergia sissoo	11.57	5.89
Tectona grandis L.	-	13.42
Garuga pinnata	-	2.56

Acacia catechu	-	7.98
Schleichera oleosa	1.93	4.08
Morus nigra	2.67	-

For determination of IVI frequency, density, abundance and their relative values was considered (Appendix V) in all life forms- herbs, shrubs and trees. Besides this canopy cover of each tree species in the quadrat was also recorded and given in Appendix I. In the SCF and MCF, altogether 13 and 21 species of trees were recorded respectively. Among them *Shorea robusta* had highest IVI i.e179.68 and *Haldina cordifolia*, *Terminalia chebula*, *Terminalia belerica* had lowest IVI i.e. 4.8 in SCF and *Shorea robusta* had highest IVI i.e. 95.46 and *Bombax ceiba*, *Terminalia belerica*, *Psidium guajava* had lowest IVI i.e. 3.19 in MCF (Table 4.3).

Table 4. 3. IVI of tree species in Siddhanath community forest (SCF) and Manehara community forest (MCF).

Scientific name	**IVI**	
	SCF	**MCF**
Shorea robusta	179.68	95.46
Terminalia tomentosa	16.12	43.72
Haldina cordifolia	4.81	18.78
Dalbergia sissoo	44.76	4.85
Syzygium cumini	7.65	60.46
Schleichera oleosa	7.62	6.07
Garuga pinnata	4.81	6.07
Aegle marmelos	-	3.19
Terminalia belerica (Gaertn.) Roxb	4.81	3.19
Acacia catechu	-	3.19
Mallotus philippensis	-	11.8
Semecarpus anacardium L.	-	4.83
Mangifera indica	7.62	6.07
Madhuca longifolia	-	4.64
Ficus benghalensis	4.81	8.19
Myrsine semiserrata	4.81	3.19
Ficus sp.	-	3.19
Bombax ceiba L.	-	3.19

Psidium guajava	7.62	3.19
Alstonia scholaris L	-	3.19
Terminalia chebula Retz.	4.81	3.19

4.1.3 Diversity indices

Both the diversity index, Shannon Wiener (H) and Simpson diversity (Ds) value for herbs, shrubs and trees were found higher in MCF than in SCF (Table 4.4).

Table 4. 4. Shannon Wiener index (and evenness) and Simpson index of herbs, shrubs and trees in Siddhanath community forest (SCF) and Manehara community forest (MCF).

Species form	Shannon's diversity index (H)	Simpson's diversity index (Ds)	Forest
Herbs	1.34	0.56	SCF
	1.5	0.71	MCF
Shrubs	1.32	0.56	SCF
	1.77	0.78	MCF
Trees	1.34	0.26	SCF
	2.49	0.66	MCF

SCF and MCF had large number of common herbs, shrubs and tree species, hence the index of similarity between these two forests was also found to be quite high (Table 4.5).

Table 4. 5. Similarity index between Siddhanath community forest (SCF) and Manehara community forest (MCF).

Habit	Index of similarity (%)
Herbs	56.25 %
Shrubs	82.35 %
Tree	76.47 %

4.2 Forest regeneration

In the present study, the total density of seedling, sapling and tree of all species in SCF were 169000 stem/ha, 13090 stem/ha and 649 stem/ha, respectively whereas in MCF seedling, sapling and tree were found to be 68250 stem/ha, 5520 stem/ha and 492 stem/ha, respectively (Figure 4.2). Density of (seedling, sapling or tree) *Shorea robusta* were found to be higher than other species in both SCF and MCF. Density of *Shorea robusta* in SCF were 150625 stem/ha seedling, 8800 stem/ha sapling and 547 stem/ha tree and in MCF were 61625 stem/ha seedling, 1390 stem/ha sapling and 258 stem/ha tree (Figure 4.3).

Similarly, seedling and sapling density of co-dominant associated species *Terminalia tomentosa* (500 stem/ha, 0 stem/ha), *Syzygium cumini* (9250 stem/ha, 1050 stem/ha) and *Haldina cordifolia* (4375 stem/ha, 0 stem/ha) respectively were also found higher in SCF than in MCF *Terminalia tomentosa* (0 stem/ha, 0 stem/ha), *Syzygium cumini (*2875 stem/ha, 1040 stem/ha) and *Haldina cordifolia* (2000 stem/ha, 0 stem/ha). Seedling, sapling and tree density of dominant species were relatively very high than seedling, sapling and tree density of co-dominant associated species. But tree density of co-dominant associated species such as *Terminalia tomentosa* (77 stem/ha), *Syzygium cumini* (73 stem/ha) and *Haldina cordifolia* (27 stem/ha) were higher in MCF than in SCF *Terminalia tomentosa* (9 stem/ha), *Syzygium cumini* (3 stem/ha) and *Haldina cordifolia* (2 stem/ha) (Figure 4.4). All species found in SCF and MCF with their regeneration status are given in Appendix VI.

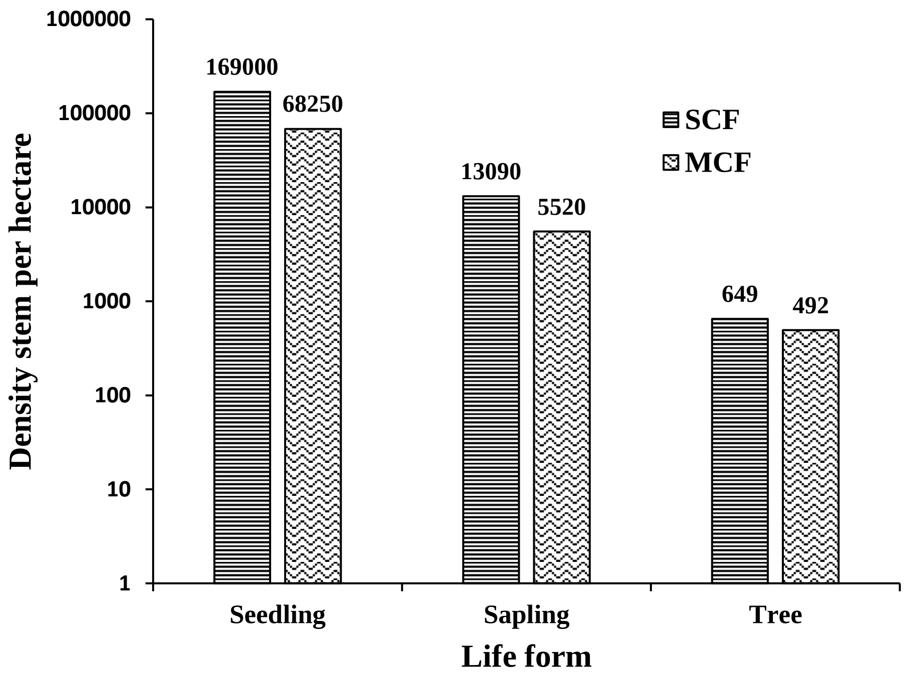


Figure 4.2. Life form diagram to show the regeneration status of all species in Siddhanath community forest and Manehara community forest.

Seedling, sapling and tree density of *Shorea robusta* were found relatively very high in SCF than in MCF (Figure 4.3).

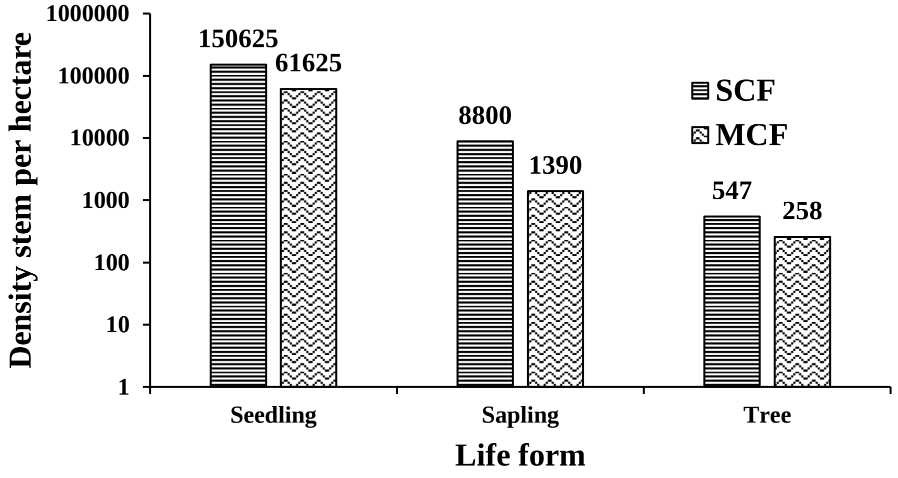


Figure 4.3. Life form diagram to show the regeneration status of *Shorea robusta* species in both Siddhanath community forest and Manehara community forest.

Seedling of co-dominamt species *Terminalia tomentosa*, *Haldina cordifolia* and *Syzygium cumini* were recorded higher in SCF than in MCF. Similarly, sapling of *Syzygium cumini* were also recorded higher in SCF than in MCF but sapling of *Terminalia tomentosa* and *Haldina cordifolia* were not found in both community forest. Tree density of *Terminalia tomentosa*, *Haldina cordifolia* and *Syzygium cumini* were also recorded higher in SCF than in MCF (Figure 4.4).

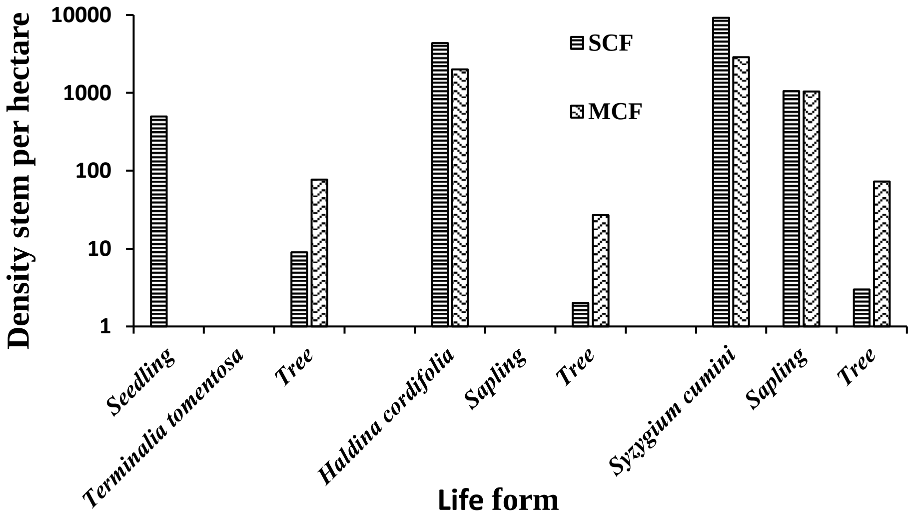
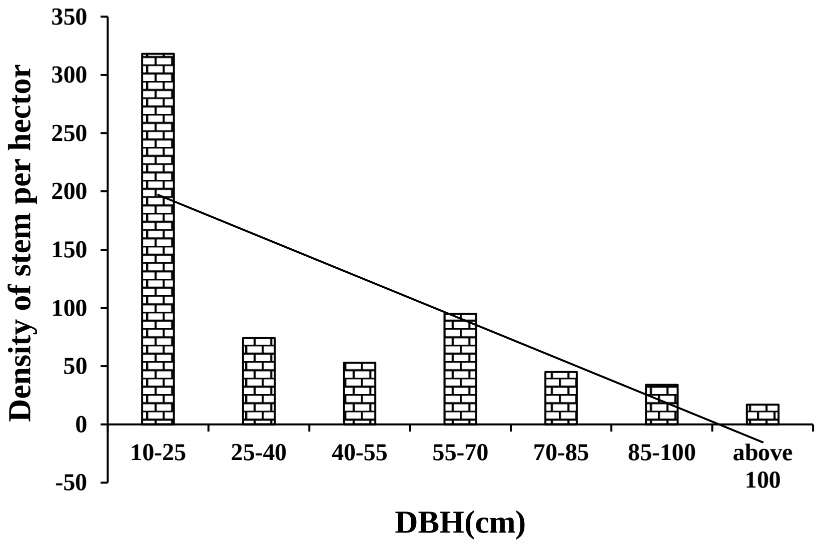


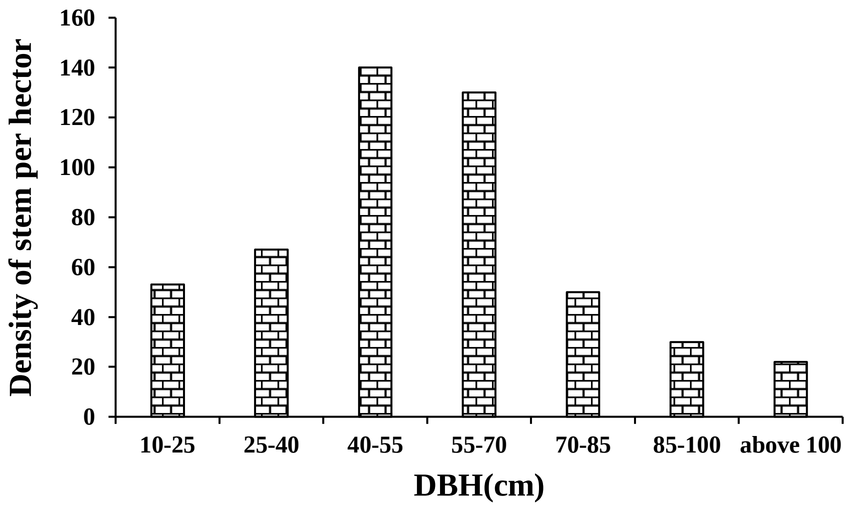
Figure 4.4. Life form diagram to show the regeneration status of three co-dominant species *Terminalia tomentosa*, *Haldina cordifolia* and *Syzygium cumini* in Siddhanath community forest and Manehara community forest.

4.2.1 Density Diameter Relationship

Tree density (per ha) was highest in density class 10-25(318 stem/ha) followed by 55-70 (95stem/ha) in SCF (Figure 4.5) where as in MCF tree density (per/ha) was highest in density class 40-55 (140stem/ha) followed by 55-70(130 stem/ha) (Figure 4.6). This showed that most of the stands were at intermediate stage of growth. Trend line indicates that there is rapid decrease in density with increase in DBH of trees in SCF but it is with gentle slope because of more or less hump shaped density with DBH class (maximum density at 40-70 cm DBH class) in MCF.



4.5 Figure: Density diameter relationship of trees ≥10cm in Siddhanath community forest.



4.6 Figure: Density diameter relationship of trees ≥10cm in Manehara community forest.

4.2.2 Basal area regeneration relationship

In average, the total basal area of all species of MCF (26.26m²/ha) was found higher than SCF (15.06m²/ha). In SCF, the highest basal area was recorded for *Shorea robusta* ($7.8m^2/ha$) followed by *Haldina cordifolia* ($1.62m^2/ha$) and *Terminalia chebula* (0.94m²/ha). Similarly, in MCF the highest basal area($6.5m^2/ha$) was recorded for *Shorea robust*, followed by *Terminalia tomentosa* (5.8m²/ha) and *Haldina cordifolia* (3.93m^2/ha) (Figure 4.7 and 4.8). Basal area of all species in both CF are given in Appendix V.

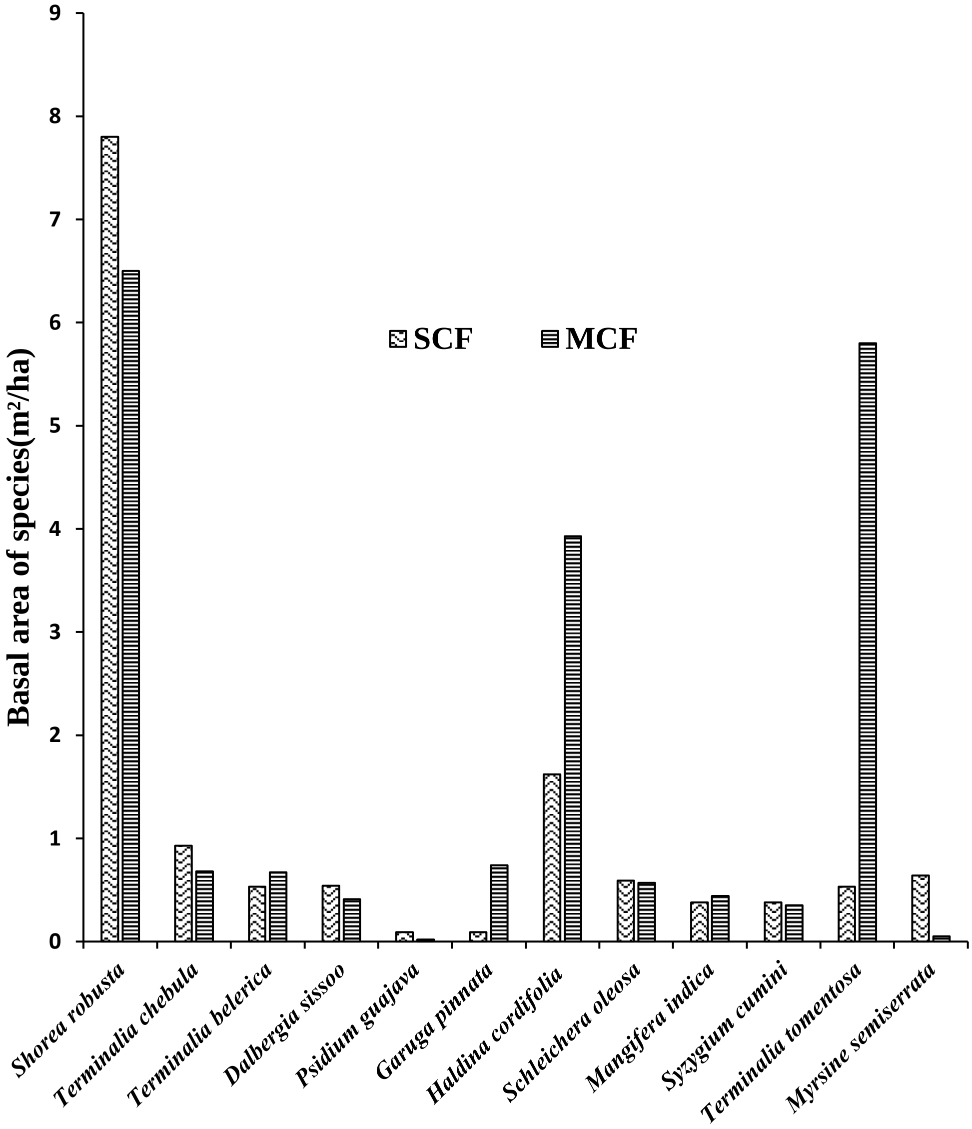


Figure 4.7. Basal area of common tree species of Siddhanath community forest and Manehara community forest.

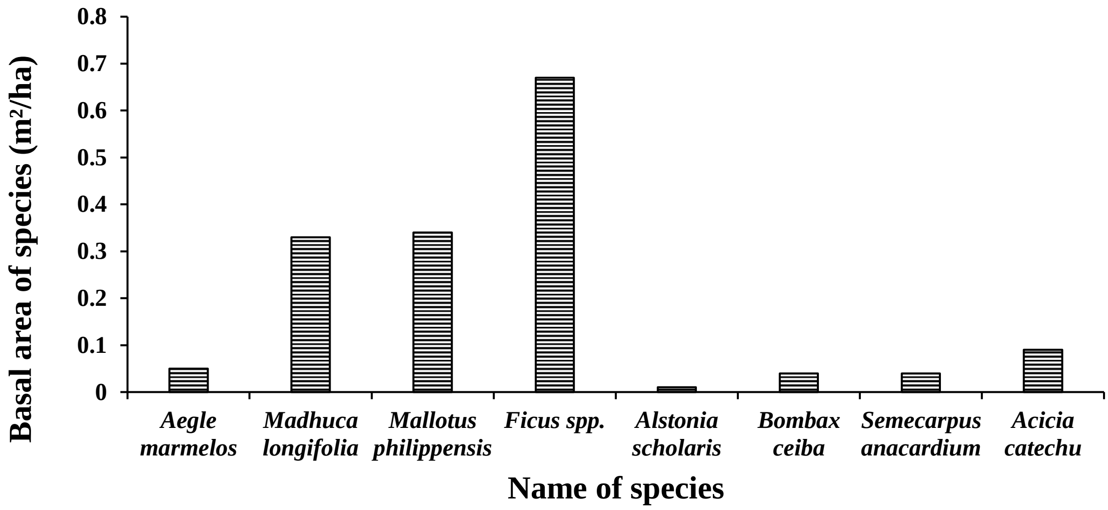
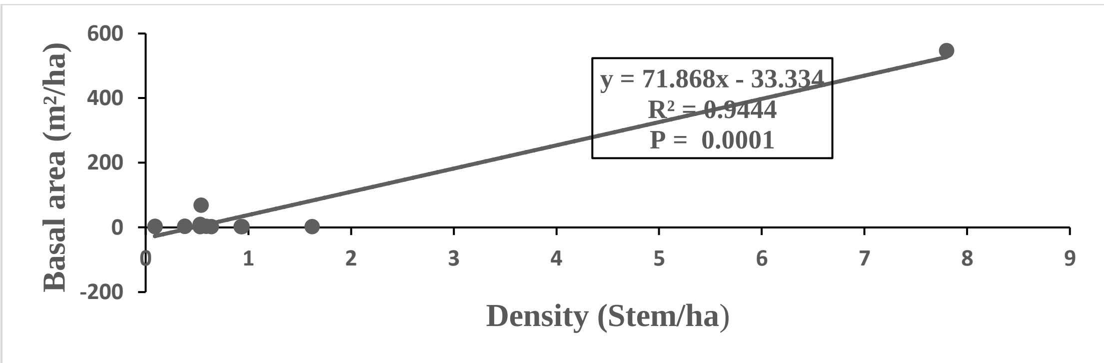


Figure 4.8. Basal area of other tree species found only in Manehara community forest.

Relation of basal area and density

In both SCF and MCF, Basal area increased with increase in density. Regression analysis showed that there was strong significant positive relationship between basal area and density in both SCF and MCF (i.e. P =0.0001). R^2 Value was higher in SCF than in MCF (Figure 4.9). a)



b)

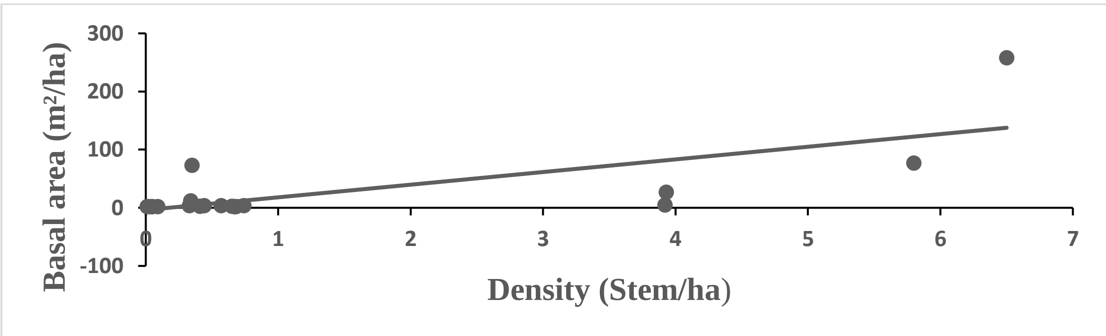


Figure 4.9. Regression analysis showing relationship between basal area and density Siddhanath community forest (a) and Manehara community forest (b).

4.3 Carbon Stock

4.3.1 Tree carbon stock

In trees, above ground biomass contain higher carbon than in below ground biomass (Table 4.6). Among plant tree species *Shorea robusta* had highest carbon in both above and below ground in both forest i. e 25.56t/ha in above ground and 5.11 t/ha in below ground in SCF and 19.29 t/ha in above ground and 4.86 t/ha in below ground in MCF and *Myrsine semiserrata* had lowest carbon in both above and below ground in both forest i. e 0.242 t/ha in above ground and 0.048 t/ha in below ground in SCF and 0.019 t/ha in above ground and 0.004 t/ha in below ground in MCF (Table 4. 6.)

Table 4. 6. Above ground and below ground carbon stock of tree species in Siddhanath community forest (SCF) and Manehara community forest (MCF).

Tree species	**Above ground carbon stock (t/ha) of SCF**	**Below ground carbon stock (t/ha) of SCF**	**Above ground carbon stock (t/ha) of MCF**	**Below ground carbon stock (t/ha) of MCF**
Shorea robusta	25.56	5.11	19.29	4.86
Terminalia tomentosa	1.46	0.296	20.25	2.85
Syzygium cumini	0.279	0.056	0.733	0.147
Schleichera oleosa	2.178	0.436	0.764	0.153
Haldina cordifolia	4.174	0.835	19.75	3.95
Aegle marmelos	-	-	0.073	0.015
Terminalia chebula	3.036	0.607	3.036	0.607
Terminalia belerica	1.316	0.263	1.840	0.368
Dalbergia sissoo	1.848	0.377	0.277	0.055
Madhuca longifolia	-	-	0.872	0.174
Mangifera indica	0.479	0.096	0.794	0.158
Mallotus philippensis	-	-	0.271	0.054
Ficus benghalensis	2.493	0.025	6.195	1.239
Ficus sp.	-	-	1.716	0.343
Alstonia scholaris	-	-	0.062	0.027
Psidium guajava	0.273	0.055	0.021	0.004

Bombax ceiba	-	-	0.054	0.012
Semecarpus anacardium	-	-	0.068	0.011
Garuga pinnata	0.125	0.025	0.672	0.134
Myrsine semiserrata	0.242	0.048	0.019	0.004
Acicia catechu	-	-	0.569	0.114
Total	43.462	8.534	77.417	15.369

The total carbon stock in living biomass of trees were found varied significantly between two community forest which were different in moisture condition (i.e. in SCF P = 0.001, t = 19.122 and in MCF P = 0.004, t = 3.078).The total carbon stock in trees of SCF and MCF were calculated to be 51.94 t/ha and 92.99 t/ha respectively (Figure 4.10). The average contribution of *Shorea robusta* was highest in both the community forests. Contribution of Carbon stock by *Shorea robusta* in average was about 26% in MCF and about 59% in SCF (Table 4.7, Figure 4.11 and 4.12). Name of tree species with carbon stock in (%) are given in Appendix VII.

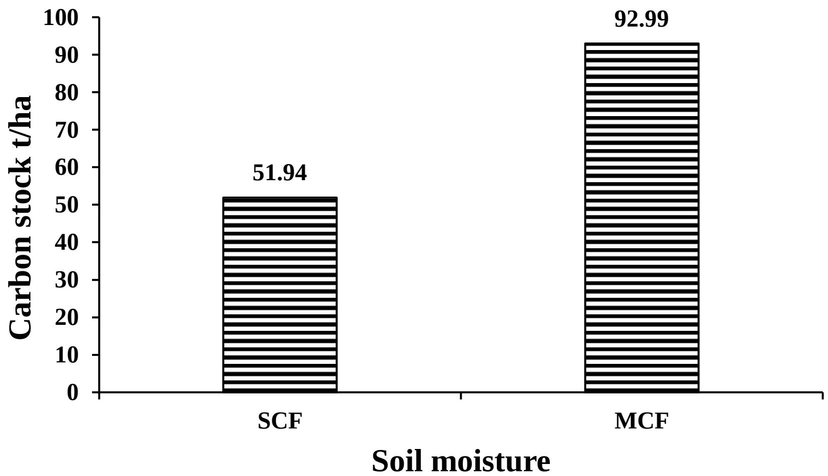


Figure 4.10. Total carbon stock in two community forest based in soil moisture.

Among all plant species *Shorea robusta* had highest contribution in carbon stock in both community forest. In SCF *Shorea robusta* was followed by *Haldina cordifolia, Terminalia chebula, Ficus benghalensis, Schleichera oleosa* and so on but in MCF *Shorea robusta* was followed by *Haldina cordifolia, Terminalia tomentosa, Ficus benghalensis* and so on which are given in Table 4.7.

Table 4. 7. Species wise carbon stock in Siddhanath community forest (SCF) and Manehara community forest (MCF).

Name of plant species	SCF carbon stock (t/ha)	MCF carbon stock (t/ha)
Shorea robusta	30.67	24.149
Terminalia chebula	3.64	3.64
Terminalia belerica	1.579	2.208
Dalbergia sisoo	1.986	0.333
Psidium guajava	0.327	0.025
Ficus benghalensis	2.992	7.723
Garuga pinnata	0.149	0.807
Haldina cordifolia	5.008	23.705
Schleichera oleosa	2.614	0.918
Mangifera indica	0.575	0.953
Syzygium cumini	0.336	0.88
Terminalia tomentosa	1.777	23.10
Myrsine semiserrata	0.29	0.082
Aegle marmelos	-	0.087
Madhuca longifolia	-	1.046
Mallotus philippensis	-	0.325
Ficus sp.	-	2.059
Alstonia scholaris	-	0.023
Bombax ceiba	-	0.065
Semecarpus anacardium	-	0.181
Acacia catechu	-	0.682
Total	51.94	92.99

4.3.2 Contribution of each species for carbon stock in percent

Among all tree species Shorea robusta (59% in SCF and 26% in MCF) had highest contribution in carbon stock in both community forest which was followed by *Haldina cordifolia* (10%), *Terminalia chebula* (7%) and so on in SCF but in MCF *Shorea robusta* was followed by *Terminalia tomentosa, Haldina cordifolia* and so on (Figure 4.11 and Figure 4.12).

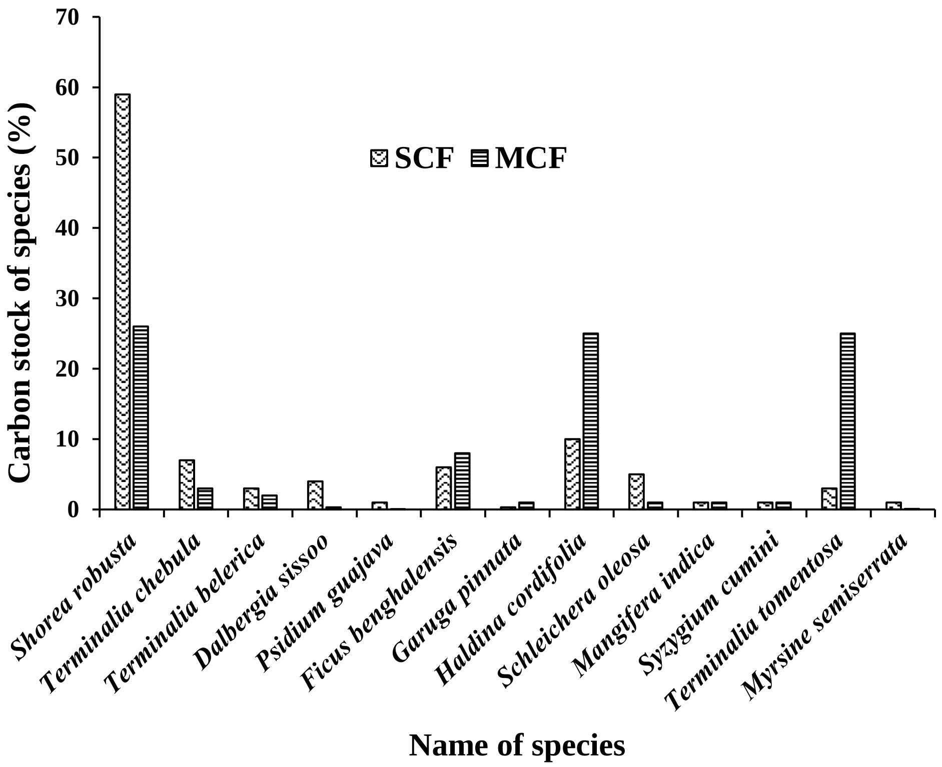


Figure 4.11. Contribution of common tree species in carbon stock of Siddhanath community forest and Manehara community forest.

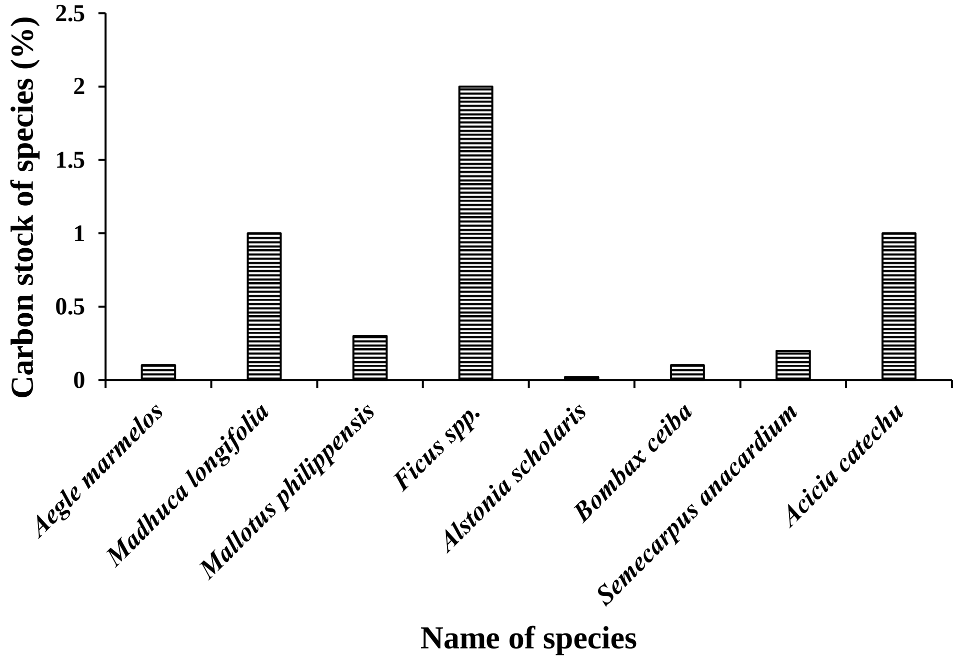


Figure 4.12. Contribution of other tree species by (%) in carbon stock of Manehara community forest.

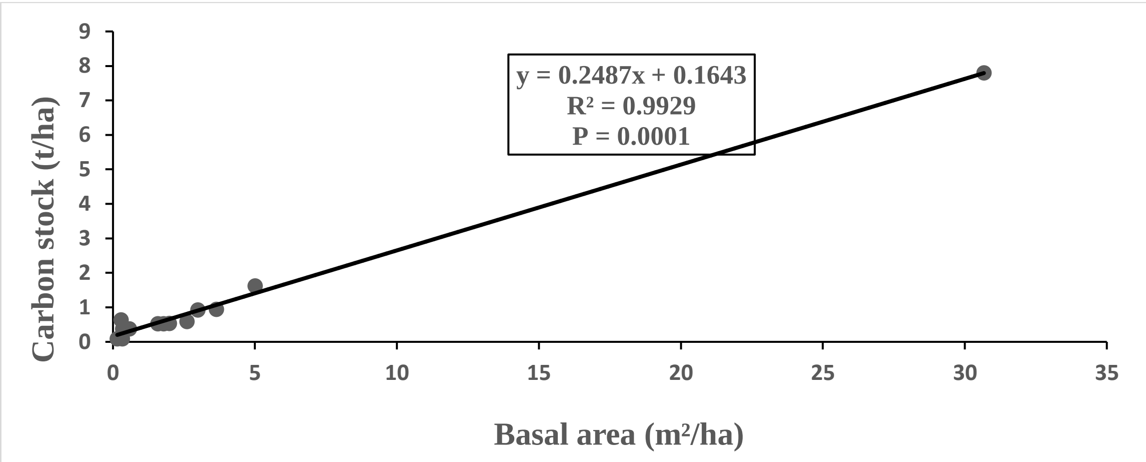
4.3.3 Tree carbon stock, basal area and density relationship

The relation of carbon stock with basal area and density were calculated on the basis of measurements of each species in both forest. Values of all variable are given in Appendix VII.

Relation of carbon stock with Basal area and density

In both SCF and MCF, carbon stock increased with increase in basal area. Regression analysis showed that there was strong significant positive relationship between basal area and carbon stock in both forest (in both SCF and MCF P =0.0001). R^2 Value was higher in SCF (R^2=0.992) than in MCF (R^2=0.895) (Figure 4.13).

a)



b)

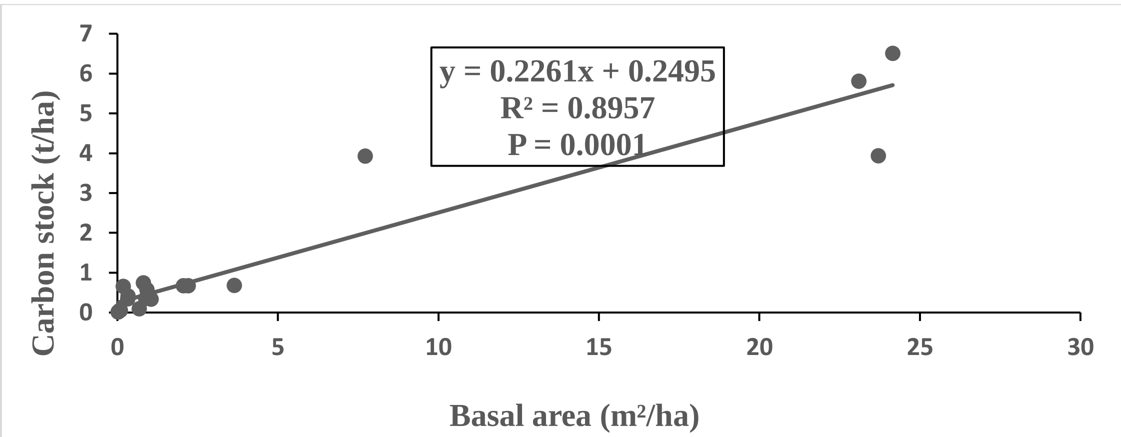
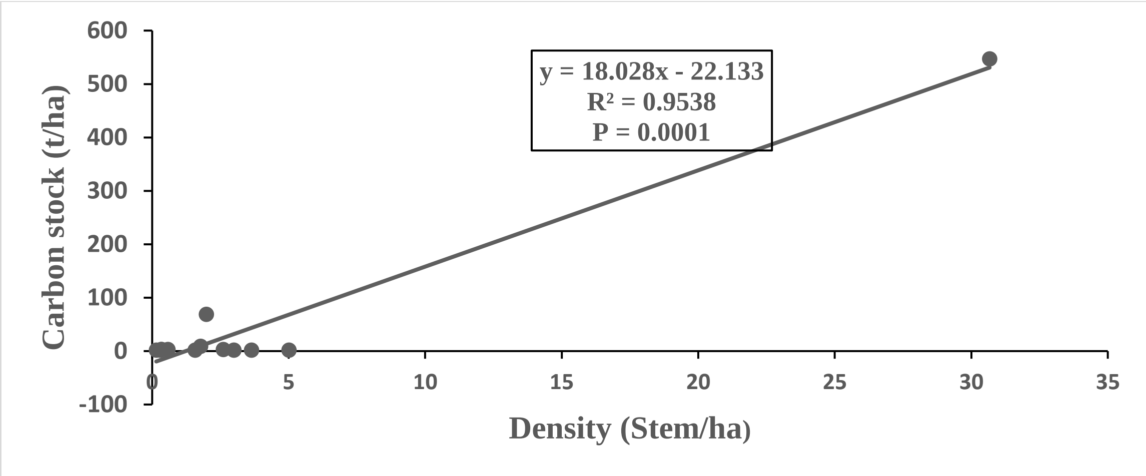


Figure 4.13. Regression analysis showing relationship between carbon stock and basal area SCF (a) and MCF (b).

In both SCF and MCF, carbon stock increased with increase in density .Regression analysis showed that there was strong significant positive relationship between density and carbon stock in SCF (P = 0.0001) and positive but weak relationship in MCF (P =0.018), in MCF other factors also affect the carbon stock of tree such as moisture condition. R^2 Value was higher in SCF than in MCF (Figure 4.14).

a)



b)

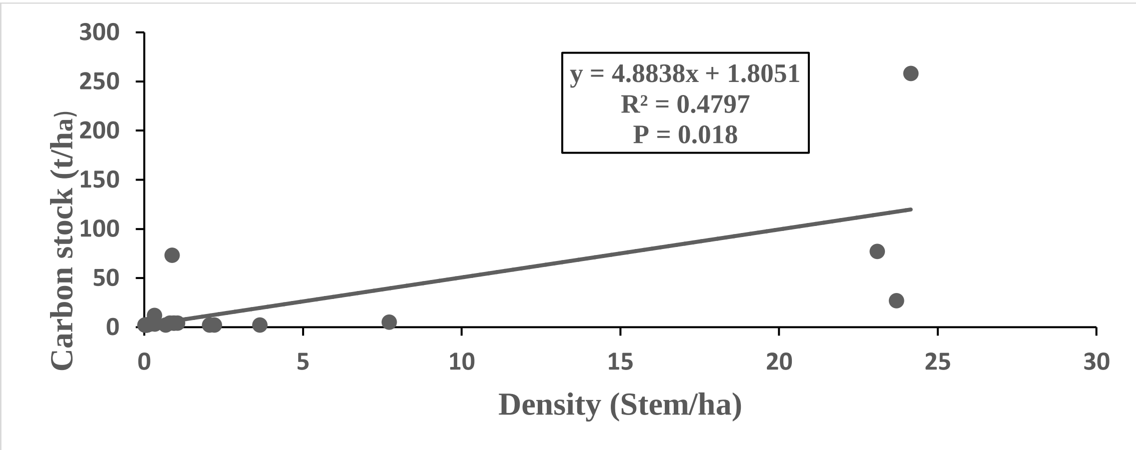


Figure 4.14. Regression analysis showing relationship between carbon stock and density SCF (a) and MCF (b).

4.3.4 Soil Carbon stock

Soil carbon in SCF was ranged from 0.099% to 4.059% and in MCF it ranged from 2.409 % to 5.709 %. The mean value of soil carbon was found 2.475 % in SCF and 3.003 % in MCF (Figure 4.15).

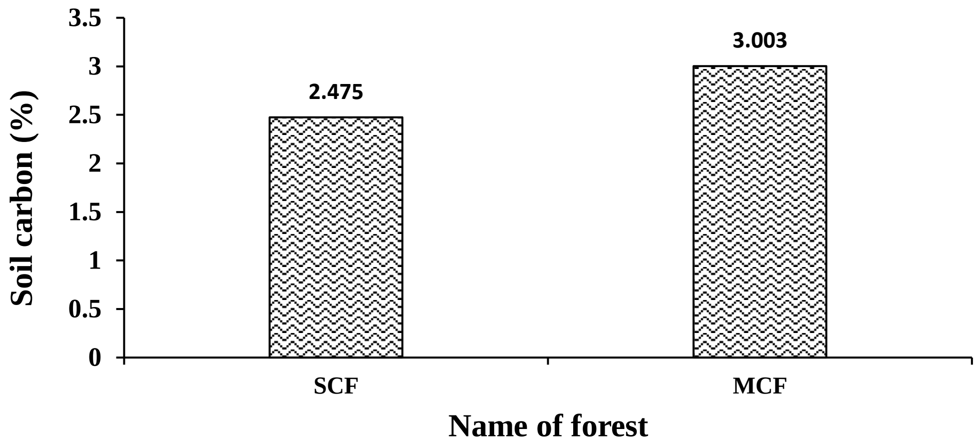


Figure 4.15. Soil carbon analysis of Siddhanath community forest and Manehara community forest.

The relationship between variables such as carbon stock and soil moisture, carbon stock and bulk density and carbon stock and soil carbon were calculated on the basis of measurements obtained from each plot. The correlation of carbon stock with soil moisture and soil organic carbon on the basis of each plot were found negative and they are statistically insignificant but correlation of carbon stock with bulk density was found positive and it is also statistically insignificant which are given in Table 4.8. Values of all variable of each plot are given in Appendix VIII.

Table 4. 8. Relationship between carbon stock and soil parameters

Correlation	SCF	MCF	P value in SCF	P value in MCF
Carbon stock and soil moisture	-0.022	-0.209	0.926	0.377
Carbon stock and bulk density	0.142	0.350	0.551	0.131
Carbon stock and soil organic carbon	-0.027	-0.136	0.914	0.568

¤

4.4 Soil properties

4.4.1 Soil moisture and bulk density

The soil sample was collected during April 22 to May 6, 2019. Soil moisture in SCF was ranged from 0.38 % to 4.31 % and in MCF it ranged from 8 % to 25.52 %. The mean value of soil moisture was found 1.97% in SCF and 16.31 % in MCF (Figure 4.16).

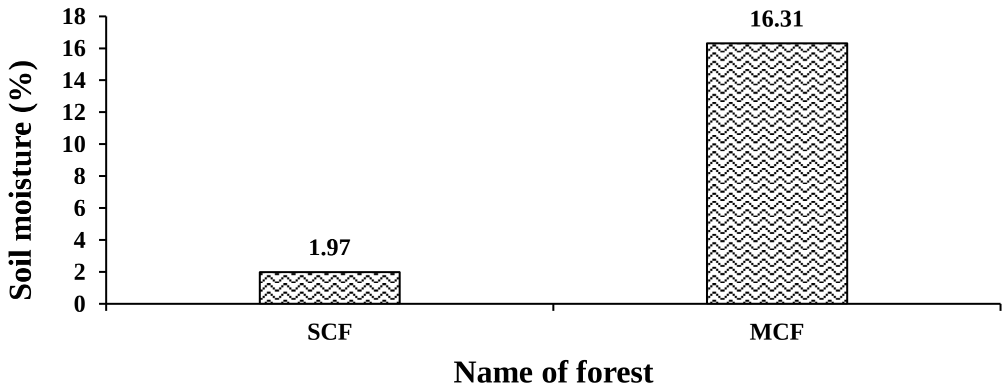


Figure 4.16. Soil moisture of Siddhanath community forest and Manehara community forest.

Bulk density in SCF was ranged from 1.40 to 1.45g/cm³ and in MCF it ranged from 1.27 to 1.42 g/cm³. The mean value of soil moisture was found 1.43 g/cm³ in SCF and 1.34 g/cm ³ in MCF (Figure 4.17).

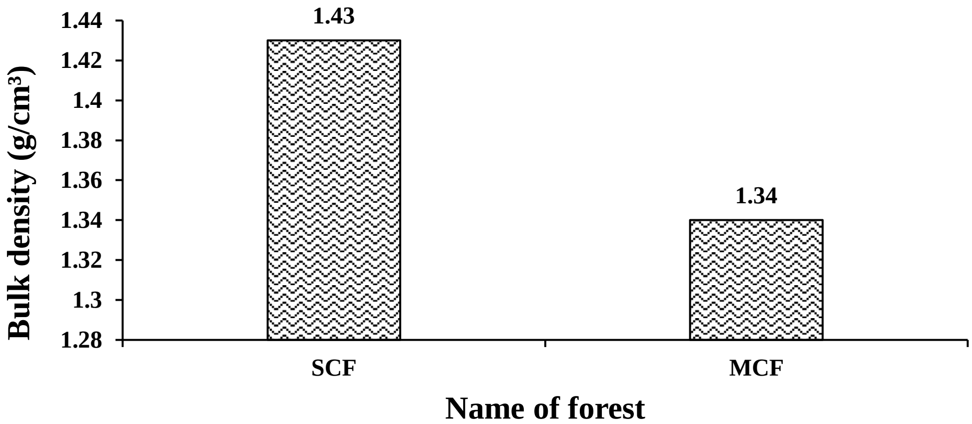


Figure 4.17. Bulk density of Siddhanath community forest and Manehara community forest

CHAPTER 5: DISCUSSION

5.1 Community Attributes

Total plant species diversity in the moist forest (MCF) was found to be higher than in the dry forest (SCF). However, the diversity of herbs was higher in dry forest (SCF) than in moist forest (MCF). Similarly, the similarity index value of herbs between these two forests was low, which might be due to dryness and low density of shrubs in SCF. Berlow *et al.*, (2003), also observed higher species diversity of herbs in the areas with less shrub cover due to response of herbs to removal of shrubs or low availability of shrubs. In this study possibly MCF with high moisture content must have supported more species of shrubs and trees.

Among all tree species IVI of *Shorea robusta* was found higher in both community forest (i.e. 179.68 in SCF and 95.46 in MCF). High IVI of a species indicates its dominance and ecological success, its good power of regeneration and greater ecological amplitude (Sameem and Kangaroo, 2011). The regeneration of *Shorea robusta* in both the forest was high. Hence, it indicates that *Shorea robusta* was the most important and dominant species in both forest.

Besides *Shorea robusta, Dalbergia sissoo, Schleichera oleosa, Terminalia belerica, Mangifera indica, Psidium guajava* and *Terminalia chebula* species were found with higher IVI in SCF which are the indicator of dryness favor plant (Jackson, 1994) and in MCF, *Ficus benghalensis, Garuga pinnata, Haldina cordifolia, Syzygium cumini, Terminalia tomentosa, Myrsine semiserrata, Aegle marmelos, Madhuca longifolia, Mallotus philippensis, Ficus spp., Alstonia scholaris, Bombax ceiba, Semecarpus anacardium* and *Acacia catechu* were found with higher IVI which are the indicator of riverine forest (Puneet *et al.*, 2006).
MCF had higher plant biodiversity and higher carbon stock than SCF. Similarly, Mandal (2016) also reported the positive and very weak relationship between carbon stock and species richness of collaborative forest.

Similarly, plant biodiversity was found higher in MCF which had lower bulk density than SCF. It is generally desirable to have soil with a low BD for optimum movement of air and water through the soil (Hunt and Gilkes, 1992).

5.2 Regeneration

Seedling, sapling and tree density was higher in SCF than in MCF. It might be due to more plant with minimum basal area and open canopy in SCF than in MCF. Opening of the canopy in a forest stand promotes regeneration and the growth of understory seedlings and saplings

(Troup, 1986; Gautam, 1990). Open canopy favors the regeneration of light demanding species (Sapkota *et al*, 2009). Presence of sufficient canopy gaps allowed sufficient light to reach the forest understory and made the light and dry environment favorable for abundant growth of *Shorea robusta* seedling and sapling. Thus light is considered very important abiotic factors which played two roles increasing photosynthesis and ground temperature which in turn accelerates litter decomposition (Sapkota *et al*., 2009). Hence, regenerating condition of *Shorea robusta* light demanding plant (Champion and Seth, 1968; Kayastha, 1985) in dry SCF was highest than in moist MCF.

Shorea robusta constitutes higher density in all the three life form than other associated species in both community forest. Poudel (2000) also reported high dominance of *Shorea robusta* in community forest and equal dominance of *Shorea robusta* and *Terminalia tomentosa* in national forest of Udayapur District. Similarly, Poudel and Shah (2015) reported dominance of *Shorea robusta* in community forest while *Shorea robusta* and *Terminalia alata* were codominant in government forest at lowland of Eastern Nepal. The result of present study are also similar to the Poudel (2000) and Poudel and Shah (2015). Similarly, associated species seedling such as *Terminalia tomentosa, Syzygium cumini, Haldina cordifolia, Dalbergia sissoo,* were found high in SCF, which might be due to open and dry environment of SCF that might have favored for abundant growth of these species seedling. But the seedling of other few species such as *Acacia catechu, Garuga pinnata, Schleichera oleosa* were found high in moist MCF because they are riverine tree and they can adopt in high moisture (Puneet *et al.,* 2006). Though the trees of associated species like *Terminalia tomentosa, Haldina cordifolia, Terminalia chebula, Terminalia belerica, Ficus benghalensis, Alstonia scholaris* were quite common in both SCF and MCF but their sapling were not found in both forest which might be due to lack of proper management of forest, illegal logging, herd grazing and bush fire and these evidences were also observed during the field study.

Regeneration status of the forest is said to be good if forest have seedling >5000 and sapling >2000 per hectare (HMG, 2004) (cited in Pandey et al., 2012). Regeneration status of forests in the present study was 169000 seedling and 13,090 sapling per hectare in SCF and 68,250 seedling and 5,520 sapling per hectare in MCF, which were higher than the above mentioned values. Hence, the regeneration status in both MCF and SCF were in good condition. Regeneration are the determinant factors for the sustainability of forests. Cutting down of trees must had led to open canopy and this must had favored good regeneration in SCF.

5.3 Carbon Stock

In the present study, canopy cover and basal area of species were found higher in MCF than in SCF and relation of these stand characteristics with total C-stock was found to be statistically significant. But density of species were found higher in SCF than in MCF and relation of this characteristic with total C-stock was found to be statistically insignificant which is similar to Thapa Magar and Shrestha (2015).

High density of tree individuals with 10-25cm diameter at breast height was observed in SCF. The result showed more number of tree individual with minimum diameter because SCF was regenerating forest. But in MCF more tree individuals with 40-55cm diameter at breast height was observed indicating it to be older than the SCF. 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). This is why the standing C-stock of old growth forest (MCF) is higher than the newly regenerating forest SCF. Similar result was also observed by Singh and Singh, (1992) in forests of Himalaya, India.

Shorea robusta was the highest contributor of C-stock in both community forest (i.e. 59% in SCF and 26% in MCF) this could be due to the highest basal area of *Shorea robusta* in both forest than other species (i.e. 7.8m²/ha in SCF and 6.5m²/ha in MCF). These value are 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). IVI value of *Shorea robusta* was highest in both forest than other associated species. Carbon stock among tree species were not in accordance to the IVI value obtained, which must be due to differences in the density of their wood. For instance, in SCF the IVI of *Shorea robusta* (179.68) was followed by *Dalbergia sissoo* (44.76), *Terminalia tomentosa* (16.12) and *Syzygium cumini* (7.65) but carbon stock of *Shorea robusta* (59%) was followed by *Terminalia chebula* (7%) and *Ficus benghalensis* (6%). Similarly, in MCF IVI of *Shorea robusta* (95.46) was followed by *Syzygium cumini* (60.46), *Terminalia tomentosa* (43.72), *Haldina cordifolia* (18.78), but carbon stock of *Shorea robusta* (26%) was followed by *Terminalia tomentosa* (25%), *Haldina cordifolia* (25%), *Ficus benghalensis* (8%), and *Terminalia chebula* (3%). The above result indicates that species having higher value of basal area contributes higher in carbon stock than having higher IVI value which is similar to the observation of Thapa Magar and Shrestha (2015). However, an increase in the height and wood density of individual tree does not necessarily always increase the stand biomass and the carbon stock.

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. In SCF, forest management group provided lots of timber to the community school for furniture and also for making bridges in the community annually. Hence, this disturbance factor may be also be one of the reasons for having less carbon stock in SCF.

Variation in carbon stock might be depends on some environmental factors such as temperature, rainfall, etc. Barbour *et al*., (1999). The present study was done based on soil moisture condition between two community forests. In total MCF (16.31%) had higher soil moisture than SCF (1.97 %) and also had higher carbon stock (92.99 t/ha) than SCF (51.94 t/ha). The correlation of carbon stock with soil moisture and soil organic carbon (in the 0-20 cm layer) in both forest by plot wise were found negative and they were also found statistically insignificant but carbon stock increased insignificantly with increasing total soil moisture and soil organic carbon in MCF. Similar result was also obtained by Deng *et al.*, (2016) according to them the soil organic carbon was only significantly positively correlated with soil moisture in the 0-10cm layer and indicating that soil moisture played an important role in soil carbon sequestration of forest ecosystem because high soil moisture contributed to a high net primary productivity and a high soil organic carbon accumulation. Thapa Magar and Shrestha (2015) also found similar result which showed increasing C-stock with increased total soil organic carbon. In plot wise, the correlation of carbon stock in both forest with bulk density was found positive but statistically insignificant. In total, bulk density of SCF was found higher i.e.1.42g/cm^3 than in MCF i.e. 1.34g/cm^3. It indicates that MCF had less soil compaction and high porosity in soil than SCF which is suitable for root growth. In general bulk density greater than 1.6g/cm^3 is tend to restrict growth (Mckenzie *et al.*, 2004). This study shows that there was insignificant effect of bulk density with soil carbon and total carbon.

Ground vegetation and regeneration were higher in SCF which had open canopy. Therefore, the hypothesis that the ground vegetation and regeneration will be higher in less dense canopy forest had been accepted.

Similarly, MCF had highest soil moisture and had high carbon stock than SCF. Therefore, the hypothesis moist forest had highest carbon stock than dry forest had been accepted.

CHAPTER 6: CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

From this study it can be concluded that regeneration is favored in Siddhanath community forest because of dry soil conditions and open canopy. As the studied forest were dominated by Sal, which favored dry conditions for regeneration and hence, the hypothesis moist forest will have higher regeneration had not been accepted. Though, the correlation of soil organic carbon and carbon stock were negative plot wise but when two forest are compared the carbon stock of trees increased with increasing soil organic carbon.

Shorea robusta is a dominant species with high basal area in both community forest and its contribution was highest for C-stock in both community forest. Besides this the moist forest condition have been found to favor increase in carbon stock.

6.2 RECOMMENDATION

- **i.** These forest should be included in REDD+ scheme so that these communities can get benefits from carbon credit trade, which will ultimately help in improvement of forest condition and livelihoods of local communities.
- **ii.** Illegal logging and grazing should be strictly prohibited for regeneration of the forest.
- **iii.** To maintain moisture in dry forest, if possible, some ponds in suitable highland areas should be constructed.

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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 (%):	Disturbance:

S.N	Plant species	Local name	DBH (cm)	Height (m)	Remarks
1					
2					
3					
.					
.					
.					

APPENDIX II

Geographical position of plots with different variables measured in these plots.

Where, plot number 1-20; for SCF and 21 -40 MCF (Alt- altimeter, CC-canopy cover, GVC-ground vegetation cover and LC –litter cover).

Plot Number	**Alt(m)**	**Latitude**	**Longitude**	**Slope(°)**	**CC (%)**	**GVC (%)**	**LC (%)**
1	167	28°40’43”	80°38’13’’	1	20	25	0
2	165	28°40’46”	80°38’17”	0	25	35	2
3	165	28°40’46”	80°38’22’’	0	30	70	4
4	163	28°40’43”	80°38’31’’	0	25	40	2
5	162	28°40’46”	80°38’39”	0	20	55	2
6	160	28°30’45”	80°38’40’’	1	32	65	2
7	160	28°40’47”	80°38’35’’	0	20	60	3
8	162	28°40’45”	80°38’27”	0	25	70	4
9	162	28°40’46”	80°38’28’’	0	35	38	5
10	160	28°40’41”	80°38’24’’	0	20	60	4
11	182	28°40’36”	80°38’58”	0	20	40	3
12	125	28°40’40”	80°38’57’’	0	30	30	1
13	181	28°40’44”	80°38’56’’	0	35	40	1
14	166	28°40’31”	80°38’60”	0	40	50	2
15	191	28°40’30”	80°39’7’’	0	25	45	3
16	168	28°40’36”	80°39’9’’	0	30	50	2
17	167	28°40’40”	80°38’58”	0	35	50	3
18	170	28°40’47”	80°38’56’’	0	25	40	5

19	123	28°40’51”	80°38’34’’	0	20	40	3
20	198	28°40’54”	80°38’45”	1	30	30	2
21	176	28°41’39”	80°37’43’’	0	15	45	1
22	156	28°41’39”	80°37’38”	0	20	35	0
23	135	28°41’40”	80°37’45’’	0	35	30	1
24	135	28°41’51”	80°37’46’’	0	40	25	0
25	163	28°41’57”	80°37’50”	0	45	30	2
26	164	28°41’57”	80°37’48’’	0	35	50	2
27	165	28°41’588”	80°37’53’’	0	30	60	3
28	165	28°41’40”	80°37’58”	1	20	65	0
29	171	28°41’27”	80°37’59’’	0	25	45	1
30	166	28°41’28”	80°38’14’’	0	50	55	0
31	126	28°41’21”	80°38’5”	0	55	50	2
32	174	28°41’33”	80°38’22’’	0	35	40	2
33	176	28°41’30”	80°38’31”	0	45	35	2
34	176	28°41’31”	80°38’35’’	0	40	25	3
35	175	28°41’28”	80°38’39’’	0	35	30	11
36	135	28°41’29”	80°38’43”	0	40	30	4
37	135	28°41’29”	80°38’47’’	0	30	40	2
38	170	28°41’24”	80°38’43’’	0	30	45	3
39	161	28°41’15”	80°38’42”	0	20	25	4
40	160	28°41’35”	80°38’49”	0	35	30	5

APPENDIX III

Wood density of tree species used to estimate carbon stock using equation Chave *et al*., (2000).

Species name	**Wood density (g/cm^3)**
Shorea robusta	0.73
Terminalia tomentosa	0.73
Syzygium cumini	0.673
Haldina cordifolia	0.58
Terminalia chebula	o.88
Terminalia belerica	0.76
Dalbergia sissoo	0.77
Mallotus philippensis	0.64
Ficus benghalensis	o.39
Acacia catechu	0.88
Bauhinia variegate	0.67
Schleichera oleosa	0.96
Garuga pinnata	0.51
Madhuca longifolia	0.74
Ficus spp.	0.39
Semecarpus anacardium	0.64
Mangifera indica	0.675
Psidium guajava	0.67
Bombax ceiba	0.37
Aegle marmelos	0.75
Alstonia scholaris	0.36

Source*:* Zanne *et al*., *2009*

APPENDIX IV

Herbs, shrubs and trees species found in Siddhanath community forest and Manehara community forest.

Scientific name of herbs	**Scientific name of shrubs**	**Scientific name of trees**
Ageratum conyzoides	*Mallotus philippensis*	*Shorea robusta*
Imperata cylindrical	*Solanum viarum*	*Terminalia tomentosa*
Eragosti curvula	*Shorea robusta*	*Haldina cordifolia*
Achyranthes bidentate	*syzygium cumini*	*Dalbergia sissoo*
Cynodon dactylon	*Phoenix acaulis*	*Syzygium cumini*
Syzygium cumini	*Myrsine semiserrata*	*Schleichera oleosa*
Haldina cordifolia	*Madhuca longifolia*	*Garuga pinnata*
Dalbergia sissoo	*Psidium guajava*	*Aegle marmelos*
Shorea robusta	*Aegle marmelos*	*Terminalia belerica*
Schelichera oleosa	*Clerodendrum viscosum*	*Acacia catechu*
Ficus benghalensis	*Ziziphus incurve*	*Mallotus philippensis*
Cassia fistula	*Dalbergia sissoo*	*Semecarpus anacardium*
Morus nigra	*Bauhinia vahlii*	*Mangifera indica*
Cyperus rotundus	*Tectona grandis*	*Madhuca longifolia*
Oxalis corniculata	*Lantana camara*	*Ficus benghalensis*
Psidium guajava	*Garuga pinnata*	*Myrsine semiserrata*
Chrysopogon aciculatus	*Bambusoideaea*	*Ficus sp.*
Terminalia tomentosa	*Acacia catechu*	*Bombax ceiba*
Mallotus phillippensis	*Schleichera oleosa*	*Psidium guajava*
Vallaris solanacea	*Morus nigra*	*Alstonia scholaris*
Acacia catechu	*Asparagus racemose*	*Terminalia chebula*
Garuga pinnata		
Phoenix acaulis		

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APPENDIX V

Frequency, density, abundance and their relative values of herbs, shrubs and tree in Siddhanath community forest and Manehara community forest.

Herbs

In Siddhanath community forest

Plant name	Total number of individual in 60 plot (Q)	F	RF %	D	RD %	A	RA %	IVI
Ageratum conyzoides	227	80	14.54	5.68	12.06	14.19	9.29	35.87
Imperata cylindrical	187	75	13.63	4.68	9.94	12.47	8.17	31.72
Eragostis curvula	45	40	7.27	1.13	2.39	5	3.28	12.94
Achyranthus bidentate	29	30	5.45	0.72	1.53	4.83	3.16	10.16
Cynodon dactylon	24	15	2.72	0.6	1.27	8	5.24	9.23
Syzygium cumini	74	65	11.81	1.85	3.93	5.69	3.73	19.46
Haldina cor-difolia	35	35	6.36	0.88	1.87	5	3.28	11.51
Dalbergia sissoo	5	20	3.63	0.13	0.28	1.25	0.82	4.73
Shorea ro-busta	1205	95	17.27	30.13	63.99	63.43	41.56	122.69
Schelichera oleosa	6	15	2.72	0.15	0.32	3	1.97	5.01
Ficus ben-	7	10	1.81	0.18	0.39	3.5	2.29	4.48

ghalensis								
Cassia fistula	2	5	0.9	0.05	0.11	2	1.31	2.32
Morus nigra	2	5	0.9	0.05	0.11	2	1.31	2.32
Cyprus rodentus	10	5	0.9	0.25	0.53	10	6.55	7.98
Oxalis corniculata	9	20	3.63	0.23	0.49	2.25	1.47	5.59
Psidium guajava	9	15	2.72	0.23	0.49	3	1.97	5.18
Chrysopogon Aciculatus	2	5	0.9	0.05	0.11	2	1.31	2.14
Terminalia tomentosa	4	10	1.81	0.1	0.21	2	1.31	3.33
Mallotus philippensis	3	5	0.9	0.08	0.17	3	1.97	3.04

Herbs in Manehara community forest

Plant name	**Total number of individual in 60 plot**	**F**	**RF %**	**D**	**RD %**	**A**	**RA %**	**IVI**
Imerata cylindrica	318	85	20.99	7.95	29	18.71	18..52	68.51
Eragostis curvula	43	30	7.41	1.08	3.94	7.17	1.69	13.04
Ageratum conyzoides	144	55	13.58	3.6	13.16	13.1	12.97	39.71
Vallaris sola-	17	25	6.17	0.42	1.54	3.4	3.37	11.08

nacea								
Cynodon dactylon	4	5	1.23	0.1	0.37	4	3.96	5.56
Shorea robusta	493	100	24.69	12.32	45	24.65	24.4	94.09
Haldina cordifolia	16	35	8.64	0.4	1.46	2.29	2.27	12.37
Schleichera oleosa	19	35	8.64	0.48	1.75	2.71	2.68	13.07
Psidium guajava	9	10	2.47	0.2	0.73	4.5	4.45	7.65
Syzygium cumini	23	10	2.47	0.58	2.11	11.5	11.38	15.96
Acacia catechu	4	5	1.23	0.1	0.37	4	3.96	5.56
Garuga pinnata	1	5	1.23	0.03	0.11	1	0.99	2.33
Phoenix acaulis	4	5	1.23	0.1	0.37	4	3.96	5.56

Shrubs

In Siddhanath community forest

Plant name	Total number of individual in 40 Q	F	RF %	D	RD %	A	RA %	IVI
Mallotus philippensis	198	90	10.43	0.99	14.39	5.5	6.60	31.42
Ficus ben-ghalensis	27	22.5	2.60	0.14	2.03	3	3.60	8.23
Syzygium cumini	105	52.5	6.09	0.52	7.56	5	6.0	19.65
Lantana ca-mara	11	10	1.16	0.05	0.73	2.75	3.30	5.19
Shorea ro-busta	880	90.1	10.43	4.4	63.95	24.44	29.33	103.71
Dalbergia sissoo	43	22.5	2.61	0.22	3.2	4.8	5.76	11.57
Myrsine sem-iserrata	50	40	4.64	0.25	3.63	3.13	3.76	12.03
Morus nigra	3	5	0.58	0.02	0.29	1.5	1.80	2.67
Clerodendrum viscosum	14	7.5	0.87	0.07	1.02	4.7	5.64	7.53
Ziziphus in-	12	2.5	0.29	0.0	0.87	12	14.40	15.56

curve				6				
Solanum viarum	20	5	0.58	0.1	1.54	10	12	14.03
Psidium guajava	1	2.5	0.29	0.01	0.15	1	1.2	1.64
Bambusoideae	5	5	0.58	0.03	0.44	2.5	3	4.02
Schleichera oleosa	2	5	0.58	0.01	0.15	1	1.2	1.93
Asparagus racemose	2	2.5	0.29	0.01	0.15	2	2.4	2.84

Shrubs in Manehara community forest

Plant name	**Total number of individual in 40 Q**	**F**	**RF %**	**D**	**RD %**	**A**	**RA %**	**IVI**
Mallotus philippensis	253	85	25.76	1.27	37.57	7.44	11.26	74.59
Solanum viarum	80	25	7.58	0.4	11.83	8	12.11	31.52
Shorea robusta	139	90	27.27	0.69	20.41	3.86	5.84	53.52
Syzygium cumini	104	47.5	14.30	0.52	15.38	5.47	8.28	38.05
Phoenix acaulis	24	20	6.06	0.12	3.55	3	4.54	14.15
Myrsine semiserrata	14	12.5	3.79	0.07	2.07	2.8	4.24	10.1

Madhuca longifolia	2	2.5	0.76	0.01	0.29	2	3.03	4.08
Psidium guajava	6	5	1.51	0.03	0.89	3	4.54	6.94
Aegle marmelos	2	2.5	0.76	0.01	0.29	2	3.03	4.08
Clerodendrum viscosum	4	5	1.51	0.02	0.59	2	3.03	5.13
Ziziphus incurva	4	5	1.51	0.02	0.59	2	3.03	5.13
Dalbergia sissoo	3	2.5	0.76	0.02	0.59	3	4.54	5.89
Bauhinia *vahlii*	6	5	1.51	0.03	0.89	3	4.54	6.94
Tectona grandis	13	5	1.51	0.07	2.07	6.5	9.84	13.42
Lantana camera	4	2.5	0.76	0.02	0.59	4	6.05	7.4
Garuga pinnata	1	2.5	0.76	0.01	0.29	1	1.51	2.56
Bambusoideae	3	5	1.51	0.02	0.59	1.5	2.27	4.37
Acacia catechu	7	5	1.51	0.04	1.18	3.5	5.29	7.98
Schleichera oleosa	2	2.5	0.76	0.01	0.29	2	3.03	4.08

Trees

In Siddhanath community forest

Plant name	Total number of indi-vidual in 20 Q	F	RF %	D	RD %	A	RA %	IVI
Shorea robusta	437	95	43.18	1.09	83.33	23	53.17	179.68
Terminalia tomentosa	7	25	11.36	0..02	1.53	1.4	3.23	16.12
Dalbergia sissoo	55	35	15.90	0.14	10.70	7.86	18.16	44.76
Haldina cordifolia	1	5	2.27	0.003	0.23	1	2.31	4.81
Syzygium cumini	2	5	2.27	0.01	0.76	2	4.62	7.65
Schleichera oleosa	2	10	4.55	0.01	0.76	1	2.31	7.62
Garuga pinnata	1	5	2.27	0.003	0.23	1	2.31	4.81
Ficus benghalensis	1	5	2.27	0.003	0.23	1	2.31	4.81
Terminalia chebula	1	5	2.27	0.003	0.23	1	2.31	4.81
Terminalia belerica	1	5	2.27	0.003	0.23	1	2.31	4.81
Myrsine semiserrata	1	5	2.27	0.003	0.23	1	2.31	4.81
Psidium guajava	2	10	4.55	0.01	0.76	1	2.31	7.62
Mangifera indica	2	10	4.55	0.01	0.76	1	2.31	7.62

Trees in Manehara community forest

Plant name	Total no. of sp. in 20Q	F	RF %	D	RD %	A	RA %	IVI
Shorea robusta	206	90	25.71	0.52	53.06	11.44	16.69	95.46
Terminalia tomentosa	61	80	22.86	0.15	15.30	3.81	5.56	43.72
Haldina cordifolia	21	30	8.57	0.05	5.10	3.5	5.11	18.78
Dalbergia sissoo	2	5	1.43	0.005	0.51	2	2.91	4.85
Syzygium cumini	58	10	2.86	0.15	15.30	29	42.30	60.46
Schleichera oleosa	3	10	2.86	0.01	1.02	1.5	2.19	6.07
Garuga pinnata	3	10	2.86	0.01	1.02	1.5	2.19	6.07
Aegle marmelos	1	5	1.43	0.003	0.30	1	1.46	3.19
Terminalia belerica	1	5	1.43	0.003	0.30	1	1.46	3.19
Acacia catechu	1	5	1.43	0.003	0.30	1	1.46	3.19
Mallotus philippensis	9	25	7.14	0.02	2.04	1.8	2.62	11.8
Semecarpus anacardium	2	10	2.86	0.005	0.51	1	1.46	4.83
Mangifera indica	3	10	2.86	0.01	1.02	1.5	2.19	6.07
Madhuca longifolia	3	5	1.43	0.01	1.02	1.5	2.19	4.64

Ficus benghalensis	4	20	5.71	0.01	1.02	1	1.46	8.19
Myrsine semiserrata	1	5	1.43	0.003	0.30	1	1.46	3.19
Ficus spp	1	5	1.43	0.003	0.30	1	1.46	3.19
Bombax ceiba	1	5	1.43	0.003	0.30	1	1.46	3.19
Psidium guajava	1	5	1.43	0.003	0.30	1	1.46	3.19
Alstonia scholaris	1	5	1.43	0.003	0.30	1	1.46	3.19
Terminalia chebula	1	5	1.43	0.003	0.30	1	1.46	3.19

APPENDIX VI

Regeneration status of all tree species in Siddhanath community forest and Manehara community forest.

In Siddhanath community forest

S.N	Name of plant	Forest regeneration stem/ha		
		Seedling	**Sapling**	**Tree**
1	*Shorea robusta*	150625	8800	547
2	*Terminalia tomentosa*	500	_	9
3	*Syzygium cumini*	9250	1050	3
4	*Haldina cordifolia*	4375	_	2
5	*Dalbergia sissoo*	625	430	69
6	*Schleichera oleosa*	750	20	3
7	*Garuga pinnata*	_	_	2
8	*Ficus benghalensis*	875	270	2
9	*Terminalia chebula*	_	_	2
10	*Terminalia belerica*	_	_	2
11	*Myrsine semiserrata*	_	500	2
12	*Psidium guajava*	1125	10	3
13	*Mangifera indica*	_	_	3
14	*Morus nigra*	250	30	_
15	*Mallotus philippensis*	375	1980	_
16	*Cassia fistula*	250	_	_
Total		169000	13090	649

In Manehara community forest

S.N	Name of plant	Forest regeneration stem/ha		
		Seedling	**Sapling**	**Tree**
1	*Shorea robusta*	61625	1390	258
2	*Terminalia tomentosa*	_	_	77
3	*Syzygium cumini*	2875	1040	73
4	*Haldina cordifolia*	2000	_	27
5	*Schleichera oleosa*	2375	20	4
6	*Psidium guajava*	1125	60	2
7	*Mallotus philippensis*	_	2530	12
8	*Aegle marmelos*	_	20	2
9	*Madhuca longifolia*	_	20	4
10	*Dalbergia sissoo*	_	30	3
11	*Bauhinia vahlii*	_	60	_
12	*Tectona grandis*	_	130	_
13	*Garuga pinnata*	125	10	4
14	*Acacia catechu*	500	70	2
15	*Terminalia chebula*	_	_	2
16	*Semecarpus anacardium*	_	__	3
17	*Mangifera indica*	_	_	4
18	*Ficus benghalensis*	_	_	5
19	*Myrsine semiserrata*	_	140	2
20	*Ficus* sp.	_	_	2
21	*Bombax ceiba*	_	__	2
22	*Alstonia scholaris*	__	_	2
23	*Terminalia belerica*	_	_	2
Total		68250	5520	492

APPENDIX VII

Basal aresa, Density stem/h of each species, Density stem/ha and DBH class and Carbon stock (%) of each tree species in Siddhanath community forest and Manehara community forest.

In Siddhanath community forest

S.N	**Plant name**	**Carbon stock (%)**	**Basal area (m^2/ha)**	**Density (stem/ha)**
1	*Shorea robusta*	59	7.8	547
2	*Terminalia chebula*	7	0.94	2
3	*Terminalia belerica*	3	0.53	2
4	*Dalbergia sisoo*	4	0.54	69
5	*Psidium guajava*	1	0.09	3
6	*Ficus benghalensis*	6	0.93	2
7	*Garuga pinnata*	0.3	0.09	2
8	*Haldina cordifolia*	10	1.62	2
9	*Schleichera oleosa*	5	0.59	3
10	*Mangifera indica*	1	0.38	3
11	*Syzygium cumini*	1	0.38	3
12	*Terminalia tomentosa*	3	0.53	9
13	*Myrsine semiserrata*	1	0.64	2

In Manehara community forest

S.N	**Plant name**	**Carbon stock (%)**	**Basal area (m^2/ha)**	**Density (stem/ha)**
1	*Shorea robusta*	26	6.5	258
2	*Terminalia tomentosa*	25	5.8	77
3	*Syzygium cumini*	1	0.35	73
4	*Schleichera oleosa*	1	0.57	4
5	*Haldina cordifolia*	25	3.93	27
6	*Aegle marmelos*	0.1	0.05	2
7	*Terminalia chebula*	3	0.68	2

8	*Terminalia belerica*	2	0.67	2
9	*Dalbergia sissoo*	0.3	0.41	3
10	*Madhuca longifolia*	1	0.33	4
11	*Mangifera indica*	1	0.44	4
12	*Mallotus philippensis*	0.3	0.34	12
13	*Ficus benghalensis*	8	3.92	5
14	*Ficus sp.*	2	0.67	2
15	*Alstonia scholaris*	0.02	0.01	2
16	*Psidium guajava*	0.03	0.02	2
17	*Bombax ceiba*	0.1	0.04	2
18	*Semecarpus anacardium*	0.2	0.65	3
19	*Garuga pinnata*	1	0.74	4
20	*Myrsine semiserrata*	0.1	0.05	2
21	*Acicia catechu*	1	0.09	2

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

S.N	**DBH class**	**SCF**	**MCF**
1	10-25	318	53
2	25-40	34	67
3	40-55	53	140
4	55-70	95	130
5	70-85	85	50
6	85-100	34	30
7	Above 100	17	22

APPENDIX VIII

Procedure applied for analyzing the soil physio-chemical parameters**.**

Soil moisture -First of all the soil sample were taken and their initial weights were taken and then the samples were wrapped by aluminium foil and kept inside hot air oven for 24 hours. After that the final weight were taken and calculation were done.

For calculation,

Initial wt. of soil (Wm) = Moist soil weight

Final wt. of soil (WD) = Dry soil weight

Soil water content (Sw) = $\frac{Wm-WD}{WD} \times 100\%$

In Siddhanath community forest

Plot	**Moist soil weight (Wm)**	**Dry soil weight(WD)**	**Soil moisture**
1	264	258	2.33
2	264	258	2.33
s3	266	255	4.31
4	264	260	1.54
5	264	260	1.54
6	266	255	4.31
7	263	255	3.14
8	263	260	1.15
9	263	260	1.15
10	262	260	0.77
11	266	258	3.10
12	261	258	0.39
13	265	263	0.76
14	261	257	1.56
15	263	260	1.15
16	266	260	2.31
17	262	261	0.38
18	266	255	4.3
19	265	260	1.92
20	263	260	1.15
Total			39.59

In Manehara community forest

Plot	Moist soil weight(Wm)	Dry soil weight(WD)	Soil moisture
1	280	233	25.23
2	280	258	8.52
3	270	248	8.87
4	280	233	25.23
5	280	233	25.23
6	270	248	8.87
7	270	248	8.87
8	279	248	18.72
9	279	258	8
10	275	250	10
11	275	253	8.70
12	275	230	20
13	277	238	16.39
14	277	234	25.52
15	277	248	11.69
16	278	248	18.33
17	278	247	18.75
18	278	247	18.75
19	280	233	25.23
20	279	242	15.29
Total			326.19

Bulk Density

At first prepare an undisturbed flat horizontal in the soil with a spade. Then, hammer the steel ring into the soil. Then, it was exhausted around the ring without disturbing the soil it contains and carefully it was removed with the soil intact. Then, the soil samples weight was taken and wrapped in aluminium foil and kept inside the hot air oven for 24 hours at 105◦c. After that the final weight of the soil was taken after drying. Further the internal diameter of steel ring was measured and calculation were carried out.

For calculation,

Soil volume = ring volume

Internal diameter of ring (D) = 3.4cm

Ring height = 20 cm

Radius of ring (r) =1.7 cm

Ring volume = $3.14 \times r^2 \times$ring height

Bulk density = $\frac{\text{Dry soil}}{\text{Soil volume}}$

Siddhanath community forest			**Manehara community forest**		
Plot	**Dry weight**	**Bulk density (g/cm^3)**	**Plot**	**Dry weight**	**Bulk density (g/cm^3)**
1	258	1.42	1	233	1.28
2	258	1.42	2	258	1.42
3	255	1.40	3	248	1.37
4	260	1.43	4	233	1.28
5	260	1.43	5	233	1.28
6	255	1.40	6	248	1.37
7	255	1.40	7	248	1.37

8	260	1.43	8	248	1.37
9	260	1.43	9	258	1.42
10	260	1.43	10	250	1.38
11	258	1.42	11	253	1.39
12	258	1.42	12	230	1.27
13	263	1.45	13	238	1.31
14	257	1.42	14	234	1.29
15	260	1.43	15	248	1.37
16	260	1.43	16	248	1.37
17	261	1.44	17	247	1.36
18	255	1.40	18	247	1.36
19	260	1.43	19	233	1.28
20	260	1.43	20	242	1.33
Total	5173			4877	

Soil Organic Carbon

Soil organic carbon was determined by Walkleys-Black Method. In this method, 0.5g air dried soil was taken in a dry conical flask (500 ml). Then 10 ml 1N potassium di-chromate (K2Cr2O7) was pipette in and swirled a little. To the mixture 20 ml of con-centrated sulphuric acid (Conc. H2SO4) was added and again swirled a little. The flask was allowed to cool down for 30 minutes and then 200 ml distilled water was added. After that 10 ml orthophosphoric acid and 1 ml diphenylamine indicator were added successively in the conical flask containing the mixture. Finally, the content was titrated with 0.5N ferrous ammonium sulphate (till the colour changed from blue violet to green). A blank was also run simultaneously.

Organic carbon in soil (%) $= \frac{N(B-S)\times 0.003}{Mass\ of\ dry\ soil(gm)} \times 100$

Where, N = Normality of ferrous ammonium sulphate (0.5N).

B = Volume of ferrous ammonium sulphate for blank titration (ml).

S = Volume of ferrous ammonium sulphate for sample titration i.e. soil (ml).

Plots	Total carbon stock t/ha (SCF)	Soil organic carbon SCF (%)	Total carbon stock t/ha (MCF)	Soil organic carbon SCF (%)
1	5.4296	2.079	0.9306	3.729
2	0.36942	2.079	17.80266	2.409
3	0.41172	4.059	4.77426	3.729
4	0.16638	2.739	3.68856	3.069
5	2.6085	2.739	3.48442	3.069
6	2.47032	4.059	4.41894	2.409
7	0.30174	2..079	4.1699	5.709
8	2.1432	0.099	3.6361	3.069
9	4.824	2.409	1.19565	3.069
10	2.1855	2.079	1.78224	3.729
11	2.67336	2.079	5.0462208	3.729
12	2.11782	2.079	2.84745	2.409
13	2.75232	4.059	2.219	2.409
14	4.4018	4.095	4.28705	3.069
15	0.53862	2.739	5.54758	3.069
16	7.64502	2.739	5.69922	3.069
17	3.17986	0.099	3.0573736	5.709
18	4.3174	2.409	7.87908	3.069
19	2.25882	2.739	7.01616	5.709
20	2.1573	2.409	3.50556	3.729

APPENDIX VIV

Photo plates

Measuring tree DBH at height 1.37 meter.