Chapter 1

Introduction

1.1 Background

Carbon stock refers to the amount of carbon stored, mainly in living biomass and soil, but to a lesser extent also in dead wood and litter. Stock of carbon represents the net exchange of carbon fluxes in an ecosystem (net ecosystem exchange) (Keith *et al*., 2009). In living biomass, the carbon stock is determined by the balance between the fluxes of carbon gain by photosynthetic assimilation by the foliage (gross ecosystem production, GEP) and carbon loss by autotrophic respiration, which results in net primary productivity (NPP). In the total ecosystem (living plus dead biomass plus soil), the carbon stock is determined by the balance between the fluxes of carbon gain by NPP and carbon loss by decomposition of dead biomass and heterotrophic respiration. Ecosystem carbon stocks vary because environmental conditions influence the carbon fluxes of photosynthesis, decomposition and autotrophic and heterotrophic respiration differently (Keith *et al*., 2009).

Carbon is cycled between the atmosphere, oceans, and terrestrial biosphere. The largest natural exchanges occur between the atmosphere and terrestrial biota, and between the atmosphere and ocean surface waters. Significant reservoirs of carbon are found in oceans, vegetation and soils. Oceans contain about 50 times as much carbon as the atmosphere, while terrestrial vegetation and soils contain about three and a half times as much carbon as the atmosphere (Kolshus, 2001). Globally carbon is distributed, and is being redistributed, among five interconnected C pools – the oceanic pool, the geological pool, the soil, the terrestrial biomass pool, and the atmospheric pool (Ringius, 2002). The increasing concentration of carbon dioxide since the industrial revolution is among the most significant of human influences on the global environment. The source of this carbon dioxide has been convincingly ascribed to the use of fossil fuels, cement manufacture and deforestation but considerable mystery remains because only a fraction of the estimated emissions of carbon dioxide remains in the atmosphere (Malhi *et al*., 1999).

Trees remove carbon dioxide from the atmosphere through the natural process of photosynthesis and store the carbon (C) in their leaves, branches, stems, bark and roots. Approximately half the dry weight of a tree's biomass is carbon **(**Johson and Coburn, 2010). Trees, because they sequester atmospheric carbon through their growth process and conserve energy, have been suggested as one means to combat increasing levels of atmospheric carbon (Nowak, 1993).

Forest systems cover more than 4.1 x 10^9 hectares of the Earth's land area (Dixon *et al*., 1994). Globally, forest vegetation and soils contain about 1146 pentagrams of carbon, with approximately 37 percent of this carbon in low-latitude forests, 14 percent in mid-latitudes, and 49 percent at high latitudes. Over two-thirds of the carbon in forest ecosystems is contained in soils and associated peat deposits (Dixon *et al*., 1994). Forests have great potential for the mitigation of CO_2 through appropriate conservation and mitigation**.** They play a key role in climate change as both sinks and sources of carbon dioxide. It has been estimated that deforestation and forest degradation contribute up to 20 percent of global emissions of carbon dioxide annually—more than the entire transportation sector—and that standing forests sequester about 20 percent of global carbon dioxide (Acharya *et.al.*, 2009).

REDD (Reduce Emission by Deforestation and Forest Degradation) is primarily about the reducing atmospheric carbon dioxide emission as an element of a comprehensive approach mandated by the Bali Action Plan in Dec 2007 (Cop13 at the Conference of Party meeting in Bali, Indonesia). It is a mechanism through which the abatement of greenhouse gases from deforestation and degradation can be achieved through a series of incentives. These incentives are provided by developed countries to developing countries for taking actions that reduce forest related emissions (Acharya *et al.*, 2009). REDD has gained major attention in international climate negotiations. It has brought forests to the forefront of both climate-change mitigation and adaptation (ANSAB, 2010).

Forests in Nepal cover nearly 29% of the total land areas and significantly contribute to mitigating the adverse impact of climate change (NBS, 2002). Nepal has a deforestation rate of 1.7% which is well above the Asian or global average. Nepal can benefit from the REDD+ mechanism by proactively acting to curb the rates of deforestation and forest degradation. Studies indicate high potential for Nepal to benefit from the REDD mechanism by expanding the community forestry programme and bringing the regime under the successful REDD+ mechanisms (Dhital, 2009).

1.2 Carbon stock in forest vegetation

Forests play a significant role in offsetting carbon dioxide emission, the primary anthropogenic GHG. Forests in the United States alone sequester about 200 million metric tons of carbon each year (Chavan, 2010). Managed forests provide climate change mitigation benefits over time through the delay of wood decay CO_2 emissions from harvested wood products, as compared with the decomposition or burning of wood in unmanaged forests. Harvested wood products that have long life cycles after production can store carbon for decades into the future. The trees act as major carbon dioxide sink which captures carbon from the atmosphere and act as sink, stores the same in the form of fixed biomass during the growth process. Therefore growing trees can be a potential contributor in reducing the concentration of carbon dioxide in atmosphere by its accumulation in the form of biomass (Chavan, 2010). Tropical riverine and *Alnus nepalensis* forest types demonstrated the highest carbon sequestration rates in Nepal (Baral *et al*., 2009).

The value of forests and trees in sequestering carbon and reducing carbon dioxide emission to the atmosphere is being recognized increasingly the world over. Forests play an important role in the carbon cycle as they sequester CO_2 from the atmosphere through photosynthesis (Kolshus, 2001). Tropical forests are a key component of the global carbon cycle and contribute more than 30% of terrestrial carbon stocks. Forests have a key role as carbon sinks, which could potentially mitigate the continuing increase in atmospheric carbon dioxide concentration and associated climate change. The majority carbon stored in global vegetation is in forests. The growth of trees and the preservation of old forests are therefore of prime importance in regulating the size of the overall terrestrial carbon sink. The temperate and boreal forests ecosystems contain a large part of the carbon stored on land, in the form of the both biomass and soil organic matter (Hyovonen *et al*., 2007). The total standing above-ground biomass of woody vegetation elements is often one of the largest carbon pools. The above-ground biomass comprises all woody stems, branches, and leaves of living trees, creepers, climbers, and epiphytes as well as herbaceous undergrowth. For agricultural lands, this includes crop and weed biomass. The dead organic matter pool includes dead fallen trees and other coarse woody debris. An estimate of the vegetation biomass can provide us with information about the nutrients and carbon stored in the vegetation as a whole, or the amount in specific fractions such as extractable wood (Hairiah *et al*., 2001). Aboveground biomass, in turn, substantially determines an ecosystem's potential for carbon storage, which plays an important role in the regulation of atmospheric CO_2 and global climate change (Bunker *et al*., 2005).

1.3 Carbon stock in forest soil

The concern about increasing atmospheric CO_2 and its role in future global climate change has lead soil scientists to quantify soil organic carbon content, also referred as stocks or storage. Planners across the globe are attempting to formulate plans for reducing the level of atmospheric CO_2 either by reducing emissions or by taking CO_2 out from the atmosphere and storing in the terrestrial, oceanic or aquatic ecosystems. The Intergovernmental Panel on Climate Change (IPCC) identified creation and strengthening of carbon sinks in the soil as a clear option for increasing removal of CO_2 from the atmosphere and has recognized soil organic carbon pool as one of the five major carbon pools for the Land Use, Land Use Change in Forestry (LULUCF) sector. Soils store 2.5 to 3.0 times as much carbon than that stored in plants and two to three times more than the atmospheric CO_2 (Gupta and Sharma., 2012)

The amount of carbon stored in the soil is about four times as high as that stored in the vegetation, and 33% higher than total carbon storage in tropical forests. Thus, there is considerable potential for long-term sequestration of carbon in the soils of temperate/boreal forests (James *et al.*, 2005). The global potential of Carbon sequestration by forests is high, about 0.4 Pg C/year in forest soils and 1-3 Pg C/year total in forest biomass (Lal, 2005). Tropical forests are well known for high rates of net primary production and store approximately 216 Pg C in the above ground biomass (Brown *et al.*, 1993; Dixon *et al*. 1994 cited in Silver *et al.* 2000). Tropical forests store approximately 206 Pg C in the soil about twice as much as mid-latitude forest, but less than half that of boreal forests (Brown *et a*l., 1993; Dixon *et al*., 1994 cited in Silver *et al*., 2000)

Soil is an important sink for the carbon storage in the form of soil organic carbon. Soil are the largest carbon reservoirs of the terrestrial carbon cycle. Soil contain about three times more carbon than vegetation and twice as much as that present in the atmosphere. Soil contain much more Carbon (2500 Pg of C) than is contained in vegetation (650 Pg of C) and twice as much C as the atmosphere (750 Pg of C) (Kumar *et al*., 2006). Soil carbon represents the largest carbon pool of terrestrial ecosystems, and has been estimated to have one of the largest potentials to sequester carbon worldwide (Oliva and Masera, 2004). Carbon sequestration in forest soils has a potential to decrease the rate of enrichment of atmospheric concentration of carbon dioxide (Lal, 2005). The impact of anthropogenic CO_2 emissions on climate change may be mitigated in part by C sequestration in terrestrial ecosystems as rising atmospheric CO_2 concentrations stimulate primary productivity and ecosystem C storage. Carbon will be sequestered in forest soils if organic matter inputs to soil profiles increase without a matching increase in decomposition or leaching losses from the soil profile, or if the rate of decomposition decreases because of increased production of resistant humic substances or greater physical protection of organic matter in soil aggregates (John *et al*., 2008).

Improved practices in agriculture, forestry, and land management could be used to increase soil carbon and thereby significantly reduce the concentration of atmospheric carbon dioxide. Understanding biological and edaphic processes that increase and retain soil carbon can lead to specific manipulations that enhance soil carbon sequestration (Post *et al*., 2004). Carbon sequestration through forestry has the potential to play a significant role in ameliorating global environmental problems such as atmospheric accumulation of GHG's and climate change. Carbon fixation through forestry is a function of the amount of biomass in a given area. Therefore, any activity or management practice that changes the amount of biomass in an area has an effect on its capacity to store or sequester carbon. Forest management practices can be used to reduce the accumulation of green house gases in the atmosphere through two different approaches. One is by actively increasing the amount or rate of accumulation of carbon in the area. The second is by preventing or reducing the rate of release of carbon already fixed (Costa, 1996).

1.4 Carbon stock in community forest

Forest management is an important carbon mitigation strategy for developing countries.
Community forest management is especially effective because it offers tangible local benefits while conserving forests and sequestering carbon (Klooster and Masera, 2000). Community forests have high potential to offset large portion of carbon emission through sequestration into both soil and vegetation and act as a natural carbon sink (Khanal., 2010). The community forest offer an easy and accessible alternatives for carbon sequestration (Mandal and Laake, 2005). Community forest management can be scientifically regarded as an effective and efficient way to reduce global carbon emission and as the local communities are actively involved in Community

forest management, they should be benefited financially through forest carbon trading in international markets via. REDD+ (Adhikari, 2011). The mean carbon sequestration rate for community forests in India and Nepal is close to 2.79 C Mg/ha/yr or 10.23 C Mg/ha/yr, under normal management conditions and after local people have extracted forest products to meet their sustenance need (Baskota *et a*l ., 2007).

1.5 Rationale of the study

Community Forests (CFs) in Nepal deserves to receive payment for its contribution of carbon conservation with growing forest density and reducing deforestation & degradation thereby allowing the forest as increased sink and decreased sources of carbon. However, none of CF is recorded to estimate biomass and carbon and prepare forest operational plan with an objective of carbon estimation and monitoring (Rana *et al*., 2008). Rising CO_2 concentrations in the atmosphere could alter Earth's climate system, but it is thought that higher concentrations may improve plant growth through a process known as the "fertilization effect". Forests are an important part of the planet's carbon cycle, and sequester a substantial amount of the CO_2 released into the atmosphere by human activities. Many people believe that the amount of carbon sequestered by forests will increase as CO_2 concentrations rise. However, an increasing body of research suggests that the fertilization effect is limited by nutrients and air pollution, in addition to the well documented limitations posed by temperature and precipitation. The existing forests are not likely to increase sequestration as atmospheric CO_2 increases. It is imperative, therefore, that we manage forests to maximize carbon retention in above- and belowground biomass and conserve soil carbon (Beedlow *et al*., 2004). Plants take CO_2 from the atmosphere. Then, through the process of photosynthesis, the energy is trapped in the organic molecules and used by the plants themselves. In this process, a number of organic substances are stored temporarily as constituents of the standing vegetation, most of which is eventually added to the soil as plant organic litter and then to the soil as SOC by microbial activity. Hence, estimation of this carbon content both in vegetation and in soil becomes imperative to assess the carbon sequestration potential (Ramachandra *et al*., 2007).

Community forest of Karahiya VDC also play a key role in the global carbon cycle as other forest, but the quantity and distribution of carbon stored in this forest is still unknown. Research work related to carbon stock in biomass and soil in this forest has not been done before. So, estimation of carbon stock both in vegetation and soil of this forest is very significant to know the contribution to climate change mitigation. Community forest of this VDC is tropical forest. As, tropical forest of Tarai region are mostly dominated by *Dalbergia sissoo* and *Shorea robusta* so, only the sites dominated by these species were selected to know their carbon stock and contribution in climate change mitigation.

1.6 Research Question

- Is there any variation in the biomass and soil carbon stock in *Dalbergia sissoo* and *Shorea robusta* dominated sites of the forest?

1.7 Objectives

General objectives

The general objective of the study is to quantify the carbon stocks in the Community Forest of tropical region *Dalbergia sissoo and Shorea robusta* dominated sites.

.**Specific objectives**

- To determine the tree trunk volume and biomass in targeted forest sites.
- To quantify the biomass (above ground and below ground biomass) carbon stock and soil carbon stock of these targeted sites of the forest.
- To compare the biomass and soil carbon stock in *Dalbergia sissoo* and *Shorea robusta* dominated sites.

1.8 Limitations

- Other forest sites were not sampled.
- Biomass of seedlings, shrubs, herb and litter was not included.
- Other soil parameters such as Nitrogen and pH were not analyzed.

Chapter 2

Study area

2.1 Geographical location, topography and elevation

Karahiya community forest is situated in Karahiya Village Development Committee (VDC) ward number 8 of Rupandehi district. It is about 20 Km south from Butwal, the district quarter of Rupandehi district. The forest is natural tropical forest with a total area of 269 ha, the main tree species are Sal (*Shorea robusta*), Sisoo (*Dalbergia sisoo*) and Asna (*Terminalia tomentosa*). The forest was established in 1989. The forest was handed over to the community in 1997 and altogether 2700 households are involved in the management of that forest. Similar to much of Nepalese society, the community is composed of members from a mixture of economic classes. The community forest user committee (CFUC) consists of 17 members including 3 women members. (Dhakal and Pinard, 2005).

Karahiya community forest is located between 27°38'2'' N to 27°39'34'' N and 83°29'38'' E to 83°30'37'' E in the ward no. 8 of Karahiya VDC of Rupandehi district, West Nepal. The soil in the forest area is sandy, loamy and black. The soil is best for the regeneration of the vegetation due to its good aeration and percolation capacity. This forest has an altitudinal range, between 140 m to 160 m. (KCF, 2012).

2.2 Climate

The area is favored with hot and humid during summer and cold during the winter. Fog abode the place during winters and lasts for several weeks starting from early January to February. There is no occurrence of frost during cold season (KCF, 2012).

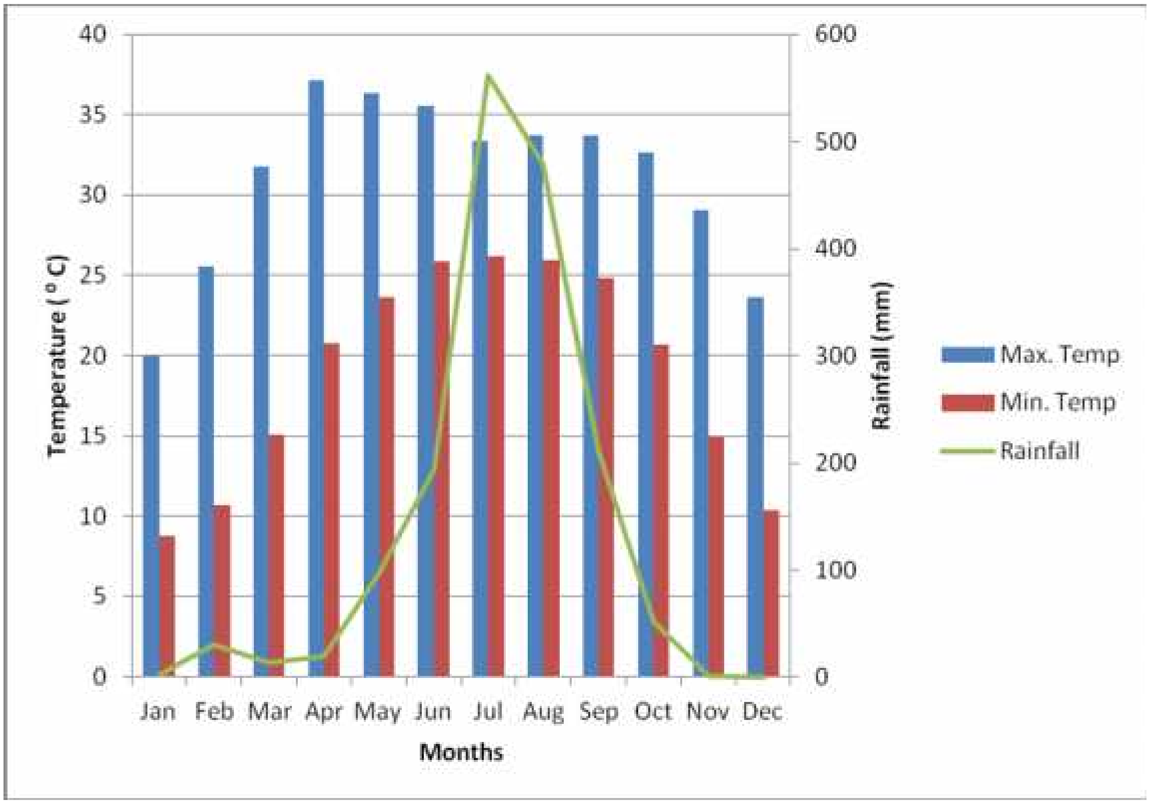

Figure 1: Average minimum-maximum temperature and rainfall (2007-2011) of Bhairahava station (Source: Department of Hydrology and Meteorology).

There is high variation in the annual temperature and precipitation. For the period of 2007-2011 the maximum average temperature is 37.14^{o}C and the minimum average temperature is 8.76^{o}C. The average annual rainfall is 1658.68 mm for the period of 2007-2011. More than 80% of annual rainfall occurs during the rainy season (monsoon rainfall) i.e from June to September (Figure 1).

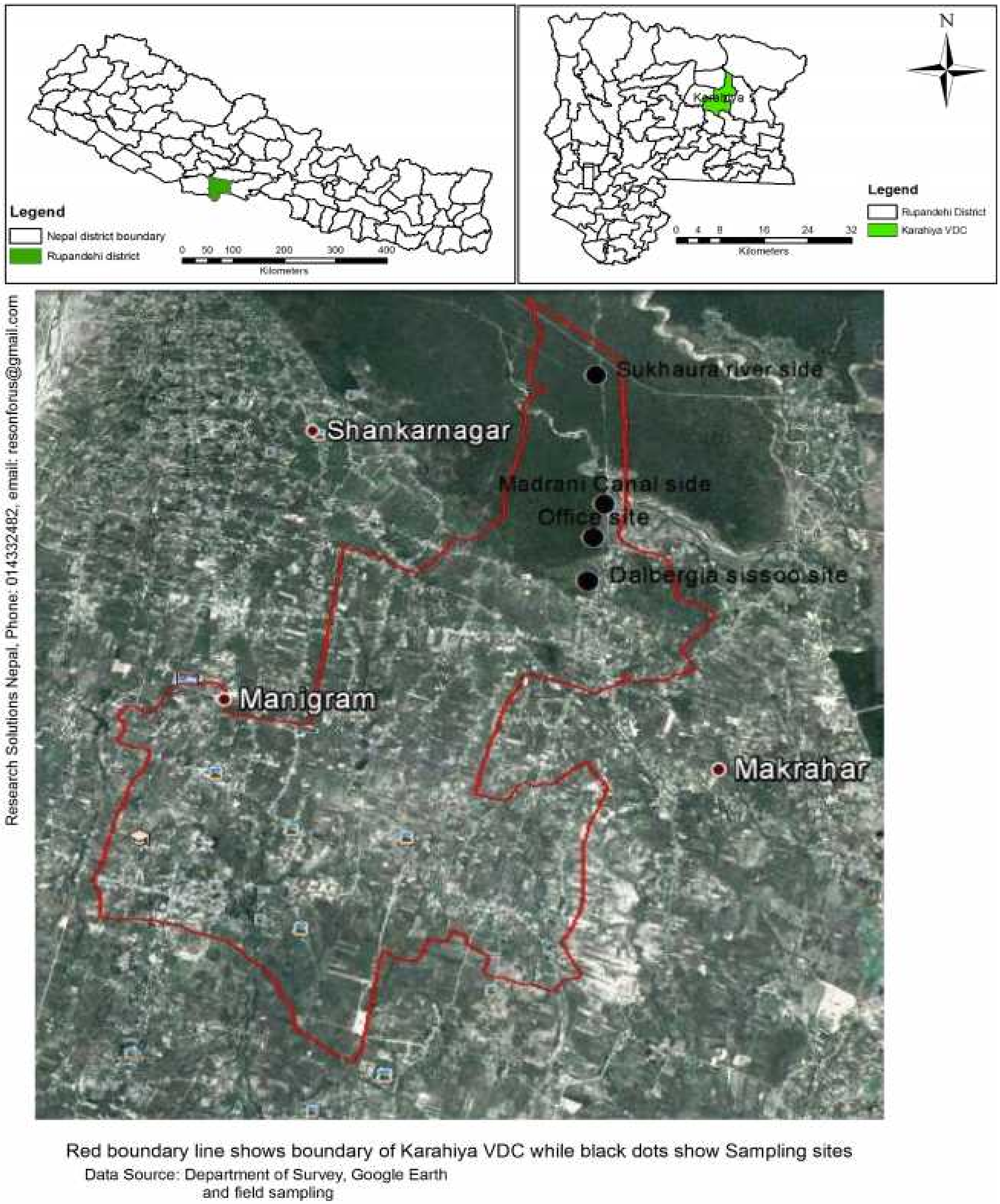

Figure 2: Map showing location of study area and sites of sampling

Figure 3: Location map of all the sites of Community forest of Karahiya VDC.

(Source: KCF, 2012)

2.3 Vegetation

The forest area was divided into seven sites by the authorities. The site 1 and 2 is dominated by planted forest of *Dalbergia sissoo*, sites 3, 5, 6 has natural forest of *Shorea robusta.* In site 4 there are planted species of *Dalbergia sissoo*, *Eucalyptus citrodora*, *Cassia fistula*, and site 7 has species of *Shorea robusta, Cieistocalyx operculatus, Lagestroemia parviflora, Litsea monopetala* Roxb. *etc.* The major plant species in this forest include, *Shorea robusta, Cieistocalyx operculata, Lagestroemia parviflora, Litsea monopelata, Carthamus tinctorius, Dalbergia sissoo*, *Eucalyptus citrodora*, *Cassia fistula, Melia azederach, Bombex ceiba, Dillenia pentagna, Acacia catechu*, *Syzygium cumini*, *Terminalia tomentosa.* The present regeneration status of this community forest is good in sites 3,5,6 and 7, normal in sites 1,2 and 4. In this forest the approximate number of Seedlings, Saplings, tress per hectare are 8311, 5441 and 31 (KCF,2012).

Table 1: Density of Seedlings, Saplings and Trees.

Site No.	Seedlings/ha	Saplings/ha	Trees/ha
1	4750	0	56
2	222	1156	33
3	17675	5740	10
4	5000	1413	0
5	11093	8809	21
6	11037	11926	41
7	8400	9040	60

(Source: KCF, 2012)

Chapter 3

Materials and Methods

3.1 Description of studied sites of the forest.

The forest consists of 7 sites. The features of the studied sites as follows:

A) Site No.- 1

- Name of site : *Dalbergia sissoo* Plantation site
- Slope : Plain
- Area : 12.85/ha
- Soil : Black soil
- Type of forest site : Plantation
- Species : *Dalbergia sissoo, Cassis fistula*
- Useful species : *Dalbergia sissoo*
- Natural regeneration status : Not good
- Total number of seedlings : 4750/ha
- Total number of saplings : Not present
- Total number of trees : 56/ha
- Density : Medium

B) Site No.- 2

- Name of site : Office site

- Slope : Plain
- Area : 17.53/ha
- Soil : Black soil
- Type of forest site : Plantation
- Species : *Dalbergia sissoo, Cassis fistula, Acacia catechu*
- Useful species : *Dalbergia sissoo, Acacia catechu*
- Natural regeneration status : Not good
- Total number of seedlings : 222/ha
- Total number of saplings : 1156/ha
- Total number of trees : 33/ha
- Density : Medium

C) Site No.- 3

- Name of site : Madrani canal site
- Slope : Plain
- Area : 80.08/ha
- Soil : Black soil
- Type of forest site : Natural
- Species : *Shorea robusta, Bombex ceiba, Terminalia tomentosa. Schleichera oleosa, Adina cordifolia.*
- Useful species : *Shorea robusta, Terminalia tomentosa.*

- Natural regeneration status : Good
- Total number of seedlings : 17675/ha
- Total number of saplings : 5740/ha
- Total number of trees : 10/ha
- Density : High

D) Site No.- 5

- Name of site : Sukhaura river site
- Slope : Plain
- Area : 86.28/ha
- Soil : Black soil
- Type of forest site : Natural
- Species : *Shorea robusta, Terminalia alata, Syzygium cumini, Cieistocalyx operculatus.*
- Useful species : *Shorea robusta, Terminalia tomentosa*.
- Natural regeneration status : Good
- Total number of seedlings : 11093/ha
- Total number of saplings : 8809/ha
- Total number of trees : 21/ha
- Density : Medium

3.2 Site selection and biomass sampling

The field work was carried out during the month of September and October, 2011 and duration of field work was 10 days. The community forest is consists of 7 sites. Sites 1, 2, 3 and 5 were selected for the biomass sampling. Sites 1 and 2 were dominated by *Dalbergia sissoo* and sites 3 and 5 are dominated by *Shorea robusta*. Quadrats of 10 × 10 m were laid randomly at different locations. In each site 8 quadrates were laid. Altogether 32 quadrates were sampled. The forest sites 1and 2 were collectively taken as the *Dalbergia sissoo* dominated sites, similarly site 3 and 5 was collectively taken as *Shorea robusta* dominated sites. So, altogether biomass and soil carbon stock of 16 quadrates of each dominated site were compared. To estimate biomass from selective tree species, it is not advisable to cut them. The biomass was therefore, measured by mathematical models by measuring diameter at breast height (DBH) directly and the girth at DBH. Girth considered is the DBH measured at breast height at approximately 1.37 meter and, diameter of tree having diameter above 10 cm are treated as trees and were measured. The DBH (at 1.37m) of individual trees greater than 10 cm and that of saplings less than 10 cm were measured in each quadrate of area 100 m^2 using DBH tape. The clinometer was used to measure the angle from the eye of the observer to the tip of the tree. Each tree was marked to prevent accidentally counting it twice. Each tree was recorded individually. Trees on the border were included if more than 50% of their basal area falls within the quadrate. Trees overhanging into the plot were excluded, but trees with their trunks inside the sampling plot and branches outside was included (ANSAB, 2010). The Clinometer determines the angle to the tip of the tree based on a fixed distance to the target tree. (Hairiah *et al*., 2001). The tree height was calculated by measuring distance from tree to the observer and angles from the eye of the observer to the base and to the top of the tree (Figure 4) (Zobel *et al*., 1987).

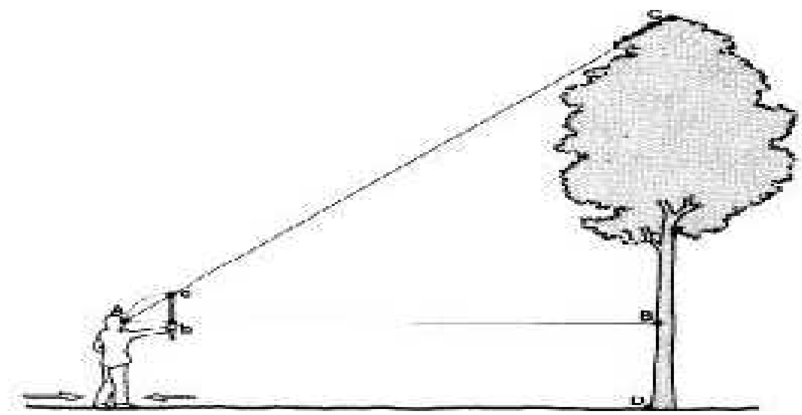

Figure 4: Measurement of angle by using clinometer.

For estimation of tree height following relation was used:

$h_1 = b\tan\theta$

$H = h_1 + h_2$

Where, H= Total height of the tree in meter

θ = angle of elevation to the top of the tree from observers eyes. (∠BAC)

b = distance between the tree base and the observer in meter.

h_1=height above eye of observer in meter (BC).

h_2=eye height of observer in meter (BD).

3.2.1 Estimation of Basal Area

Tree trunk size is often expressed as area of cross section at breast height and is called basal area (BA). It is expressed in square meters. BA can be calculated by the following formula:

$$\text{Basal area (BA)} = \frac{\pi(dbh)}{4}$$ (Zobel *et al.*, 1987)

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

3.2.2 Estimation of tree trunk volume (TTV)

The tree trunk volume of a tree may be used as an index of its biomass or of its worth as a commercial product (timber, firewood). The tree trunk volume can be estimated using the formula as follows:

$$\text{Tree trunk volume (TTV)} = \frac{BA \times H}{2} \qquad \text{(Zobel } et\ al.\text{, 1987)}$$

Where, TTV = Tree trunk Volume in cubic meter

BA= Basal Area in square meter

H = Height of tree in meter

$$\text{Average tree trunk volume} = \frac{\text{Sum of TTV} \times 100 \times 100}{\text{Size of quadrate}}$$

Sum of TTV of all the individual trees in the population is given as Mg/ha.

3.2.3 Estimation of biomass

The mathematical equation has been developed and used by many researchers for biomass estimation of trees (Brown *et al*., 1989; Negi *et al*., 1988) cited in Chavan *et al*. (2010). For the estimation of biomass of trees and saplings of the studied forest sites in the present study, different allometric equations were followed recommended by different researcher. The equations which are used in this study are:

$$AGTB = 0.0509 \times p(dbh)^2H \qquad \text{(Chave } et\ al.\text{, 2005)}$$

$$AGSG = a(dbh)^b \qquad \text{(Zianis, 2008)}$$

3.2.3.1 Above ground tree biomass (AGTB)

Above ground biomass of trees were estimated by using different relation and allometric models. Above ground biomass of trees with dbh ≥ 10cm was estimated by using allometric models developed by Chave *et al*., (2005). The following model was used as the forest is moist tropical forest having annual rainfall 1658.68 mm.

The allometric equation for above ground biomass is as follows:

$$AGTB = 0.0509 \times p(dbh)^2H \qquad \text{(Chave et al., 2005)}$$

AGTB = Above ground tree biomass (kg).

p = Wood specific gravity (gm/cm^3).

dbh = tree diameter at breast height (cm).

H = tree height (m).

3.2.3.2 Above-ground sapling biomass (AGSB)

Above ground biomass of saplings with dbh<10cm, height>137cm were estimated using global equation of Zianis (2008) cited in Ranjitkar (2010). The equation is as follows:

$$AGSG= a(dbh)^b \qquad \text{(Zianis, 2008)}$$

Where, AGSB = Above ground sapling biomass (kg).

a = 0.1424 and b = 2.3679

After taking the sum of all the individual weights (in kg) of a sampling plot and dividing it by the area of sampling plot (100 m^2), the biomass stock density was attained in kg/m^2. This value can be converted to Mg/ha by multiplying it by 10. Since the sites are part of tropical region, the biomass stock densities are converted to carbon stock densities after multiplication with the IPCC (2006) default carbon fraction of 0.47 (ANSAB, 2010).

3.2.3.3 Below-ground biomass

The below ground root biomass is 1/5 of above ground biomass and was calculated by multiplying the above ground biomass by 0.25 or 1/5 (ANSAB, 2010). The root-to-shoot ratio of 1:5 is used to estimate below ground biomass The biomass stock densities are converted to carbon stock densities after multiplication with the IPCC (2006) default carbon fraction of 0.47 (ANSAB, 2010).

Below-ground biomass (Mg/ha) = 0.25 x Above ground biomass (Mg/ha)

3.2.4 Total biomass carbon stock

The total biomass carbon stock was obtained by combining above ground biomass (trees and saplings) and below ground biomass (trees and saplings).

Total biomass carbon stock =   above ground biomass + below ground biomass

3.3 Soil Sampling

Soil sampling was carried out during the month of September and October, 2011 from the same quadrat of biomass sampling. Materials such as metal digger and metal core were used for the soil collection. Soil samples were collected from forest sites (1, 2, 3 and 5) dominated by *Dalbergia sissoo* and *Shorea robusta* tree species during the same day of biomass sampling. Soil samples were collected in each quadrat layout in four sites. For the soil sampling litter from the upper soil surface was totally remove and metal core of 10cm was inserted into the soil surface. Then, the soil was emptied into the zipper bag. Similarly, same metal core was inserted into the subsurface and soil was taken into the another zipper bag. In this way, soil samples were collected from the surface (0–10 cm) and subsurface (10–20 cm) soil layers of four sites randomly. Altogether 64 soil samples were collected. The soil samples were air dried for one week in shade and stored in air tight zipper bags until laboratory analysis.

3.4 Soil analysis

The soil analysis was carried out during the month of November and December, 2011 and duration of lab work was 8 days. Samples of soil were brought from the field for further analysis. These Soil samples were analyzed at the Ecology laboratory in the Central Department of

Botany, Tribhuvan University. Soil Organic Carbon (SOC) and Bulk Density were estimated in the soil samples using methods described by Gupta (2000) and Zobel *et al*. (1997).

3.4.1 Soil bulk density

Metal Core soil sampler of 3 cm in diameter and 10 cm long was used for collecting the soil from the 20cm depth layer. For the estimation of BD, the soil was oven dried at 70°C for 24 hr, crushed into fine particles with the help of mortar and pestle, it was sieved properly through fine sieve (0.5mm) and then fine soil was weighed in the electric weighing machine. Finally, bulk density was estimated by using the equation as follows:

$$\text{Bulk Density (BD)} = \frac{\text{Mass of soil (gm)}}{\text{Volume of soil (cm}^3\text{)}}$$

3.4.2 Soil Organic Carbon (SOC)

Soil organic carbon for the samples collected from each depths (0-10cm and 10-20cm) was measured individually. Walkey and Black's rapid titration method was used to calculate the soil organic carbon. Firstly, the soil samples was crushed with the help of mortar and pestle and then sieved through fine sieve (0.5mm). After that 0.5gm of soil was taken in 500ml conical flask and 20 ml Conc. H_2SO_4 and 10ml of $K_2Cr_2O_7$ was added in each sample. It was shacked and kept for 30 min to cool down at room temperature. Then, 200 ml of distilled water and 10ml orthophosric acid was added. After that 2-3 drops of diphenylamine indicator was added and shacked. The content was titrated with 0.5 N ferrous ammonium sulphate solution which was run from burette. It was continuously added drop wise till the colour changes from blue-violet to bright green. From the burette, reading was noted to know the volume of ferrous ammonium sulphate consumed during the titration. The soil organic carbon was calculated by using the following relation prescribed in Zobel *et al*., (1987).

$$\text{Amount of carbon present in soil} = \frac{0.003 \times 10(B-C)}{S \times B}$$

$$\text{Organic carbon} = \text{Organic carbon estimated} \times 1.3$$

$$\text{Organic carbon in soil (\%)} = N \frac{(B-C)}{S} \times 0.003 \times 100$$

Where, S = Mass of soil samples

B = Blank reading

C = Titration reading

N = Normality of ferrous ammonium sulphate

3.5 Soil Carbon Stock

For the estimation of soil carbon stock, the relation adopted by Mestagh *et al*. (2005) was used. The relation is as follows:

Soil Carbon Stock (C Mg/ha) $= [\{(\%SOC \times BD_{0\text{-}10} \times 10)\} + \{(\%SOC \times BD_{10\text{-}20} \times 10)\}] \times 100$

Where, %SOC = soil organic carbon expressed as a decimal fraction

BD = bulk density (gm/cm^3)

3.6 Total carbon stock in the selected sites of forest

The total carbon stock of the selected sites of the forest (*Dalbergia sissoo* and *Shorea robusta* dominated sites) was calculated by summing the carbon stock of the individual carbon pools of that stratum using the following relation.

Total carbon stock (C Mg/ha) = Carbon stock in biomass + Carbon stock in soil

3.7 Statistical analysis

For analysis of data, statistical packages SPSS 16.0 (SPSS Inc., 1989-2007)) was used. Parameters like Means, standard error (SE) and standard deviation (SD) of different variables were estimated. Student *t-test* was applied to compare the means of the *Dalbergia sissoo* and *Shorea robusta* dominated forest sites to know significant differences in soil and biomass carbon stocks. Statistical software Microsoft Excel was also used. For the presentation of results by table, graphs and figures SPSS version 16 and Microsoft Excel were used.

Chapter 4

Results

4.1 Basal area

Mean basal area of the selected site of the Community Forest was found 41.22 m^2/ha. The mean basal area of *Dalbergia sissoo* dominated sites and *Shorea robusta* dominated sites were 46.75m^2/ha and 35.68m^2/ha respectively (Figure 5). Maximum and minimum mean basal area was found 138.87m^2/ha and 5.80m^2/ha in *Shorea robusta* dominated site of the forest (Figure 6). The mean basal area of *Dalbergia sissoo* and *Shorea robusta* dominated site are not significantly different (t-test; p= 0.279).

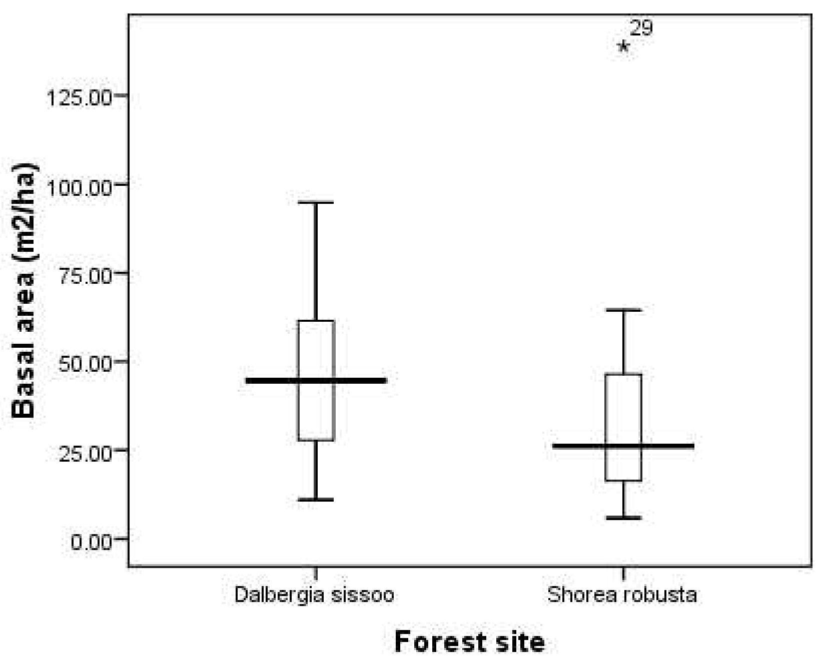

Figure 5: Basal area in *Dalbergia sissoo* and *Shorea robusta* dominated sites in the forest.

4.2 Tree trunk volume

The mean tree trunk volume of the selected sites was found 330.83m^3/ha (ANNEX III). The mean tree trunk volume of *Dalbergia sissoo* and *Shorea robusta* were 389.40m^3/ha and 272.26m^3/ha (Figure 6). Although the *Dalbergia sissoo* has higher tree trunk volume than that of *Shorea robusta*, the tree trunk volume of two species dominated sites are not significantly different (t-test; p= 0.248).

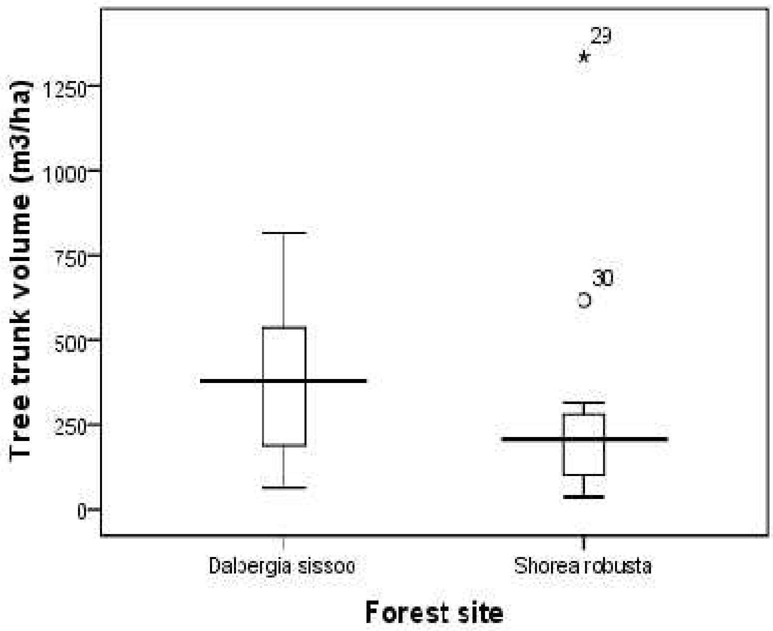

Figure 6: Tree trunk volume in *Dalbergia sissoo* and *Shorea robusta* dominated sites of the forest.

4.3 Biomass

The Mean total biomass (stem and root) was found to be 436.60 Mg/ha in the selected sites (ANNEX III). The mean above ground (stem) and below ground biomass (root) of the selected sites were found to be 363.65 Mg/ha and 72.64 Mg/ha respectively (ANNEX III). The mean total biomass of *Dalbergia sissoo* and *Shorea robusta* were 471.60 Mg/ha and 401.60 Mg/ha (Figure 7). The mean biomass of the *Dalbergia sissoo* and *Shorea robusta* dominated site were not significantly different. (t-test; p=0.180).

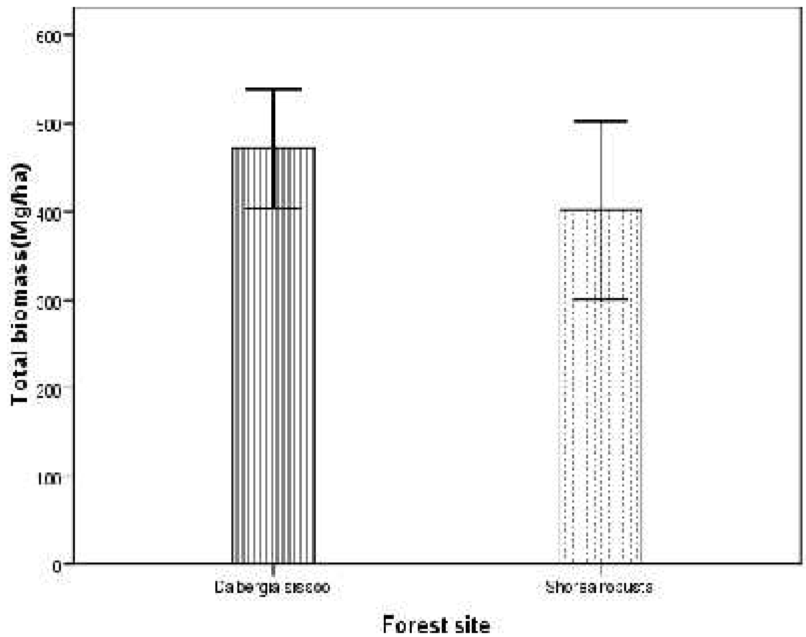

Figure 7: Total biomass (Mean ± S.E) in the *Dalbergia sissoo* and *Shorea robusta* dominated sites.

Table. 3: Biomass in *Dalbergia sissoo* and *Shorea robusta* dominated sites of the forest (N=16).

	Above ground biomass(Mg/ha)	**Below ground biomass(Mg/ha)**	**Total biomass(Mg/ha)**
Forest site	**Mean ± SE**	**Mean ± SE**	**Mean ± SE**
Dalbergia sissoo	393.00 ± 56.29	78.60 ± 11.26	471.60 ± 67.55
Shorea robusta	334.30 ± 83.87	66.67 ± 16.81	401.60 ± 1.01

4.4 Biomass carbon stock

The mean biomass carbon stock of selected sites was found 205.12 Mg/ha (ANNEX III). The mean biomass carbon stock of the *Dalbergia sissoo* and *Shorea robusta* dominated sites of forest were 221.70 Mg/ha and 188.55 Mg/ha respectively (Figure 8).The above ground biomass carbon stock was higher than those of below ground biomass carbon stock (t-test; p=0.179).

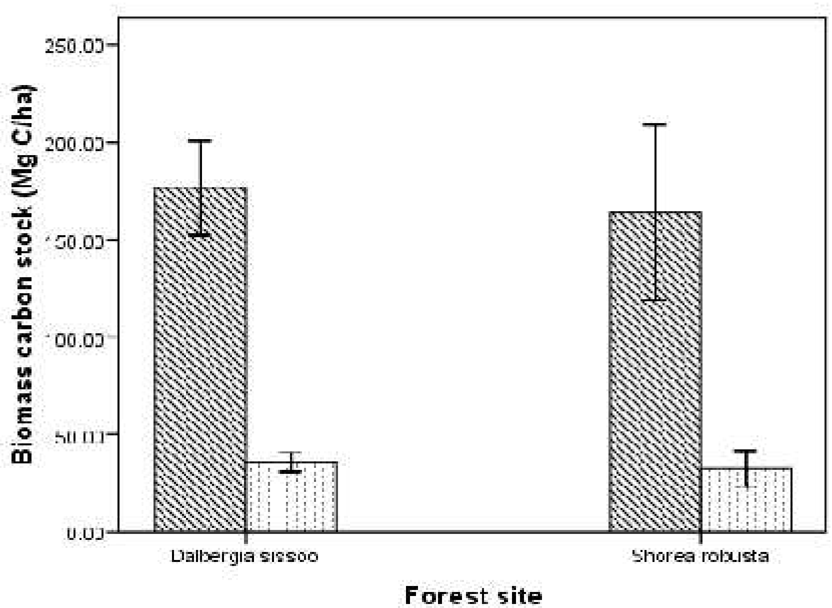

Figure 8: Mean total biomass carbon stock (Mean ± SE) in *Dalbergia sissoo* and *Shorea robusta* dominated sites of forest.

4.5 Soil bulk density

The mean bulk density of the selected sites was found to be 0.93 gm/cm^3 (ANNEX III). The mean soil bulk density at depth 0-10cm and 10-20cm were 0.95gm/cm^3 and 0.96gm/cm^3 in *Dalbergia sissoo* dominated sites and 0.92gm/cm^3 and 0.93gm/cm^3 in *Shorea robusta* dominated sites respectively (ANNEX II, Table 3). The mean bulk density at depth 0-10cm and 10-20cm were 0.935 gm/cm^3 and 0.944 gm/cm^3. The mean bulk density of both the depth were not significantly different (t-test; p=0.831).

Table. 3: Soil bulk density at different depths (cm) in *Dalbergia sissoo* and *Shorea robusta* dominated sites of the forest (N=16).

Forest site	**Depth**	**Min**	**Max**	**Mean ± SE**
Dalbergia sissoo	0-10 10-20	0.55 0.61	1.79 1.28	0.95 ± 0.069 0.96 ± 0.041
Shorea robusta	0-10 10-20	0.76 0.80	1.05 1.01	0.92 ± 0.164 0.93 ± 0.179

4.6 Soil carbon stock

The total mean soil carbon stock in the forest was 66.21 C Mg/ha (ANNEX III). The mean soil carbon stock in *Shorea robusta* dominated sites and *Dalbergia sissoo* dominated site were 81.40 C Mg/ha and 51.00 Mg/ha respectively (Figure 9). The mean soil carbon stock of *Dalbergia sissoo* and *Shorea robusta* sites were significantly different (p= 0.022).

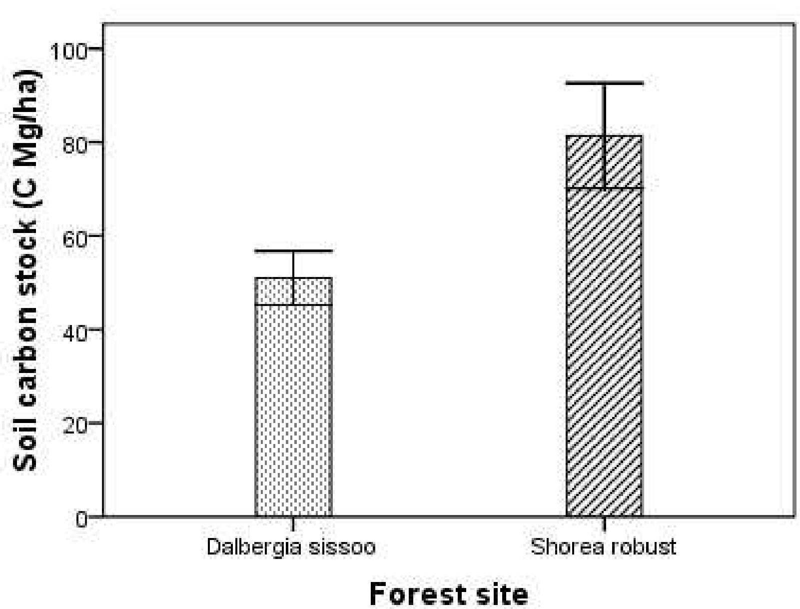

Figure 9: The soil carbon stock (Mean ± SE) in *Dalbergia sissoo* and *Shorea robusta* dominated site of the forest.

4.7 Total carbon stock in the selected sites of the forest

The Mean total carbon stock of the selected sites of forest was 271.33 C Mg/ha (ANNEX III). The mean total carbon stock of *Dalbergia sissoo* and *Shorea robusta* sites were 272.71 C Mg/ha and 269.95 C Mg/ha respectively (ANNEX III). The above ground parts (stem) store high amount of carbon than the below ground parts (root) and the soil (Figure 10). The biomass carbon stock was three times the soil carbon stock. In the *Dalbergia sissoo* sites, the biomass carbon stock was 4 times greater than the soil carbon stock but, in *Shorea robusta* sites biomass carbon stock was 5 times greater than the soil carbon stock. There was no significant difference ($p = 0.42$) in the mean total carbon stocks of *Dalbergia sissoo* and *Shorea robusta* forests.

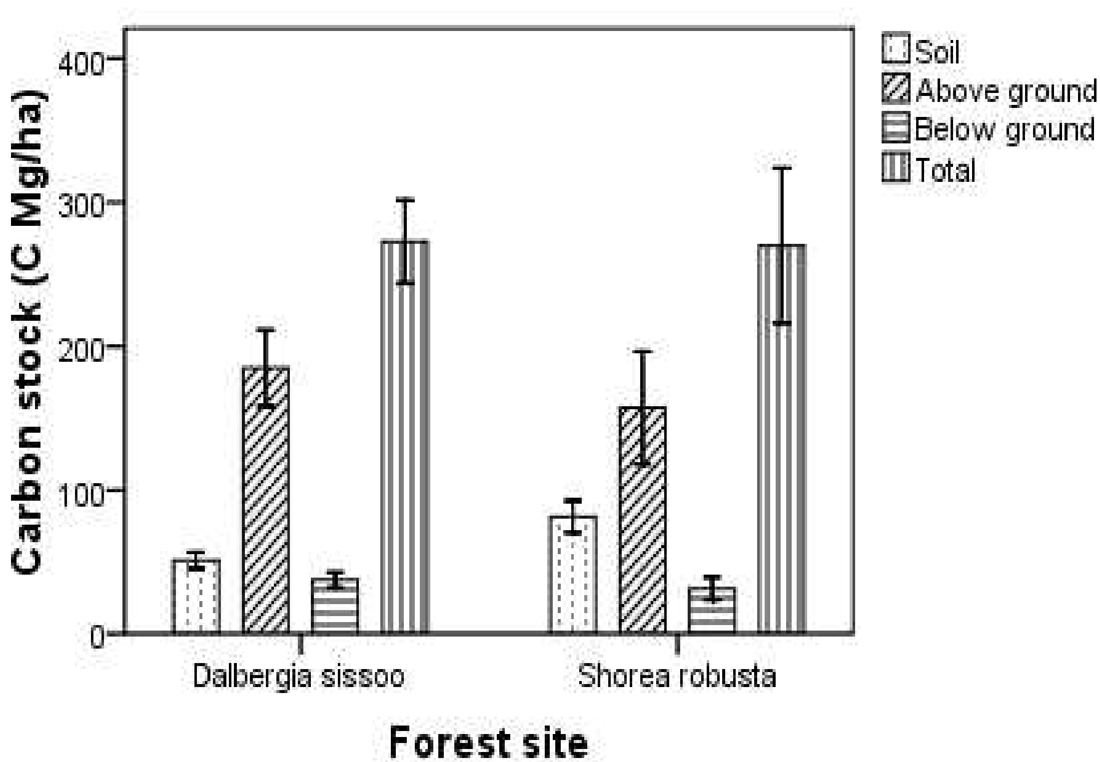

Figure 10: Carbon stock in different parts as above ground, root and soil of *Dalbergia sissoo* and *Shorea robusta* dominated sites of the forest.

Chapter 5

Discussion

5.1 Community forest management

The Karahiya Community forest was established in 1989. Since then the forest is running smoothly without the funding of government and non-government organizations. Selling of firewood is the main source of income. Some of the specific objectives set by the community forest include, provision of training facilities such as carpentering, tailoring, bee keeping etc, to improve the skill and technical knowledge of poor people. The forest provides local people with certain forest resources such as firewood, timber, fodder grasses, grazing for the cattle and 15cubic feet of timber at 50% discount to the poor categories. Basically, community forest management involves three main aspects: forest protection, production and distribution of products, all of which include the participation of users. As the FUG (Forest User Group) is the manager of community forest, members of the FUG decide the operations to be carried out in order to meet the objectives. Criteria of sustainable forest management as followed by the forest management group include, extraction of forest products, such as firewood, timber and fodder grasses in a sustainable manner, yearly afforestation program to increase the plant species richness and to maintain the availability of forest resources in future too.

5.2 Basal Area.

The estimated total mean basal area of the sampled forest sites was two times higher than the Mexican tropical dry forest (Jaramilo *et al*., 2003) and also two times higher than the moist tropical forest in Barro colorado Island, Panama by Chave, 2003. This low value in studied sites might be due to the lower amount of precipitation, sample size, succession stage of the stand, species composition and age of the area. On the basis of the present study, the mean basal area of the *Dalbergia sissoo* dominated sites was slightly higher than the basal area of *Shorea robusta* dominated sites. The high value in the *Dalbergia sissoo* sites was due to the higher number of mature trees than the seedlings and saplings but in the *Shorea robusta* dominated sites, there was large number of saplings and seedlings.

5.3 Tree Trunk Volume

In the present, work the tree trunk volume of *Dalbergia sissoo* was higher as compared to *Shorea robusta*. This might be due to the sampling of only trees and saplings in this research work and there were higher number of trees and saplings in *Dalbergia sissoo* dominated sites than the *Shorea robusta* dominated sites.

5.4 Biomass

Because the world's forests play a major role in regulating nutrient and carbon cycles, there is much interest in estimating their biomass (Cairns *et al*., 1997). The total mean biomass of *Shorea robusta* of studied sites of the forest was two times higher than the *Shorea robusta* in the tropical forest of far western, Nepal (Gautam *et al*., 2009); *Albezzia lebbek* and *Magnifera indica* in the tropical forest of Aurangabad, India (Chavan and Rasal, 2012). The high value of the studied species in the studied sites might be due to the large dbh and height of this species. The resulted total mean biomass of the sampled forest sites of study area was four times higher than the secondary tropical forest estimated by Brown and Lugo, 1990 and two times higher than the tropical moist forest of Brazilian Amazon assessed by Brown *et al*., 1992. The biomass (Mg/ha) increase with increasing basal area (m^2/ha) and in the *Dalbergia sissoo*, it was slightly higher than the *Shorea robusta*. This might be attributed to the matures trees with large DBH classes in the *Dalbergia sissoo* sites.

5.4.1 Above ground biomass

The above ground biomass estimated in studied forest sites was comparatively lower than in the semi-evergreen tropical flood plain forests (Jaramilo *et al*., 2003). But, the above ground biomass was two times lower than the tropical moist managed forest in Eastern Panama (Kirby and Potvin, 2007). This high value in the Eastern Panama might be due to sampling of only those trees having dbh ≥ 10cm and Palms as well. The value is two times lower than in mature dipterocarp tropical forests of Phillipines (Rasco *et al*., 2006). The low above ground biomass in the studied forest sites might be due to sampling of only trees, sapling but lianas, seedlings, herbs, was not sampled. The estimated value of the forest sites was two times higher than that in the tropical rain forests of Uttara Kannada District, Western Ghats, India (Bhat and Ravindranath, 2011); This might be due to the variation in soil types, soil nutrients, successional status and disturbance regime; two times higher than in moist tropical forest on Barro Colorado Island, Panama (Chave, 2003). This low value in Panama might be due to the sampling of tree having dbh ≥ 1cm. The recorded value was also two times higher than in natural tropical forest of Northern Borneo (Berry *et.al*., 2010). This low value in Northern Boreneo might be due to sampling of only those trees having dbh≥ 5cm. The recorded value of studied sites was two times less than in tropical riverine forest of Chitwan as recorded by Baral *et al*., 2009; and three times higher than in dry tropical forest as estimated by Jaramilo *et al*., 2003.

Overall, mean above ground biomass for the *Dalbergia sissoo* was greater than the *Shorea robusta* . The above ground biomass of *Dalbergia sissoo* of present study was many times higher than the *Dalbergia sissoo* of the tropical forest of Banthra village, lukhnow, India (Goel and Singh, 2008). The low value in this village might due to sampling of trees having dbh 2.5-12.1cm. The recorded above ground biomass of *Shorea robusta* was comparatively similar to the *Shorea robusta* plantation and natural forest in the humid tropics in north east India (Baishya *et al*., 2009) but much higher than that record in *Shorea robusta* closed forest of Satpura plateu in Madhya Pradesh, India (Pande and Patra, 2010) and four times than *Shorea robusta* in tropical forest of far western forest, Nepal recorded by Gautam *et al*., 2009. The high value of the *Shorea robusta* of the studied sites might be due to the trees with large dbh and height.

The estimated above ground biomass of both tree species of the studied sites of the forest was five times higher than the other tropical species such as *Albizzia lebbek* and *Magnifera india* reported by Chavan and Rasal, 2012 in the forest of Aurangabad, India, but less than the *Eucalyptus* sp. (Chavan and Rasal, 2011). The low value in studied sites might be due to the sampling of smaller area than the other studies. The high value of the studied species might be due to the more height and occurrence of large number of trees in the sampled plot.

5.4.2 Below ground biomass

Trees allocate a large portion of gross primary production in belowground for the production and maintenance of roots and mycorrizae (Giardina and Ryan, 2002). The mean below ground biomass estimated in studied sites was two times higher to that reported in the Mexican tropical floodplain forest by Jaramilo *et al*., 2003. But, four and five times greater than in the tropical dry forest and moist tropical forest in west central costa Rica (Vance and Nadkarni, 1992). The higher value in the studied sites might be due to the trees with large dbh. But, two times less than the tropical moist managed forest in Eastern Panama (Kirby, and Potvin., 2007). This high value in the Eastern Panama might be due to sampling of only those trees having dbh ≥ 10cm and Palms as well.

Similarly, the mean below ground biomass was higher in the *Dalbergia sissoo* sites than the *Shorea robusta* sites. The recorded below ground biomass of both the species of studied area was higher than the *Shorea robusta* closed forest of Satpura plateau M.P, India (Pande and Patra, 2010) and four times higher than the tropical species *Magnifera indica* and *Albezzia lebbek* dominated forest of Aurangabad city, India (Chavan and Rasal, 2012) but two times lower than the *Eucalyptus* sp. (Chavan and Rasal, 2011). The low value in present study might be due to the sampling of smaller area than other forest of other area. The high value of the studied species might be due to the more height and occurrence of large number of trees in the sampled plot.

5.5 Biomass carbon stock.

5.5.1 Above ground biomass carbon stock

The mean above ground biomass carbon stock of the studied forest sites of the study area was two times higher than in tropical riverine forest of Kumrose CF in Chitwan (Baral *et a*l., 2009); in logged tropical forests in northern Boreno (Berry *et al*., 2010). This low value in Northern Boreno might be due to sampling of only those trees having dbh≥ 5cm and less activeness of tree species in carbon sequestration. The record of the studied sites was comparatively similar to the tropical savanna of northern Australia (Chen *et al*., 2003). But the recorded value was less than in managed tropical forest of Australia (Roxburgh *et al*., 2006). This high value in the tropical forest of Australia due to the sampling of trees and litter and less than the tropical moist managed forest in Eastern Panama (Kirby and Potvin, 2007). This high value in the Eastern Panama might be due to sampling of only those trees having dbh ≥ 10cm and Palms as well.

The mean above ground biomass carbon stock of *Dalbergia sissoo* was greater than that of *Shorea robusta*. This might be due to the high number of mature trees and saplings with large diameter in *Dalbergia sissoo* dominated sites. The above ground biomass carbon stock of both species of the studied sites was four times higher than that of *Magnifera indica* in the forest of Aurangabad city, India (Chavan and Rasal, 2012) but two times lower than the *Eucalyptus* sp. as estimated by Chavan and Rasal, 2011). The value of studied species might be due to the sampling them from the smaller area. The high value of the studied species might be due to the more height and occurrence of large number of trees in the sampled plot. The biomass carbon stock of the *Shorea robusta* of the studied sites was many times higher than the *Shorea robusta* of tropical forest of Paschim Medinipur, India as recorded by Jana *et al*., 2009. The low value of this district forest species might be due to the sampling of the only young *Shorea robusta* trees.

5.5.2 Below ground biomass carbon stock

The mean below ground biomass carbon stock of the studied forest sites of the study area was higher than the result by Chen *et al*., 2003 in tropical Savana of northern Australia, but two times higher than in the Tropical forest of Hawaii (Giardina and Ryon, 2002). The high value in the studied sites might be due to the higher number of mature trees with large dbh and dense forest. But, three times lower than the tropical moist managed forest in Eastern Panama (Kirby and Potvin, 2007). This high value in the Eastern Panama might be due to sampling of only those trees having dbh ≥ 10cm and Palms as well.

The mean below ground carbon stock of the *Dalbergia sissoo* was higher than that in *Shorea robusta*. The below ground carbon stock of the both the species was three times higher than that of *Magnifera indica* (Chavan and Rasal, 2012) and two times lower than that of *Eucalyptus* sp. (Chavan and Rasal, 2011). The low value of studied species might be due to the sampling them from the smaller area. The high value of the studied species might be due to the more height and occurrence of large number of trees in the sampled plot.

5.5.3 Total biomass carbon stock

The mean biomass carbon stock in the selected sites of the forest was double than the tropical forest in Eastern Ghats of Tamilnadu, India (Ramachandra et al. 2007) in *Shorea robusta* and four times than the tropical Savana of northern Australia as recorded by Chen *et al*., 2003. This low value in the savana might be due to occurrence of less number of trees than the shrubs and grasses. The mean biomass carbon stock of the *Dalbergia sissoo* was higher than the *Shorea robusta* in the present study. The biomass carbon stock of the *Shorea robusta* was higher than the mature *Shorea robusta* trees (Kaul *et al.*, 2010). The carbon stock of both the species was six to seven times higher than other species such as *Albezzia lebbek* and *Magnifera indica* (Chavan and Rasal, 2012). The high value of the studied species might be due to the more height and occurrence of large number of trees in the sampled plot

5.5.4 Soil bulk density

Variation in the bulk density is attributable to the relative proportion and specific gravity of solid organic and inorganic particles and to the porosity of the soil (Nizami, 2010). Bulk density normally decreases as mineral soils become finer in texture. Generally in normal soils bulk density ranges from 1-1.65 gm/cm^2. In very compact soil, sometimes, it goes up to 2.0 gm/cm^3 (Gupta, 2000). The mean bulk density of the studied sites of the forest was 0.939 gm/cm^3. The present study reveals that the bulk density does not differ significantly according to depth. Bulk densities under the both trees were similar. The mean bulk density in the *Dalbergia sissoo* dominated sites was greater than that of *Shorea robusta* dominated sites. The lower value in the *Shorea robusta* dominated sites is due to the high amount of litter fall and dense forest.

5.5.5 Soil carbon stock

Restoration of soil quality through soil organic carbon (SOC) management has remained the major concern for tropical soils. The contributions of SOC on physical, chemical and biological properties of soils in sustaining their productivity are well established. To sustain the quality and productivity of soils, a knowledge of SOC in terms of its amount and quality is essential (Bhattacharya *et al*., 2000). Soil is the largest pool of terrestrial organic carbon in the biosphere, storing more C than is contained in plants and the atmosphere combined (Schlesinger, 1997 cited in Jobba and Jackson, 2000). It is the fundamental building block of soil organic matter. Therefore, accurate quantification of soil carbon is necessary for detection and prediction of changes in response to changing global climates (Chen *et al*., 2003).

The study determined that the mean soil carbon stock in the studied sites of the forest was two times lower than that in *Shorea robusta* forest in Broad leaved forests of Mid hills of Nepal, (Shrestha, 2009) ; in tropical deciduous and evergreen forest as estimated by Ramachandra *et a*l., 2007 in the Kolli hills in Eastern Ghats of Tamilnadu, India; three times lower than the tropical savanna of northern Australia (Chen *et al*., 2003). This high value in the savanna might be due to the sampling of soil up to the depth of 0-1m. The recorded value was also two times lower than the tropical forests of Asia estimated by Brown *et al*., 1993. The low range of soil carbon stock in the study area might be due to the fast decomposition of organic matter and soil was sampled from the depth up to 0-20cm only. The result was two times higher than that under the plantation of *Eucalyptus sp*, *Pinus roxburgii*, and *Dalbergia sissoo* in Uttarakhand State of India (Gupta and Sharma, 2012). But, higher than the tropical moist managed forest in Eastern Panama (Kirby and Potvin, 2007). This might be due to the slow decomposition of the litter in studied sites.

The current study showed that the soil carbon stock under the *Shorea robusta* forest sites was significantly higher than the *Dalbergia sissoo* forest sites. This is because of high amount of litter and slow decomposition under the *Shorea robusta* sites and these sites were denser with high percentage of growing seedlings.

5.5.6 Total carbon stock in the selected sites of forest

Both vegetation and soil carbon contribute to the total carbon stock in the forest ecosystem (Nizami, 2010). The total carbon stock in the studied sites was close to the estimation in the tropical forest of the world by Malhi (1998), Press *et al*., (2000); in tropical forests of Asia (Brown *et al*., 1993). The present result was three times higher than the result reported by Baral (2009) in Terai forest but three times lower than the result in Nyungue montane tropical forest in Rwanda (Nasabimana, 2009).

Chapter 6

Conclusion

Community forest helps into offset a portion of the carbon emission, thereby contributing to climate change amelioration through the sequestration of atmospheric carbon to vegetation and soil and by acting as a natural carbon sink. Better management of forest with less anthropogenic activities and afforestation strategies enhance the carbon sequestration. Plantation is a very important land use not only to increase soil carbon store, but also as a good tool for increasing carbon sink. Plantations are good sink of carbon to facilitate carbon store in the soil as well as in biomass, therefore, increase in the carbon as CO_2 in the atmosphere can be stabilized. Thus, plantation done in large scale can be a way of climate change mitigation. To fight against global warming, the community forests must be encouraged. From the present study it is evident that the selected forest sites were well managed by forest user groups and had most of the matured trees.

In this study, the amount of total carbon stock in both the forest sites was similar. So, the present study reveals that the carbon sequestration potential of both sites was high. Total biomass carbon stock of *Dalbergia sissoo* and *Shorea robusta* was 221.70 C Mg/ha and 188.55 C Mg/ha respectively which was not significantly different. But, soil carbon stock in both the sites was significantly different with 51.00 C Mg/ha under *Dalbergia sissoo* and 81.40 C Mg/ha under *Shorea robusta* respectively. The present study indicates that the SOC content was lower than the above-ground biomass carbon stock .

Recommendation

- Necessity of proper management of community forest by different community user group at the regional and national level.
- Afforestation strategies should be followed in Tarai region to enhance the carbon sequestration by the plant biomass and the soil.
- Increasing the carbon stock of the forest should be done by planting species with high potential for carbon accumulation.
- Sustainable utilization of forest resources such as timber, firewood, fodder should be ensured to fulfill the requirement of the local people and to maintain the forest for future generation.
- Public awareness programmes should be conducted to make them aware of the climate change and significant role played by the forest.
- Carbon financing should be encouraged in order to help severe poor people in conserving their forest.

The research recommends the significance of community forests in both Terai and elswhere, and advocates that if we want to fight against global warming, we must encourage the community forests and that the people living in severe poverty in these forest areas who become the unsung heroes in the war against global warming, must be paid in lieu of saving their forests, which ultimately become the sink for increased CO_2 worldwide. This business or ‘carbon trading’ will indeed evolve as the panacea against the war against global warming.

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ANNEXES

ANNEX I

Biomass and carbon stocks in sampled quadrats.

Q. No.	B.A (m^2/ha)	TTV (m^3/ha)	AGB (Mg/ha)	AGB carbon (C Mg/ha)	BGB (Mg/ha)	BGB Carbon (C Mg/ha)	Total biomass (Mg/ha)	Carbon stock in biomass (C Mg/ha)	Soil Carbon stock (C Mg/ha)	Total Carbon stock (C Mg/ha)
1	71.1	744.86	753.44	354.12	150.69	70.82	904.13	424.94	33.318	458.258
2	78.89	815.5	824.89	387.69	164.98	77.54	989.87	465.24	11.637	476.877
3	21.82	149.65	147.3	69.23	29.46	13.84	176.77	83.08	49.16	132.24
4	23.42	147.22	146.1	68.67	29.22	13.73	175.33	82.41	31.848	114.258
5	59.54	471.22	474.89	223.19	94.97	44.69	569.86	267.84	25.517	293.357
6	24.66	205.65	207.69	97.62	41.54	19.52	249.23	117.14	39.636	156.776
7	44.22	368.11	372.34	175	74.47	35	446.81	210	51.7671	261.7671
8	33.81	346.34	350.33	164.66	70.07	32.93	420.39	197.59	63.0705	260.6605
9	63.51	594.55	595.13	279.71	119.03	55.94	714.15	335.65	17.874	353.524
10	38.95	265.75	268.81	126.34	53.76	25.27	322.57	151.61	65.052	216.662
11	57.88	478.22	483.73	227.35	96.75	45.47	580.47	272.82	61.49	334.31
12	48.71	389.26	393.75	185.06	78.75	37.01	472.5	222.82	57.582	280.402
13	44.9	390.03	394.52	185.42	78.9	37.08	473.42	222.5	75.621	298.121
14	30.81	172.7	174.68	82.1	34.94	16.42	209.62	98.52	86.321	184.841
15	10.91	63.36	64.08	30.12	12.82	16.02	76.9	36.14	90.567	126.707
16	94.84	628.04	636.29	299.06	127.26	59.81	763.55	358.87	55.688	414.558
17	18.39	141.41	158.14	74.33	31.63	14.87	189.77	89.19	26.16	115.35
18	26.42	281.18	312.69	146.96	62.54	29.39	375.23	176.36	43.01	219.37
19	31.04	221.46	251.56	118.23	50.31	23.65	301.87	141.88	27.432	169.312
20	8.14	37.06	55.22	25.95	11.04	5.19	66.26	31.14	55.7	86.84
21	25.77	202.24	230.6	108.38	46.12	21.68	276.72	130.06	15.881	145.941
22	5.8	53.1	52.46	24.66	10.49	4.93	69.95	29.59	59.713	89.303
23	18.24	150.47	168.89	79.38	33.78	15.88	202.67	95.25	65.563	160.813
24	59.62	260.25	136.25	64.04	24.25	12.8	163.49	76.84	62.478	139.318
25	11.26	47.3	54.25	25.5	10.85	5.1	65.1	30.6	63.128	93.728
26	14.27	85	115.69	54.37	23.14	10.87	138.82	65.25	137.138	202.388
27	21.06	117.59	132.9	62.47	26.58	12.49	159.49	74.96	122.592	197.552
28	64.43	277.78	701.07	329.5	140.21	65.9	841.28	395.4	144.619	540.019
29	138.87	1336.4	1155.2	542.96	231.04	108.59	1386.27	651.55	136.703	788.253
30	57.57	617.48	704.67	331.19	140.93	66.24	845.6	397.43	140.441	537.871
31	34.87	212.68	242.25	113.86	48.45	22.77	290.7	136.63	113.606	250.236
32	35.22	314.84	877	412.19	175.4	82.44	1052.4	494.63	88.267	582.897

A

SOC% and bulk density in the sampled

	SOC %			Bulk density (gm/cm^3)		
	Horizon		Mean	Horizon		Mean
Q.No.	0-10	10-20		0-10	10-20	
1	2.10	3.30	2.70	0.627	0.607	0.617
2	1.20	0.60	0.90	0.546	0.747	0.647
3	2.10	1.80	1.95	1.244	1.277	1.261
4	1.50	1.68	1.59	0.899	1.104	1.002
5	1.02	0.90	0.96	1.794	0.864	1.329
6	2.28	2.04	2.16	0.902	0.933	0.918
7	2.40	2.58	2.49	0.869	1.210	1.039
8	2.70	3.00	2.85	1.075	1.138	1.107
9	0.30	1.50	0.90	0.993	0.993	0.993
10	3.90	3.30	3.60	0.899	0.908	0.904
11	4.50	2.58	3.54	0.865	0.872	0.869
12	2.94	3.36	3.15	0.901	0.927	0.914
13	4.08	3.72	3.90	0.967	0.972	0.969
14	4.44	4.68	4.56	0.960	0.933	0.947
15	5.40	5.04	5.22	0.732	1.003	0.868
16	3.00	2.94	2.97	0.971	0.904	0.938
17	1.20	1.80	1.50	0.888	0.856	0.872
18	2.52	2.16	2.34	0.922	0.916	0.919
19	1.56	1.32	1.44	0.960	0.945	0.953
20	3.00	2.76	2.88	0.948	0.986	0.967
21	1.08	0.96	1.02	0.760	0.797	0.779
22	3.12	3.36	3.24	0.877	0.966	0.922
23	3.48	3.30	3.39	0.938	0.996	0.967
24	3.90	3.12	3.51	0.956	0.824	0.890
25	3.00	3.12	3.06	1.049	1.014	1.032
26	7.62	7.50	7.56	0.893	0.921	0.907
27	6.78	7.08	6.93	0.868	0.901	0.885
28	7.98	7.86	7.92	0.896	0.930	0.913
29	8.34	8.22	8.28	0.845	0.806	0.826
30	7.32	7.44	7.38	0.935	0.968	0.952
31	5.88	5.76	5.82	0.967	0.985	0.976
32	4.80	4.08	4.44	0.979	1.009	0.994

ANNEX III

Mean (±S.D) values of BA, TTV, AGB, BGBC, Total biomass, Biomass and Soil carbon stock, and soil characteristics of total sampled quadrats and species dominated sites.

	All quadrats studied	*Dalbergia sissoo* dominated site	*Shorea robusta* Dominated site
Basal Area (m^2/ha)	41.22 ± 28.49	46.75 ± 23.00	35.68 ± 32.92
Tree trunk volume(m^3/ha)	330.83 ± 276.00	389.40 ± 222.45	272.26 ± 317.23
AGB(Mg/ha)	363.65 ± 282.65	393.00 ± 225.18	334.30 ± 335.49
AGBC(C Mg/ha)	170.92 ± 132.84	184.71 ± 105.84	157.12 ± 157.68
BGB(Mg/ha)	72.64 ± 56.60	78.60 ± 45.04	66.67 ± 67.22
BGBC(C Mg/ha)	34.49 ± 26.28	37.57 ± 20.33	31.42 ± 31.54
Total biomass(Mg/ha)	436.60 ± 338.93	471.60 ± 270.22	401.60 ± 402.21
Biomass carbon stock(C Mg/ha)	205.12 ± 159.42	221.70 ± 127.00	188.55 ± 189.22
Soil carbon stock (C Mg/ha)	66.21 ± 38.38	51.00 ± 23.16	81.40 ± 44.89
Total carbon stock (C Mg/ha)	271.33 ± 170.21	272.71 ± 115.01	269.95 ± 215.97
SOC%	3.57 ± 2.14	2.72 ± 1.28	4.42 ± 2.51
Bulk Density (gm/cm^3)	0.939 ± 0.135	0.957 ± 0.182	0.922 ± 0.064

ANN

Forest types, representative species and w

S.No	Forest types	Representative species	Relative weight	Density (kg/m^3)
1	Sal forest	Shorea robusta	0.90	880
		Terminalia tomentosa	0.02	950
		Adina cordifolia	0.01	670
		Anogeissus latifolia	0.02	900
		Lagestroemia parviflora	0.05	850
2	Khair-sissoo	Acacia catechu	0.50	960
		Dalbergia sissoo	0.50	780
3	Oak forest	Quercus floribunda	0.10	970
		Q.lamellosa	0.10	940
		Q.leucotrichoflora	0.10	1020
		Q.lanata	0.10	880
		Q.semecarpifolia	0.60	860
4	Birch forest	Betula utilis	1.00	700
5	Tarai/Lower slopes mixed hardwood forest	Schima wallichii	0.45	690
		Castanopsis spp.	0.35	740
		Myrica esculanta	0.05	750
		Daphniphyllum himalense	0.05	640
		Eugenia/ Syzygium spp.	0.05	770
		Diospyros spp.	0.02	840
		Shorea robusta	0.03	880
6	Upper slopes mixed hardwood forest	Alnus nepalensis	0.20	390
		Schima wallichi	0.20	690
		Acer spp.	0.20	640
		Litsea spp.	0.20	610
		Rhododendron arboreum	0.20	640
7	Chir pine forest	Pinus roxburghii	1.00	650
8	Blue pine forest	Pinus wallichiana	1.00	480
9	Fir forest	Abies pindraw	0.50	480
		A.spectabilis	0.50	480
10	Mixed and other Conifer forest	Cedrus deodara	0.15	560
		Cupressus torulosa	0.15	600
		Larix griffithiana	0.15	510
		Juniperus indica	0.15	500
		Tsuga dumosa	0.40	450
11	Chir pine-Sal forest	Pinus roxburghii	0.45	650
		Shorea robusta	0.45	880
		Schima wallichi	1.10	690
12	Birch-Fir forest	Betula utilis	0.45	700
		Abies spectabilis	0.45	480
		Schima wallichi	0.10	690
13	Other Mixed Hardwood-Conifer forest	Abies spp.	0.20	480
		Betula utilis	0.10	700
		Castanopsis spp.	0.10	740

Source: HMG/MPFS/FRISDP 1988

ANN

Tree species encountered within quadrats s

S. No.	Plant species
1.	*Shorea robusta* Gaerth
2.	*Dalbergia sissoo* Roxb
3.	*Acacia catechu* Willd
4.	*Cassia fistula* L.
5.	*Bombex ceiba* L.
6.	*Syzygium cumini* L.
7.	*Terminalia tomentosa* Heyne ex Roth
8.	*Adina cordifolia* Hook
9.	*Schleichera oleosa* Lour

A

Number of trees and saplings encountered ts sampled

Sites	Site 1		Site 2		Site 3		Site 5	
Q.No.	**No. of trees**	**No. of saplings**	**No. of trees**	**No. of saplings**	**No. of trees**	**No. of saplings**	**No. of trees**	**No. of saplings**
1.	17	0	13	0	9	2	7	2
2.	14	0	8	0	7	3	5	7
3.	22	0	9	7	11	2	7	7
4.	17	0	10	4	3	11	4	12
5.	15	0	11	2	9	4	3	7
6.	13	0	6	1	3	4	7	1
7.	6	0	10	0	8	5	18	1
8.	10	0	7	3	11	3	6	8
Total	**114**	**0**	**74**	**17**	**61**	**34**	**55**	**45**

PHOTO PLATE

Photo 1 : *Dalbergia sissoo* dominated site.

Photo 2 : *Shorea robusta* dominated site .

Photo 3 : Collection of soil samples.

Photo 4 : Measurement of DBH in sampling site.