CARBON SEQUESTRATION STATUS AT SUNAULO GHYAMPE DANDA COMMUNITY FOREST, KATHMANDU

A dissertation submitted to
The Central Department of Environmental Science
Tribhuvan University, Kirtipur
Katmandu, Nepal

for
the requirement of the partial fulfillment of Master's degree in Environmental Science

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Recommendation

This is to certify that Mr. Pabitra Dahal has prepared this thesis entitled "CARBON SEQUESTRATION STATUS AT SUNAULO GHYAMPE DANDA COMMUNITY FOREST, KATHMANDU" for partial fulfillment of the requirement for the completion of Master's Degree in Environmental Science under my supervision and guidance.

This thesis bears the candidate's own effort and is in the form as required by the Central Department of Environmental Science, Tribhuvan University.

I therefore recommend the thesis for approval and acceptance.

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Abstract

Climate change induced by increased greenhouse gases emission is real and has begun to affect us all. Human activities have increased the concentration of carbon dioxide in the atmosphere from 280 ppm to 372 ppm in less than two centuries and global temperatures by 0.6°C in the past century.

Carbon sequestration is the process where atmospheric carbon is absorbed into carbon sinks such as oceans, forest and soil. Forest land use plays a significant role in stabilizing the accumulation concentration of carbon dioxide in the atmosphere. Terrestrial ecosystem, in which carbon is retained in above ground biomass, under ground biomass in soil which plays an important role in the global carbon cycle.

Kyoto Protocol is the first international treaty negotiated on the principles of equity and sharing the liabilities for improving the global environment community. The community forest has a high potentiality in making income generation from the carbon credit in community forestry system under CDM scheme.

Only very limited research program has been conducted on the carbon sequestration in Nepal. This study was carried out to determine the carbon sequestration and to estimate the monetary value of carbon sequestration. The study was carried out in two different forest types which were Pine Forest and Mixed Broad Leaf Forest of Sunaulo Ghyampe Danda Community Forest. Different measurement of the tree and soil were done. Above ground biomass and under ground biomass were calculated by using the methods of biophysical measurement. The biomass of the tree was calculated using the allometric equation. The total biomass was converted to organic carbon assuming 50% of the dry biomass would be the organic carbon. The soil organic was measured by using the Walkely-Black method.

The biomass organic carbon in Pine Forest was (116 ±16.39) ton/ ha and in Mixed Broad Leaf Forest was (25.95±8.09) ton/ ha and soil organic carbon was (10.12±1.03) ton /ha in Pine Forest and (24.62±1.18)ton/ha in Mixed Broad Leaf Forest. Soil organic carbon of pine forest and mixed broad leaf forest was (10.15±1.03)ton/ha and (24.62±1.18)ton/ha respectively. The above ground biomass organic carbon of Pine Forest and Mixed Broad Leaf Forest was 99.79ton/ ha and 23.54 ton/ ha and below ground biomass organic carbon was 21.79ton/ha and 26.22 ton/ha respectively. The carbon sequestration status as biomass of Pine Forest and Mixed Broad Leaf Forest was 1 ton/ha/yr and 2.95ton/ha/yr respectively. Per annum the additional benefit by carbon sequestration to community forest users groups by carbon trading ranges minimum from $563.15 to maximum based on community forest category. Inadequate information about the status of biomass and carbon stocks in the community managed forest of Nepal after 1990 has been a major problem to estimate total contribution of community forest on sequestrating carbon and claming for the compensation from global climate funds.

Keywords: Climate Change, Carbon Sequestration, Soil Organic Carbon, Biomass organic carbon, Clean Development Mechanism**.**

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ABBREVIATIONS

CBS	:	Central Bureau of Statistics
CDM	:	Clean Development Mechanism
CERs	:	Certified Emission Reductions
CO_2	:	Carbon dioxide
DBH	:	Diameter at Breast Height
DFID	:	Department for International Development, UK
ET	:	Emission Trading
EM	:	Emission Mechanism
F	:	Female
FAO	:	Food and Agricultural Organization
FM	:	Flexible Mechanisms
GHGs	:	Green House Gases
GIS	:	Geographic Information System
GtC	:	Giga Tonnes Carbon
HMG/N	:	His Majesty´s Government of Nepal
ICIMOD	:	International Center for Integrated Mountain Development
IPCC	:	Intergovernmental Panel on Climate Change, UN
JI	:	Joint Implementation
ln	:	Logarithm to base e
LRMP	:	Land Use Resources Mapping Project
M	:	Male
MBLF	:	Mixed Broad Leaf Forest
MoPE	:	Ministry of Population and Environment
NARMSAP	:	Natural Resource Management Sector Assistance Programme
NIR	:	National Inventory Report
NTNC	:	National Trust for Nature Conservation
PF	:	Pine Forest
PgC	:	Pentagram Carbon
ppb	:	parts per billions
ppm	:	parts per millions
SOC	:	Soil Organic Carbon
ton/ha	:	tonnes per hectare
UNEP	:	United Nations Environment Program
UNFCCC	:	United Nation Framework Convention on Climate Change
USEPA	:	United State Environmental Protection Agency
VDC	:	Village Development Committee
WRI	:	World Resources Institute

CHAPTER ONE

INTRODUCTION

1.1 Background

The sun is driving the energy system on the Earth. Part of the energy is radiated back into the space. The Earth has a natural temperature control system. Certain atmospheric gases are critical and known as GHGs (Matthew & Robortson 2001). The gases trap some of the heat causing the surface warmer than it would be. This phenomenon is known as green house effect or global warming (Muller 1998 cited from Gautam 2002). Global warming is amongst the most dreaded problems of the new millennium. Carbon emission is supposedly the strongest causal factor for global warming (Ravindranath et *al*. 1997). The atmospheric concentration of CO_2 has increased rapidly since the beginning of industrialization (Kirschbaum 2003). Burning of fossil fuel such as coal has increased the atmospheric concentration of CO_2 is about 25% from the pre industrial level concentration which continue to increase about 0.4% per year. The latest estimate is that industrial process for emission of about 21.8 billion metric ton of CO_2 annually on about 78% of global is human induced. Emission from the fossil fuel use alone increased 3.6 times since 1950. If this trend persists and the concentrations of GHGs continue to rise, mean global temperature will increases by 0.3ºC per decade (WRI 1994). Since the year 1750; the atmospheric concentration of the CO_2 has increased by 31% due to human activities. The present CO_2 concentration level is the highest in the past 20 millions years (IPCC 2001). The projected concentration CO_2 gas in the year 2100 ranges from 540 to 970 ppm compared to 280ppm in pre-industrial era and about 368 in the year 2000 (IPCC 2001). This emission scenario of CO_2 result is an increase in globally averaged surface temperature 1.4ºC to 5.8ºC over the period 1990 to 2100. This is about two to ten times than the central value of observed warming over the 20th century (IPCC 2001).

1.1.1. Sources of Greenhouse Gases

Certain atmospheric gases are critical to Earths natural control system and are known as GHGs. The naturally occurring GHGs are Water Vapours, CO_2 Gases, Ozone, Methane and Nitrous Oxide; they together create a natural effect. The main sources of gases are fossil fuel combustion, cement production, fertilizer liquid coolants and dielectric fluid. Trees are amongst the most significant elements of any landscape, both due to biomass and diversity. However, it is paradoxical that the vegetation has undergone destruction and degradation in the modern times due to industrial and technological advancement achieved by human society. This advancement has resulted in emission of carbon in the ecosystem (Ravindranath *et al*. 1997). Globally, deforestation, forest degradation, forest fires and burning of fossil fuel are playing a significant role in producing the GHGs (IPCC 2000). Some important sources of green house gases are listed below.

Table 1. Sources of Greenhouse Gases

Greenhouse gases	**Pre. Ind. Conc.(ppb)**	**Conc. In 1994(ppb)**	**Atmospheric life time**	**Anthropogenic sources**
CO_2	278000	358000	Variable	Fossil fuel combustion, Land use conversion, Cements production.
Methane	700	1721	12.2+/- 3	Fossil fuel, Rice paddles waste dumps, livestock
Nitric Oxide	275	311	120	Fertilizer, Industry and Combustion.
ChloroFloro Carbon-12	0	0.503	102	Liquid coolant foams.
HCFC-22	0	0.105	12.1	Liquid coolants
Perfluro Methane	0	0.070	50000	Production of Aluminum
Sulphur	0	0.032	3200	Dielectiic fluid.
WaterVapour.				
Hexe-floride				

Source: Arendal (2001) cited from Gautam (2005)

1.1.1.1. Most and least GHGs Emissions Countries

Elia (2002) listed out the developed and developing countries based on emitting GHGs per person with their value. The developed countries are higher emitter of GHGs per person where developing countries were lower emitter of GHGs per person. Some of the countries are listed below.

Table 2. List of Countries, Emitting the Green House Gases per person with their value

Rank	Territory	Value(*)
1	Qatar	86
6	Australia	27
10	United States	23
197	Nepal	0.11
198	Afghanistan	0.05

(*)Tones of GHGs emitted per person per year in 2002 Source: Elia (2002)

1.1.1.2. Past, Present and Projected CO_2 Emission Scenario

IPCCa (2001) showing and projected CO_2 emission scenario trend of increasing level of CO_2 gas and global mean temperature change (°C). Past, present and projected CO_2 emission scenario is listed below.

Table 3. Past, Present and Projected CO_2 Emission Scenario

Date	1750	2000	2025	2050	2100
Carbon dioxide Concentration(ppm)	280	368	405-460	445-640	540-970
Global mean temp. Change(°C)	-	0.4	0.4-1.1	0.8-2.6	1.4-5.8

Source: IPCCa (2001)

1.1.1.3. Evidence for Global Climate Change*:* Evidence for global climate change is accumulating, and there is a growing consensus that the global temperature is believed to be rising due to human activities that releases CO_2 to the atmosphere (i.e. global warming) (IPCC 2001). The major culprits are thought to be fossil fuel burning, Deforestation, and changes in carbon sequestration caused by land use, such as lack of regeneration after wood harvesting, extended shifting cultivation, drainage, and soil erosion (Lal & Bruce 1999). CO_2 is accumulating in the atmosphere at the rate of about 3.5 Billion metric tones per annum as a result of fossil fuel combustion and tropical deforestation During the period 1850–1998, approximately 405 gigatons (GtC) was emitted as CO_2 into the atmosphere as a result of fossil fuel burning, cement production (67%) and land use change (33%), predominantly from forested areas (IPCC 2000).

Table 4. Evidence for Global Climate Change

Impact area	**Damages included in the study**
Damages included in the study	Expansion of the area amenable to parasitic and vector borne diseases
Agricultural impacts	Changes in area suitable for certain crops and technical changes e.g. irrigation
Water supply impacts	Impacts changes in water resources Sea-level rise losses of land and wetlands; Costs of protection; Migration effects.
Impacts on ecosystems	Valuations based on estimates of species loss
Hazards of extreme weather events	Changes in frequency and severity of cold spells, Heat waves, Drought, Floods, Storms and tropical cyclones

Source: Eyre & Hoekstra (1998)

1.1.2. Carbon Sequestration

Carbon is held in the terrestrial ecosystems as vegetation and in soils. In addition, oceans hold a large volume of carbon so does atmosphere. Carbon sequestration is the process of removing additional carbon from the atmosphere and depositing it in other reservoir principally through changes in land use. The terrestrial carbon sequestration is the net removal of CO_2 from the atmosphere and storing it in terrestrial ecosystem (Sedjo & Marland 2003) .In practical terms carbon sequestration occurs mostly through the expansion of the forests (Houghton 1996). There fore only low cost option of reduction of emitted CO_2 is by increasing forest area and reducing production of CO_2 from different modernized industrialization and development process.

1.1.2.1. Forest and Carbon Sequestration: Forestry is only the major option for carbon sequestration in the terrestrial ecosystem among agricultural systems and agroforestry systems (Kalpan 2003 cited from Singh 2005) has concluded that the total carbon was found highest in the naturally grown forest in the Inner Terai of Nepal, and the result also showed that the land where the stock in highest also had the highest of SOC in comparison to other land uses system.

Plants store carbon for as long as they live, in terms of live biomass. Once they die, the biomass becomes a part of the food chain and eventually enters the soil as soil carbon. Carbon accumulation potential in forests is large enough that forests offer the possibility of sequestering significant amounts of additional carbon in relatively short periods – decades (Luxmoore 2001). The carbon sequestration process involved in individual tree is an important concern in environmental system (Sedjo & Marland 2003). So, the forest expansions and sustainable forests, as mitigation measure, have a significant contribution to the environmental benefit but any shrinkage of forests, as CO_2 emission, has a long term influence and impact. Therefore, the sustainable forest, as a carbon sinks, is the key factor to balance the GHGs emission (Levy *et al*. 2004). The process of carbon sequestration is the most rapid during the early stage of the life of tree while, as tree reaches maturity the above two processes become increasingly similar. Additionally, the rate of carbon sequestration is less particularly in over mature stage of the tree. Hence, the tree or forest expands the capacity of carbon sequestration also increases and vice-versa (Sedjo & Marland 2003).Forest has a prime role in sequestering carbon from the atmosphere. In reality, the forest is a reservoir, a component or components of the climate system where GHGs is stored, as well as sink (Pearce *et al*. 2003). Thus the forest is the complement of carbon sequestration. Conclusively, sustainable forests are reliable sinks of GHGs (Levy *et al*. 2004). Among these, the community forest management which is a successful example of sustainable forest management is the preferable option of carbon sequestration, primarily in developing countries (Klooster & Masera 2000).

1.1.2.2. Soil Carbon Sequestration: The long term conversion of grass land and forest land to cropland and grazing lands has resulted in the historic losses of SOC world wide but there is a major potential for increasing soil carbon through restoration of degraded soils and wide spread adaptation of soil conservation practices. Soil conservation practices not only reduce soil erosion but also increase the SOC content of the soils. Principal conservation strategies which sequester carbon include converting marginal lands to compatible lands use systems, restoring degraded soils and adopting best management practices.

1.1.3 Kyoto Protocol

The Kyoto Protocol is an agreement made under the UNFCCC. The treaty was negotiated in Kyoto, Japan in December 1997, opened for signature on March 16, 1998, and closed on March 15, 1999. The agreement came into force on February 16, 2005. As of December 2006, a total of 169 countries and other governmental entities have ratified the agreement representing over 61.6% of emissions from Annex I countries (UNEP 1997).

The Kyoto Protocol is an agreement under which industrialized countries will reduce their collective emissions of greenhouse gases by 5.2% compared to the base year of 1990. The goal is to lower overall emissions of six greenhouse gases - CO_2 , methane, nitrous oxide, sulfur hexafluoride etc. calculated as an average over the five-year period of 2008-12. National limitations range from 8% reductions for the European Union and some others to 7% for the US, 6% for Japan, 0% for Russia, and permitted increases of 8% for Australia and 10% for Iceland (UNEP 1997).

The objective of the protocol is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (UNFCC 2005).

- At its heart, the Kyoto Protocol establishes the following principles:
- Kyoto is underwritten by governments and is governed by global legislation enacted under the UN’s aegis.
- Governments are separated into two general categories: developed countries, referred to as Annex I countries (who have accepted GHGs emission reduction

obligations and must submit an annual GHGs inventory); and developing countries, referred to as Non-Annex I countries (who have no GHGs emission reduction obligations but may participate in the CDM).

- Any Annex I country that fails to meet its Kyoto obligation will be penalized by having to submit emission allowances in a second commitment period for every ton of GHGs emissions they exceed their cap in the first commitment period (i.e., 2008-2012).
- By 2008-2012, Annex I countries have to reduce their GHGs emissions by a collective average of 5% below their 1990 levels.
- Kyoto includes "FM" which allow Annex(I) economies to meet their GHGs emission limitation by purchasing GHG emission reductions from elsewhere. These can be bought either from the financial exchanges, from projects which reduce emissions in non-Annex(I) economies under the CDM, from other Annex(I) countries under the JI, or from Annex(I) countries with excess allowances.

1.1.3.1. Clean Development Mechanisn: GHGs reduction Project Financed by an Annex(I) country but implemented in a non Annex(I) developing country. Reductions are accredited by an independent third psrty as `CER credits´. To be banked until 2008 when they will count towards reductions under the first commitment period, that is 2008-12. Of these CDM is of intrest to developing countries as the other two are JI and EM between industrilized countries only. The purpose of CDM is to assist parties not included in Annex(I) in achieving sustainable development. The CERs genetated through CDM projects are used by the Annex(I) parties in achieving compliance with their quautified emission limitation and reduction commitments (Abbi *et al*. 2006).

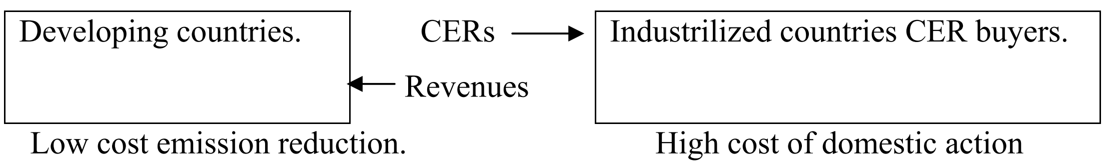

Fig: Schemetic representation of CDM. Source: Abbi *et al*. (2006)

The Kyoto Protocol's CDM registered its 500th project on Monday 12 February 2007. CDM projects are being conducted in more than 40 countries and have so far generated more than 31 million CER units, each equivalent to one tones of CO_2. The mechanism is anticipated as of today to generate more than 1.8 billion CERs in the first commitment period of the Kyoto Protocol to 2012 – equivalent to the combined annual missions of Canada, France, Spain and Switzerland.

1.1.3.2. Nepal Ratified Kyoto Protocol: Experts in Nepal have openly welcomed Nepal's ratification of Kyoto Protocol— an international treaty on climate change and reduction of GHG emission. But, as claimed by the treaty, will Nepal benefit to achieve a sustainable development with an active participation in GHG emission reductions.

Ratification of Kyoto will qualify Nepal to participate in the CDM business. CDM is one of the three Kyoto Mechanisms, allows developed countries to implement projects that reduce emissions in developing countries, in return for CERs. Other two mechanisms are "JI" and "ET" devised exclusively to facilitate emission reduction credits trading between developed countries. Nepal is to receive benefit from the biogas as CDM projects in Nepal (Pokhrel 2005).

1.1.3.3. Important reasons for the inclusion of forest in the Kyoto Protocol include

- Reducing carbon emissions, as it is estimated that 20 of the increases in GHG levels are contributed by deforestation and degradation of forest (Bishop & Landell-mills 2002).
- Being cost effective in comparison with other carbon sequestration method (Kauppi & Sedjo 2001).
- Providing the potential capacity to store large volume of carbon as huge historic losses has occurred from terrestrial ecosystem (Upadhya *et al*. 2005. Kauppi & Sedjo 2001).
- Opening up a 'virtual' marker of carbon as a non timber forest product where previously forest product had no linkages with markets (Skutsch 2004), there by contributing to the development of payments for environmental services.

- Improving soil fertility, ecosystem and biodiversity which in turn lead to other benefits (Janzen 2004).

Source: above all cited from Banskota & Karky (2006)

- Enhancing livelihood options for the poor communities that are dependent on the forest resources.
- Providing an adaptive strategy to cope against adverse effect on climate change.

Source: Banskota & Karky (2006)

1.1.3.4. Community Forest: The community forest management which is an essential part of life of local people in developing countries such as Nepal has a high potential as carbon sink for CDM. In this management system, the local people have been working to transform the unsustainable forests to sustainable ones (Klooster & Maresa 2000).

Communities are to engage in this sort of forest management and thus to promote the protection of forests avoiding the deforestation (Skutsch & Zahabu 2003). Obviously, contributions of community forest can help to meet the binding target of emission reduction of Kyoto Protocol (Gundimeda 2004). Conclusively; the community forest management has a global role in reversing the process of deforestation and sequestrating carbon, and a local function of promoting rural development activities. These roles of community forests are the prime assurance for eligibility under CDM. However, the assessment of carbon in Community Forests is a major difficult task (Skutsch & Zahabu 2003).

As far as community forest management is concerned globally, it is an accepted fact that community forests are additional carbon sinks for environmental benefit. However, since issues of leakage, permanence and additionally are still under debate and so community forest is not eligible yet under CDM. Infact, the main purpose of the Kyoto Protocol "to think global and act local" will be robust (Skutsch & Zahabu 2003; Garcia-Quijano *et al.* 2004) possibly by community forests. Therefore, the strategies of expansion of carbon sinks needed to be extended towards the forest conservation as community forest management. Reliable argument of comparison between the community forest management with afforestation and reforestation is that both have a role in additional carbon sinks but extra resources and open lands aren't need for community forests. According to Article 3.3. of the UNFCCC Kyoto Protocol, Parties can use the net changes in GHGs emissions from sources and removals by sinks to meet their commitments, but only those resulting from direct human-induced land-use change and forestry activities and limited to afforestation, reforestation, and deforestation since 1990. Additional land-use and land-use change activities that could be used to contribute to the fulfillment of the Kyoto target may be specified under Article 3.4 of the Kyoto Protocol. The Kyoto Protocol has permitted afforestation and reforestation activities for the first commitment period (2008–2012) for carbon trading under the CDM. However, FM till date renders community forestry as ineligible (Sharma *et al*. 2007).These are the main issue for community forest yet to be eligible under CDM.

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1.1.4. Nepal's Contribution to Climate Change

MoPE (2004) estimated the GHGs emission inventories (Gt) of Nepal for base year 1994/95. The net emission of CO_2 was 9747Gt; CH_4 was 877 Gt and Nitric oxide 30 Gt. Based on different sources of GHGs, emission and removal of GHGs are listed below.

Table 5. GHGs emission inventories (Gt) of Nepal for base year 1994/95

	GHGs Source and Sink Categories	CO_2 Emission	CO_2 Removal	Methane	Nitric oxide
1	Energy	1465			
2	Industrial process	165			
3	Solvent & other product use	0			
4	Agriculture			867	29
5	Land use change & forestry	22895			
6	Waste				
7	Other				
8	Total emission and removals	24525	-14778	877	30
9	Net emissions	9747		877	30

Source: MoPE (2004) cited from Shrestha (2007)

1.1.4.1. Climate change in Nepal: Temperature observation in Nepal from 1977-1994 showed generally warming trend (Shrestha *et al*. 1999) with significantly greater warming at higher elevations in the northern part of the country than the lower elevation in the south. Most of the Nepal showed a positive trend of between 0ºC to 0.5ºC per decade. Agrawal *et al*. (2003) pointed out that the temperature differences are most pronounced during the dry winter season and least during the height in the monsoon season.

1.1.4.2. Impact of climate change in Nepal: There are the numbers of anecdotal perception about Nepal's changing climate change. In the Terai belts during the winter, news reports indicate that fog persists until late morning, and winter mornings are thus much cooler than previous years. Winter days in Katmandu valley are less cold, frost is being rare, and the summer is warmer. The being of spring, has become a persistent cold rain. Rain has become less predictable and dependable, both in distribution and amount. There has been less snow and more ice (ICIMOD 2006).

One of the few measured changed is that of the glacier retreat. The increased in temperature in the Himalaya and the vicinity appears to have been higher in the uplands than in the lowland (Shrestha *et al*.1999). The warming has resulted in marked retreat of the glaciers with the reduction in both area and ice volume (Agrawal *et al*. 2003).

1.1.5. The Role of Community Forestry of Nepal in Carbon Sequestration

From land-use data from 1978/79 to 1994, the total forest area decreased from 38 percent of the national land area to 29 percent (5616.8 thousand ha to 4268.8 thousand ha) while shrub land increased from 4.7% to 10.6% (1559.2 thousand ha from 689.9 thousand ha). Between 1978 to 1994, the carbon in standing stock in forests increased from 151 megaton to 176.9 megaton with the net increase of 25.9 megaton. Moreover, the carbon sequestered in under-storey trees of less than 10 cm diameter and shrubland, whose area increased by 869.3 thousand ha during the same period (1978-94), the actual amount, would be higher than this. Furthermore, if the amount of carbon retention in varieties of harvested products[i] and pools from 1978-94 was counted the net sequestration would be higher again.

Table 6. Comparison of carbon sequestration in Nepal's standing forest (except shrub land)

Year	Forest ('000 ha)	Aboveground biomass (Megaton)	Above & below ground biomass	Total Carbon (Megaton)
1978/79	5616.8	238.7	302.0	151.0
1994	4268.8	279.6	353.7	176.9
Change (78-94)	- 1348	+ 40.9	+51.7	+ 25.9

Source: MFSC (1999)

1.2. Rational of the study

Nepal is extended from the lowland of Terai on South to higher Himalayas on the North. Topographically the country is divided into six roughly parallel zones, from south and north (Jackson 1987). The study area lies in central Nepal i.e. Katmandu valley, which is densely populated region of Nepal.

The growing evidence of climate change resulting from the continued increase of GHGs concentration in the atmosphere has made it a powerful political, social and trade issue. In response to climate change threats, interest in increasing carbon stocks in trees, and the use of tree biomass for fossil fuel substitution to minimize the increase in the atmospheric CO_2 concentration, has been growing among scientist, policy maker, and government **(**Baral & Guha 2004**)**. Forestry is one of the means of offsetting carbon emissions there by sequestering carbon in biomass and also giving positive effect on livelihood of the rural farmer, due to its cost effectiveness and associated environmental and social benefit. (Gautam 2002). In response to the problems of climate change, Kyoto protocol- the protocol of regulating the carbon emission which was adopted in December 1999 (UNFCCC 2003). Relating to trade of carbon in ' Kyoto protocol' there is market mechanism which is known as CDM. The CDM has twin goals of lowering the overall cost of reducing GHG emissions released to the atmosphere, while also supporting sustainable development initiatives within the developing countries. The CDM can also provide necessary financial support to developing countries for sustainable use and conversion of their lands.

The study on carbon sequestration in community forest is stared in India and few African countries, but very rarely in Nepal (Dahal 2003). In Nepal, many studies have been conducted on agro forestry and agricultural crops for their benefits whereas very few studies have been done on intangible benefits like carbon sequestration (Gautam 2002). Various studies conclude that the level of carbon sequestration by different countries and amount of carbon credit from community forest has been quantified. The study on carbon sequestration in community forest of Madhya Pradesh, India has shown that community forest absorbed additional three metric ton carbon/ha/yr. In this way, if one hector community forest sequesters one ton additional carbon per year, it can earn net 1dollor/ha/yr (Dahal 2003) by our country. If the community forest of Nepal is included in the ' Kyoto protocol ' under CDM, it can regularly get certain income from the CDM. Under this mechanism, it has been clarified that the forest that has been managed through the participatory approach will get income through their carbon trading. Natural forest, which has been managed as community forest has been excluded from carbon trading, but in the international level the loud voices are being raised to include natural community forest under the CDM (Singh 2005). If 1 dollar is added into any community forest's accounts one ton carbon/ha/yr, the total of 10 million hector community forest can earn 10 million dollar per year (Dahal 2003).Once community forest is endorsed under the CDM, the community forest of Nepal will have high chance of getting paid for their work of forest conservation which is mainly done for house hold need fulfillment. Thus, it is promising that carbon sequestered by community forest will become a form of non-timber forest product at no additional cost (Adhikaree 2005).Thus, estimation and valuation of carbon content in any community forest system is very important. This study is very imperative and useful to any community forest users in Nepal.

1.3. Objective

1.3.1. General objective

To estimate the soil and biomass carbon stock at Sunaulo Ghyampe Danda Community Forest:

1.3.2. Specific objectives:

- Quantitative analysis of Biomass and Soil organic Carbon of Sunaulo Ghyampe Danda Community Forest:
- To estimate the Carbon Sequestration Rate in Sunaulo Ghyampe Danda Community Forest:
- To estimate the Carbon Sequestration benefit in monetary value for Community Forest User Groups.

1.4. Hypothesis

- Different depths have different soil organic carbon stock.
- Different forest types have different biomass carbon stock.
- Different forest types have different carbon stock.

1.5 Limitations of the study

The current study allows for the estimation of the carbon stock in the soil and biomass. There are the several steps in which error may affect the accuracy of the estimates. This includes the small plot size, slope of the sampling area, insufficient number of the replicates, use of the allometric equations for the estimation of the tree biomass, soil sampling technique for both laboratory analysis and estimation of bulk density.

- The area sampled for the tree biomass was $250m^2$ in both type of the forest ie. in Pine Forest and Mixed Broad Leaf Forest. Brown (1997) has recommended that the area of sample should be 2500 sq.m for obtaining accurate measurement. In tropical forest, the Kyoto protocol has also recommended the size of quadrate to 5m X 100m in areas where there are trees with a DBH>25cm (Palm *et al.* 2000).

- Another source of error could be related to allometric equation used for the estimating the biomass of trees on their DBH and Height. The applied equation was developed primarily for the matured tree forests that included only trees greater than 12cm in diameter (Sharma *et al*. 1990). Where as for the tree having diameter 5-12 cm different allometric equation is used (Brown & Pukkla 1997). The tree less than 5cm in diameter was excluded.

- The density of wood of mature tree is greater than that in young tree, and re-growing trees. It is assumed that taking the average wood density can minimize the error.

- For the estimation of the root biomass, no different constant value was used for the measurement of root biomass of the different tree species. 15% of stem biomass was assumed for the estimation of the root biomass (MacDickhen 1997) for the different tree species.

- The crop biomass, litter biomass and the microbial biomass were excluded.

CHAPTER TWO

LITERATURE REVIEW

2.1 Carbon sequestration in forest and soil

Dixon *et al*. (1993) estimated that the combination of woody perennials and crops has the potential to store anything between 29 and 53 Mg/ha C aboveground carbon in the humid highlands of Africa, between 39 and 195 Mg/ha C in South America and between 12 and 228 Mg/ha C in Southeast Asia.

Dixon *et al.* (1994) estimated that the global carbon stock in the temperate forest is 59(PgC) in plant as biomass and 100(PgC) in 1m depth soil and on the tropical forest is 212(PgC) in plant as biomass and 216(PgC) in 1m depth soil and on Boreal forest is 88(PgC) in plant as biomass and 471(PgC) in 1m depth soil.

Brown *et al*. (1996) estimated that, deforestation and promoting natural forest regeneration and afforestation could increase carbon stocks by about 60 to 87 PgC over the period 1995 to 2050, mostly in the tropics.

Garg (1998) estimated that, *Prosopis juliflora* has been grown on salt-affected soils in northwest India and increased the SOC pool from (10 to 45) ton/ha in an eight-year period.
IPCC (2000) estimated an average carbon stock of 86 ton/ha in the vegetation of the world's forest at mid-1990s.The corresponding carbon in biomass and dead wood in forests reported the amounts to 82 ton/ ha for the year 1990 and to 81 ton/ ha for the year 2005.

IPCC (2000) estimated at the global level, 19 % of the carbon in the earth's biosphere is stored in plants, and 81 % in the soil. In all forests, tropical, temperate and boreal together, approximately 31 % of the carbon is stored in the biomass and 69 % in the soil. In tropical forests, approximately 50 % of the carbon is stored in the biomass and 50 % in the soil.

Valentini *et al*. (2000) cited from IPCC(2001) estimated that managed and even old growth forests (of the temperate and boreal zone) sequester carbon at rates of up to 6 ton/ha.

Lal (2000) cited from IPCC (2001) estimated that the annual increase in atmospheric CO_2 can be nullified by restoration of 2 billion/ha of degraded lands, which would increase their average carbon content by 1.5 ton/ha in soil and vegetation.

Haripriya (2003) estimated that, India, neighboring Nepal, acted as a net source of 12,723 giga gram of carbon during 1993-1994 through the forestry sector.

Yang *et al*. (2003) has estimated that the carbon stock and sequestration in a 27-year-old mixed *Cunninghamia lanceolata* and *Tsoongiodendron odorum* and a pure *C. lanceolata* forest in Sanming, Fujian Province, China, was studied. The total carbon stock of the mixed forest was 222.508 ton/ha, 21.85% higher than the pure forest. The carbon stocks of the living parts and the soil of the mixed forest were 139.755 and 80.281 ton/ha, respectively, contributing to 62.81 and 36.08% of the total carbon stock of the mixed forest.

FAO (2005) estimated that the soil carbon (ton/ha) of the Asian region of the different year is as:

Table 7. Soil Carbon Status of Asian region of different years.

Asian region	SOC(ton/ha)		
	1990	2000	2005
East Asia	66.5	66.5	66.2
South and South east Asia	69.0	68.8	68.4
Western and Central Asia	41.6	41.6	41.2

Lehtonen (2005) reported that, the biomass carbon pool increased by an average of 27gC/m^2 annually in the 1990s while the carbon pool of soils increased by 11 g C/m^2, including the effect of land-use change, which was close to nil during 1990's, in Finland.

Umadevi & Thiyagarajan (2007) reported that worldwide, SOC in the top 1 meter of soil comprises about 3/4 of the earth's terrestrial carbon; nevertheless, there is tremendous potential to sequester additional carbon in soil.

FAO (2007) pointed out that the Global forest vegetation stores 283 Gt of carbon in its biomass, and an additional 38 Gt in dead wood, for a total of 321 Gt. Soils (down to 30 cm) and litter contain 317 Gt of carbon.

2.2 Carbon Stock on Forest and Soil of Nepal

Gautam (2002) reported that the highest total organic carbon was found to be 98 ton/ha. in natural forest. The total organic carbon content ranges from 33.2 to 55.5 ton/ha and from 35 to 74.6 ton/ha in annual cropping system and in the plantation orchard respectively. The SOC was highest (53.2 ton/ha) in naturally grown forest followed by 52.6 ton/ha in vegetable grown field and least in streamside (3.6 ton/ha).

Adhikaree (2005) reported that biomass carbon store 114.25 ton C/ha in pine forest where as in the mixed broad leaved forest, 125.33 ton C/ha is stored as biomass carbon.

FAO (2005) estimated that, the SOC of Nepal up to soil depth 100cm with correction factor 0.684, of the different years is:

Table 8. SOC status of Nepal up to soil depth 100cm

SOC(millions tones)	1990	2000	2005
Original figures	432	350	326
Adjusted figures	295	239	223

Gautam (2005) has studied that the carbon sequestration potential of agro forestry and forestry projects was studied in Nepal. Carbon sequestration in biomass was 2.0 Mg C/ ha/yr in regeneration of natural forests in Nepal.

Maraseni et al. (2005) compared the carbon sequestration in Nepal's standing forest (except shrubland) as above ground biomass (megaton), both above and ground biomass (megaton) and total carbon content (megaton) of the two different years.

Table 9. Carbon sequestration status of Nepal's standing forest of two different years

Year	Above ground biomass (Megaton)	Above & below ground biomass ((Megaton)	Total Carbon (Megaton)
1978/79	238.7	302.0	151.0
1994	279.6	353.7	176.9
Change (78-94)	+ 40.9	+51.7	+ 25.9

Singh (2005) has found that total above ground carbon sequestration was 451.5436 ton/ha and under ground carbon sequestration was 81.29 tons/ha of community forest of Kaski district.

Upadhyay *et al*. (2005) studied net emissions of Carbon due to land-use changes in Nepal were reported to be 6.9×10^6 to 42.1×10^6 Mg/ yr by earlier studies. In contrast to these findings, they estimated the net emissions of Carbon for the year 1994 was 1.47×10^6 Mg/ yr, representing Carbon emissions from fuel wood consumption and loss of soil due to erosion less Carbon fixation due to annual vegetation growth.

Dhakal (2006) pointed out that forest soil was good potential for sinking soil SOC having capacity of 8.12 kgC/m^2.the forest soil of (0-13)cm depth has contributed almost 50.6% of total soil organic carbon in Balkhu Khola Watershed.

NTNC (2006) stated that the biocarbon increment in Manang (3.3 ton C/ha) is found to be more than in Illam (2.94ton C/ha) and Lamatar(1.30ton C/ha).

Thapa (2007) estimated that the total carbon stock of Hasantar community forest of an forest area of 64ha which was 7562.85tC, and also reported that the carbon stored in forest soil was 4-times more than in tree biomass.

CHAPTER THREE

SITE DISCRIPTION

3.1. General Description of the Study Area

Our country is situated in the southern flank of the central Himalayas. Nepal lies in between the latitude 26°4′ N to 30°27′ North and longitude 80°4′ to 88°12′ East. The elevation ranges from 60m to 8848 meter above sea level. The area of country is 1, 47,181 Sq.km (CBS 2001).

Geographically, our country is divided in three regions, viz. the Mountain, Hills and Terai regions. The mountains occupy 35% land of country area, where as the hills occupy 42% of the total lands. It consists of gregarious mountains, highs peaks hills, valleys and lakes. This region is famous for horticulture, generation of hydropower. The southern range, the Terai is the Gangatic Plain of alluvial soil and consists of dense forest areas. This region is famous for crop production. It occupies about 23% land of Nepal (CBS 2001).There are five development regions and 75 administration districts. Districts are further divided into smaller units, called VDC or Municipality. Currently there are 3914 VDCs and 58 Municipalities in the country. Agriculture is practiced on the 18% area of the country (CBS 1998).

The forest areas are decreasing every year. It decreased from 37.4% in 1986(LRMP 1986) to 29% in 1994 (DFRS 1994) and to 37.4% in 2000 (JAFTA 2000). The average annual deforestation rate is 1.7% in each year. Where as the annual rate of deforestation in fragile hill ecosystem is 2.3% and in Terai is 1.3 % (Adhikari 2001 cited from Gautam 2002).

3.1.1. Geographical Locations: The study area, Seti Devi VDC is located in the Katmandu district, in the way of Pharping which lies in the Central Development Region of the Katmandu valley. The study was carried in the Sunaulo Ghyampe Danda Community Forest lies at the ward no 7, 8 and 9. It is situated in between the latitude 27º37′22" to 27º38′48" and longitude 85º16′35" to 85º17′10". The elevation of the study area ranges from 1100 to 1700m above the sea level. It was handed over as community forest on 2054B.S. The total area of the community forest is 51.4 hectares. The studied community forest is surrounded by Hattiban Community Forest from the West, where as from East and North it is surrounded by Hattiban Forest.

3.1.2. Location Map of the Study Area

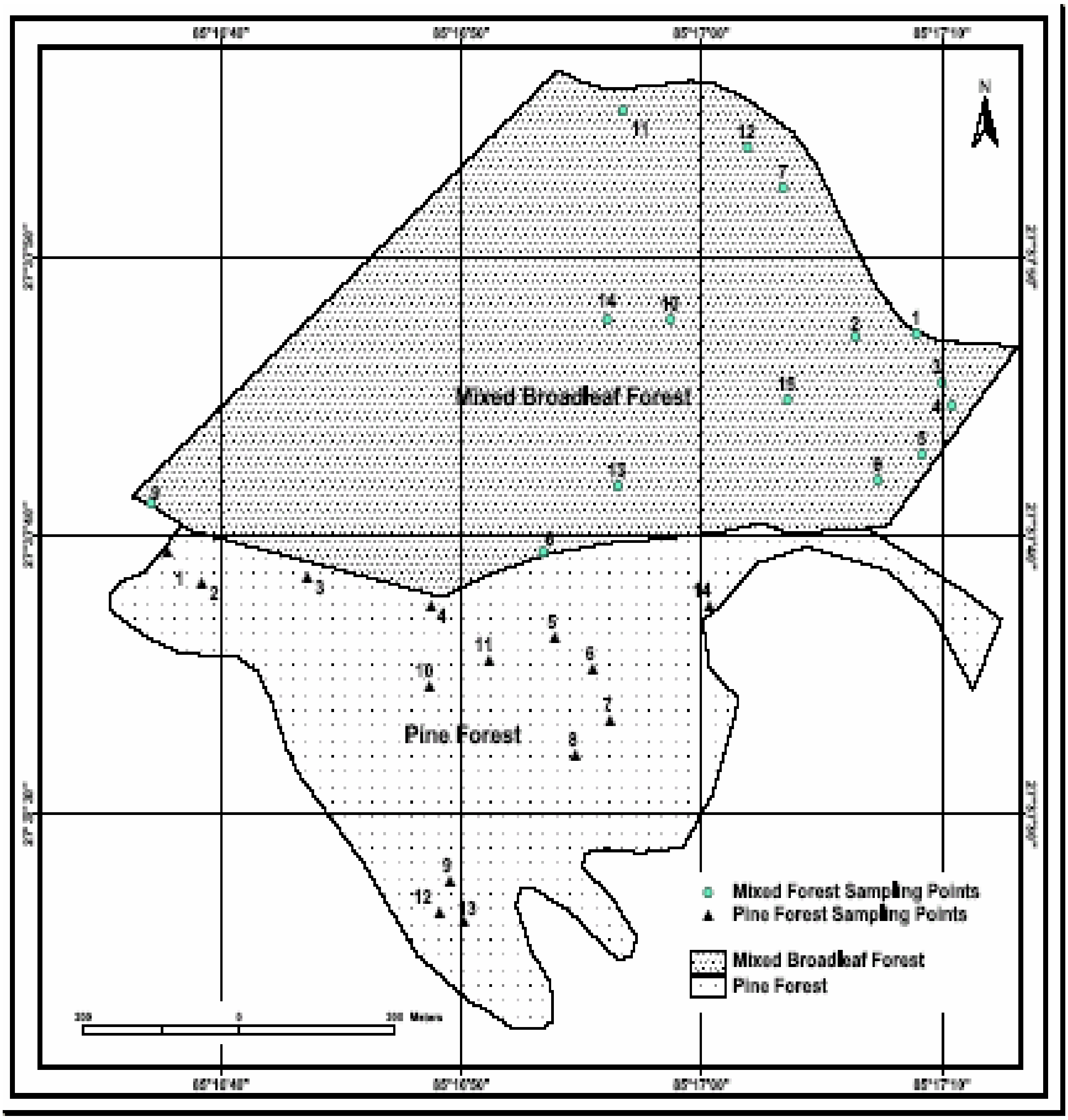

Fig1. Location Map of Study Area with Sampling Point

3.2. Socio Economic Situation

3.2.1. Demography: Total population of Seti Devi VDC is 3636 (M-1806, F-1830) with total household 746. Out of total 3636 population; maximum people lies with in the age group (10-14) with (M- 6.84%, F- 6.35%) and minimum population lies with in the age group (70-74) with (M- 0.55% F-0.66%).

The study area has ethnic groups from all four cast hierarchies (Brahmin; Chhetries; Vaisya and Sudra), where Brahmin (4.3%), Chhetri (26.5%); Newar (19.8%); Magar: (9.1%), Damai: (3.3%), Sarki: (1.7%); Chepnng: (1.7) %, Sanyasi: (1.6%) and remaining others: (3.5%). The Tamangs are dominants (26.5%) residents. In relation with the mother tongue, maximum speak Nepali (71.9%) than Tamangs (19.6%), Newar(7.4%), Tharu .(02%).and others (0.1%). In the study site most of the residents were Hindu (71.7%), than Buddhist (26.0%), Christian (1.7%) Shikhs (0.1%) and others not stated (0.5%) (CBS 2001).

3.2.2. Education: The total number of people over the age of 6 years is 3267(M-49.3%, F-50.6%). 1129 number of population cannot read and write (M-30.3%, F-69.6%).75 number of population can read only (M-5% and F-4%). 2057 number of population can read and write (M- 59.7%, F -40.2%) (CBS 2001).

3.2.3. Economic: The major economic activity in the study site is Agriculture. Out of total 746 household, 152 households have only Agriculture land, 3 households have livestock only; 176 households have both land and livestock; 38 households have land and poultry; 5 households have livestock and Poultry; 18 household have land and livestock; 212 households have Poultry; and 100 household have none of all (CBS 2001).

The economically active population over 16 years of age are of 2936.(M-49.3% , F-50.6%). Besides 2936 population, economically active population were 1128 (M-69.5% F-30.4%) and economically inactive population are 1808 (M-36.8%, F-63.1%). Only few households are involved in economic activity (3.7%) and remaining households are not involved in economic activity (94.2%). The economically active household are involved in business (28.5%) and others (71.1%) (CBS 2001).

3.2.4. Agro Forestry and Forest Dependency: Trees for the purpose of fodder, fuel wood are of great significance in the farming systems and in the overall economy of households in the study area. Trees provide timber and fuel wood for the household and fodder for livestock.

90.2% of the people depend on the Agro Forestry for the fuel wood, timber, Fodder. There is no pressure on the community forest for the fuel wood. Rather than stall feeding; they prefer to graze their livestock, so the grazing pressure on the pine forest is higher than Mixed Broad Leaf Forest. Rice wheat, maize, vegetables are grown in Khet and Bari. Seven house hold of the study area have Gobar Gas plan.

3.2.5. Women Involvement on Community Forest Management: Women involvement in the community forest management is excellent. Each woman from each household are involved in community forest management. There are four different Women's Groups working for the management of community forest. They are:

- Sayapatri Womens Group
- Makhamali Womens Group.
- Laliguras Womens Group
- Mahilla Sanjal Samuha.

3.3. Climate

The climate of this area is sub tropical, i.e. neither so cold nor so hot. 20 years Rainfall, Temperature and Humidity data of Katmandu Airport was used for the study.

3.3.1. Rainfall: The average annual rain fall of the study area is 1490.79mm. The monsoon begins in the June and ends in September, receiving 75% of total annual rainfall. Maximum rainfall receives at the month of June (382.25mm) and low rainfall receives at the month of November (8.75) mm. 25% of water falls at pre-monsoon and winter seasons.

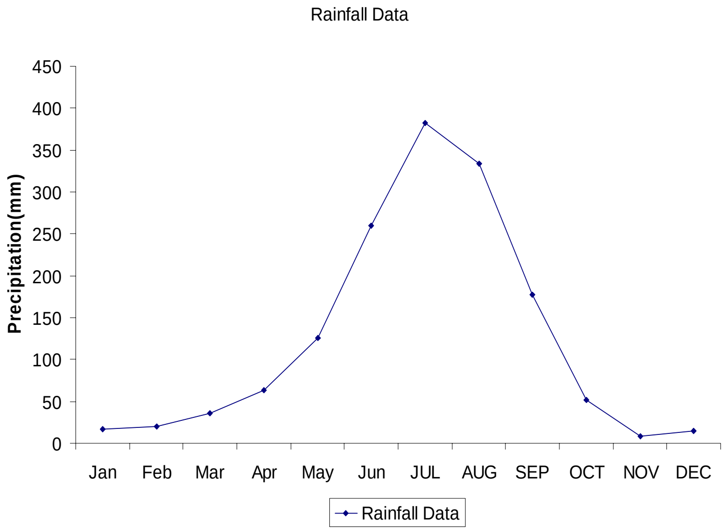

Fig 2. Rainfall of Katmandu Airport Station of the year 1986-2006

3.3.2. Temperature: The average annual temperature of the study area ranges from 307.43°C to 143.68°C. The average monthly maximum temperature was in July before the monsoon breaks and minimum temperature was in January.

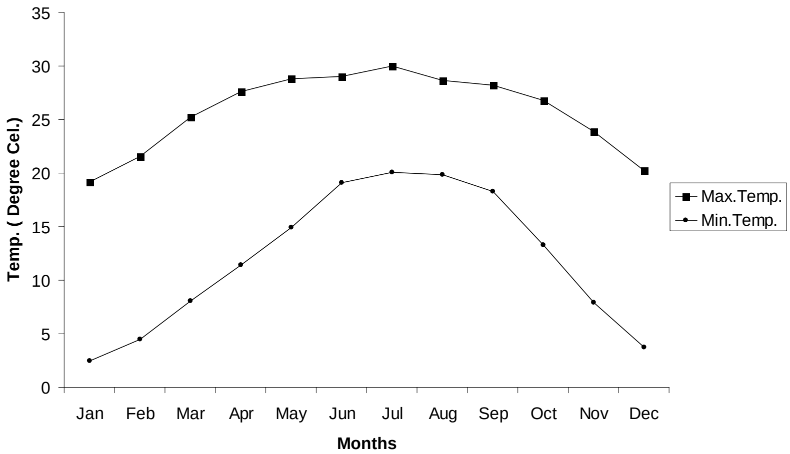

Fig 3. Temperature of Katmandu Airport Station of the year 1986 -2006

3.3.3. Relative Humidity: The average annual humidity of the of the study area ranges from 1027.4 to 803.15.The average monthly maximum relative humidity was in January and minimum was in April.

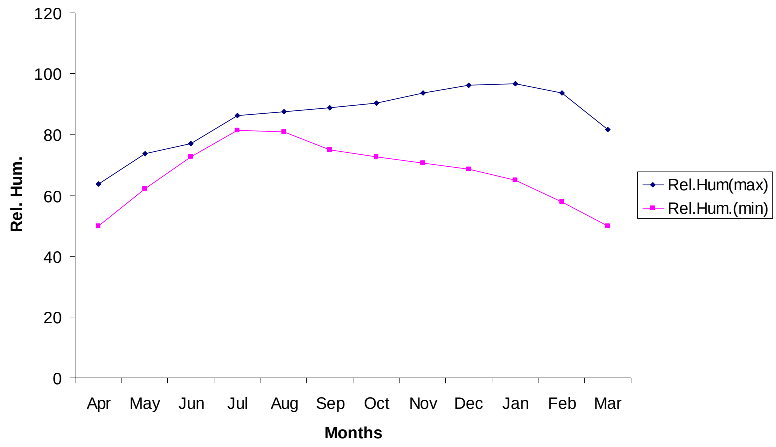

Fig 4. Relative Humidity of Katmandu Airport Station of the year 1986- 2006

3.4. Slopes: The slope of the study area ranges from 5° to 40°. The slope of the land with in the Pine Forest ranges from 5° to 35°, and Mixed Broad Leaf Forest ranges from 10° to 40°.

3.5. Geology and Soil: The lacustrine sediments are widely distributed in the area. The sediments consist of clay, silts and medium of fine sands. Color of the sediments is reddish to black. Clays are sometimes carbonaceous due to deposition of organic matter buried during the sedimentation. The hill and obviously the bedrock below and unconsolidated sediments constitute of Chandragiri limestone of Phulchoki group. The area is structurally complex as the formation changes its strike and dip due to folding and faulting. Most of the area is covered by vegetation (Adhikaree 2005).

3.6 Vegetation: Vegetation of the study area changes with the altitude. Two types of forest are recognized in this study area. In the southeastern part of the forest is covered by the conifer tree (Pine Forest) and the north eastern part of the forest is covered by Mixed Broad Leaf forest.

<u>Pine Forest</u>

Tree Species: Pine forest is dominated by the *Pinus roxburghii species* abundant in the altitude of range 1550-1700m. Along with *P. roxburghii, Eucalyplus citriodora* (Masala), *P.wallichina, Schimma wallichina (*Chulaune) tree were also obtained.

Shrub Species*:* *Berberis asiatica* (Chutro), *Rubus ellipticus* (Aaiselu), *Eupatorium adenophorum* (Banmara), *Lantana camera, Calibrakia opposifolia (*Dhursun).were dominant shrub species in this pine forest.

Herbs Species: .*Digitaria ciliaris* (Banso), *Kush vetivera* (Kush) *Cynondron dactylon* (Dubo), *Oalis latifolia* (Aamila ghas), *Gonostegia* sps. (Chiple ghans), *Dryopleris filix* (Unyu), *Boenninghausenia albiflora* (Dampate), *Parochetus communis* (Badame jhar), *Eulaliopsis binata* (Babyio), *Lysimachia allirnifolia* (Bute ghas)), *Imperta cylindrica* (Siru ghans), *Nephrolepis cordifolia* (Pani amala)s), *Vernonia cinerea* (Phluke ghans) *Breynia refusa* (Sanu nun dhaki), *Osyris nightiana* (Nun dhaki*), Skimmia laureda* (Chaulanni), Seto lahara, Bagkha ghans

Mixed Broad Leaf Forest

Tree Species: The major dominant tree species were *Schima wallichina* (Chilaune), *Rhododendron arboreum* (Lali guras), *Castanopsis tribuloides* (Musure katus), *C. indica* (Dhale katus), *Myricia esculanta* (Kafal), *Engelhardia spicata* (Mauwa), *Lyonia ovalifolia* (Angerai), *Quercus glauca* (Phalant), *Acer oblongum* (Phirpire). Other not dominant tree species which were *Myrsine capillellata (*Setikath), *M. semiserrata* (kalikath), *Albezzia lebbek (siris)*, *Celtis australis* (Khari), *Fraxinus floribundus* (Lakuri), *Alnus nepalnensis* (Utis), *Zizyplus incurva* (Hade bayar), *Semicarpus anacardium* (Bholayo), Lapsi.

Shrub Species: *Osyris nightiana* (Nun dhaki), *Hypericum uraium* (Khareto), *Mncuna pruriens* (Sim kauso), Falame kada, etc.

Herbs Species: *Cynodon dactylon* (Dubo), *Ageratum conyzoides* (Ganaune Jhar), *Eulaliopsis binata* (Babyio), *Grewia elaslica* (Syal pusre ghans), *Imperta cylindrica* (Siru ghans), *Mariscus sumalensis* (Koraente ghans), *Elaegnus infundibulosia* (Guienli), *Osyris nightiana* (Nundhaki), *Vernonia cinerea* (Puurke ghans)), *Arundina graminifolia* (Orchid), *Oxlalis latifolia* (Amile ghans), Pan pate ghans, Bhuse kharuki, etc.

CHAPTER FOUR

METHODOLOGY

4.1. General Work Divisions

4.1.1. Literature Survey: The various literatures, documents, journals, and the various articles were searched which are needed for the preparation of proposal and discussed with supervisor and other personals have been done to gather information. Hence, the proposal was prepared focusing on the problem identification, definite objective, and with detail working methods.

4.1.2. Preliminary Field Work: The field work was started with the preliminary survey of the field in the month of December to obtain the basic information needed for the field works. The boundary line of the community forest was identified, as well as the boundary line with in the community forest was also identified. The secondary information about the forest was also collected during the field trip.

4.1.3. Field Work: The field work was stared from the last of December. The field work was carried out for twenty days. Vegetation analysis was done by random sampling method and soil samples were collected according to sample design in the proposal. The boundary line and sampling points was also collected by GPS.

4.1.4. Post Field Work: This is the final stage of the research which includes the laboratory works, data compilation, data analysis, data verifications, interpretation and research paper writing.

4.1.5. Collection of Secondary Information: World Wide Web (www) was used as the major sources of literatures for reviewing the data and scientific understanding related to this study. The various government offices as well as non government organization were identified information analysis.

4.2. Field Data Collection

Sunaulo Ghyampe Danda Community forest was chosen having an area of 51.4 hectare. The forest was identically divided into two types of forest community:

- Mixed Broad Leaf Forest:20 ha
- Pine Forest: 31.4 ha

Measuring Carbon Pools*:* For the measurement of carbon pools, the carbon stored as biomass and in the soil was measured. The following three carbon pools were measured using methodology developed by MacDickhen (1997)

A) Above ground biomass

B) Below ground biomass

C) Soil carbon

15 sampling plots were laid in Mixed Broad Leaf Forest and 14 sampling plots were laid into Pine Forest totaling 29 sampling plots in both forest types. The plots were circular with an area of 250m.sq and were laid randomly. Once the plot centre was identified, the radius of 8.92m was measured for the requirement of the sampling plots. The unidentified plants were tagged and by taking with the help of local people and experts they were identified.

For Biomass*:* Sampling plot size for trees: 250sq.m

For Soil Carbon: Soil samples were collected from the center of the sampling plots, at different depth:

(A) 0-25 cm.
(B) 25-50 cm.

4.2.1. Biomass Measurement

For the purpose of this study, woody plants with ≥5cm DBH were considered as tree. Trees were classified into 2 classes:

- Small tree: 5-12cm DBH
- Large tree: ≥12cm DBH.

The major component of biophysical measurement is the height and diameter of the trees. For the large trees both height and diameter were recorded, where as only diameter was recorded for small trees. The most commonly measured is diameter at breast height, which is measured outside the bark at 1.3m above the ground level.

Diameter was measured using diameter tape, where as tree height was measured by using the clinometers.

Estimation of tree height:

$H = \tan\theta \times b + a$

Where: H= total height of the tree in meter

θ= angle of elevation to the top of the tree from observers eyes.

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

a = height of the observer in mete**r.**

4.2.2. Biomass Estimation

Biomass estimation of big trees is difficult to measure directly in suti. The important character, such as volume and biomass predicated are by the combination of measurement models. The diameter and height are to some extent only auxiliary measurement, which are used to derive more important tree characteristic: volume and biomass. The biomass was multiplied by biomass expansion factor (Brown 1997 & Montagnini & Porras 1998), to get the carbon content.

Biomass can be expressed either as fresh mass or dry mass. Dry mass may further be given as air dry or oven dry. The moisture content of a fresh mass is generally 30-60 % and air dried wood usually contains about 25% water (Sharma & Pukkla 1990).

Following are the stepwise details of biomass carbon estimation:

- Field data was tabulated in MS-Excel program.
- The logarithmic transformation of the allometric formulae is used in estimating volume and biomass. Total stem volume of trees with more than 12cm DBH was calculated using equation developed by (Sharma & Pukkla 1990)

The allometric equation for the estimation of biomass and volume is as follows.

$\ln(v) = a + b \times \ln(d) + c \times \ln(h)$

Where: v= volume of the stem.

d =diameter of the tree at breast height.

h = height of the trees.

ln = logarithms

Parameters a,b, and c are the constants.

Where: a=intercept

b=slope

The constant value for major tree species of Nepal was calculated.

- The equation suggested by Brown (1997), which gives directly the total stem biomass in kg, was used to calculate biomass of tree with 5-12 cm DBH. The equation is as follows.

$$\text{Biomass (kg)} = \exp\{-2.134 + 2.530 \times \ln(\text{DBH})\}.$$

- After the calculation of the volume of the tree, it is multiplied by the wood density of the species to get the stem biomass.

Stem biomass (kg) = Stem Volume (m^3) X Stem Density (kg/m^3)

Wood density of the different tree species and forest type of Nepal was calculated.

- Total stem biomass was multiplied by respective constant to get branch and foliage biomass.

Respective constant to get branch and foliage biomass of the major tree species and forest type was calculated.

But in some cases the entire constant a, b and c as well as density was not available of the tree species. Only measured diameter at the breast height (DBH) was used to calculate above ground biomass of trees. Following regression model was used to calculate above ground biomass of trees (NARMSAP 2000).

Regression model is

$$\text{Ln } W = a + b \times \text{Ln (DBH)}$$

Where: W = Green weight of tree component (biomass) in kg.

a=intercept

b=slope

DBH = diameter of the tree at breast height.

- The measurement of root biomass is not calculated by using the allometric equations. The root biomass was assumed to be 15% of total aboveground biomass as suggested by MacDickhen (1997).

But, in some cases the allometric equation is also used for the calculation of the root biomass (Shanmughavel *et al*. 2001).

$Wr = 0.0112 \ X \ (D^2 \ X \ H)$

Where: Wr = Root biomass,

D = Diameter of the tree, and

H = Total height of the tree.

- Total stem biomass, branch biomass, foliage biomass and root biomass was summed to get total biomass and was multiplied by carbon expansion factor, i.e. 0.5 (Brown 1997, Montagnini & Porras 1998) to get the biomass carbon stock.

4.2.3. Soil Sampling

The soil samples were collected from the different depth i.e (0-25)cm and (25-50)cm at the centre of the circular plots. Before collecting the soil samples all the vegetation and litter were removed from the soil surface prior to sampling. The soil samples from the each stratum were collected by soil sampler for each incremental depth at every selected site. About 1.5kg of the fresh soil samples were collected from each depth and kept on polythene bags for the soil organic analysis as well as another soil samples were also collected for the determination of the bulk density using core sampler of 10cm diameter and height 12.73 cm (volume-999.305cc). Each and every collected soil samples were well labelled and were transported to laboratory for the chemical analysis.

4.2.3.1. Soil Organic Carbon: The well labelled soil samples which were collected for the analysis of the SOC was air dried and was passed through the 2mm sieve to prepared soil sample for the determination of the SOC. As the soil contains two types of carbon, an organic and inorganic carbon, only SOC was determined, which is the most important source of organic carbon. SOC of the soil samples were determined by titrimetric method based on Walkey & Black Method.

- Air dried soil sample were taken.
- Oven dried soil samples were passed through a 2mm sieve to prepare sample for determining soil organic carbon.
- 1gm of dried soil was weighed and transferred to the well labeled dried 500ml conical flask.
- 10ml 1N potassium dichromate solution and 20ml conc. Sulphuric acid was added and mixed by gentle swelling.
- The flask was kept for about 30min to react with the mixture.
- After the reaction was over, the mixture was diluted with 200ml of distilled water and 10ml of phosphoric acid was added followed by 1ml of Diphenylaime indicator.
- The sample was titrated with 0.4N ferrous ammonium Sulphate, and end point was changed to the brilliant green.
- The blank was run as followed by above procedure but with out soil sample.

4.2.3.2. Bulk Density: Soil bulk density was determined using core sampling method (Baruah & Barkhakur, 1999) of known volume. The soil samples were collected by means of core samplers with out disturbing the natural structure. The well labeled soil samples, collected for the analysis for the bulk density were oven dried at 65 degree Celsius for 48 hrs. The weight of oven dried soil samples divided by its volume gave the bulk density.

$$\text{Bulk density} = \frac{\text{Weight of oven dried soil}}{\text{Volume of core samplers}}$$

4.2.3.3. Calculation: The SOC was calculated using the following equation(Walkey & Black Method).

$$\text{\% of SOC} = \frac{3.951}{g} \times (1 - T/S)$$

Where: g = weight of soil sample taken in gm.

S= ml (ferrous) solution with blank titration.

T= ml (ferrous) solution with sample titration

4.2.3.4. Carbon stock: The soil organic carbon was calculated using the method (Batjes 1996, Chhabra et *al*. 2002).

SOC (kg/m^2) = % SOC X soil bulk density (Kg/m^3) X thick ness of the soil horizon (m)

Further it was expressed into ton/ha.

4.3. Measurement of Net Carbon Value

Hedges *et al*. (1986) cited from Gautam (2002) determine the mean proportion of carbon in the woody and herbaceous vegetation by converting 43% of dry mass into carbon density. Kilawe *et al* (2001) has used 45% of dry mass into carbon density.

In this study biomass carbon was calculated by using the stock based method (Maclaren & Ford 2001).The carbon content ids assumed to be 50% of dry biomass (Brown 1997). The formulae used for above and belowground carbon is:

1-Total above ground biomass organic carbon = (total above ground biomass of tree + total twig and litter biomass + total annual crop biomass) X 50%.

2 - Total below ground organic carbon = (total root biomass of tree + total root biomass of annual crops) X 50% + total soil organic carbon.

4.4. Measurement of Carbon Sequestration Rate: Carbon sequestration rate = carbon storage of this year- carbon storage of previous year.

4.5. Monetary Value of Carbon Sequestration: The value of one ton carbon sequester by the community forest at US$ 5 (Banskota & Karky 2006).

4.6 Statistical Analysis

(i) Standard deviation (S) = $\frac{\sqrt{(\sum X^2 - X\ X \sum X)}}{\sqrt{(N-1)}}$

Where: $\sum X$= total number of individuals of a species

X= mean number of individuals of a species

N= number of observation.

ii) Sample Variance (S^2) = $\frac{(\sum X^2 - X\ X \sum X)}{(N-1)}$

(iii) Standard error (S.E) = $S/\sqrt{N}$

(iv) Range, = $\frac{X \pm S.E}{A}$

Data analysis was done by using latest version software Microsoft Excel, SPSS software (version 10).

CHAPTER FIVE

RESULT AND DISCUSSION

5.1. RESULT

5.11. Biomass Carbon Stock: Mean carbon content of the Pine Forest and Mixed Broad Leaf Forest was found to be (116.50±16.39)ton/ha and (25.95±.8.09)ton/ha respectively. In the Pine Forest maximum biomass carbon was found to be (262.35±16.39) ton/ha in site 10 and minimum biomass organic carbon was found to be 14.55 ton/ha in site 3 (Annex: 2). In the Mixed Broad Leaf Forest maximum biomass organic carbon was found to be (111.20±8.09) ton/ha in site 11 and minimum biomass organic carbon was found to be 1.60 ton/ha in site 13 (Annex: 3).

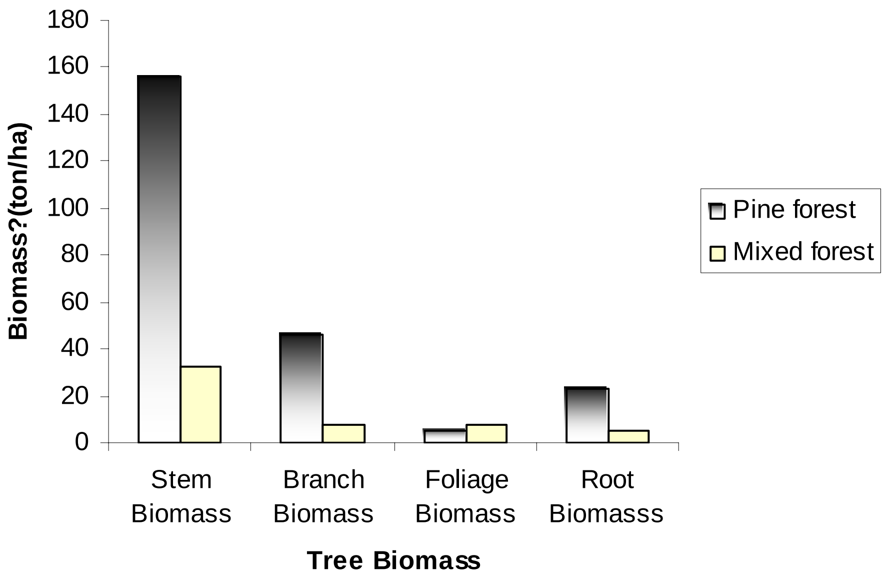

Fig-5: Biomass Carbon Content of Pine Forest and Mixed Broad Leaf Forest (Annex: 8a Graph)

In the regenerative community forest, 2006 survey stated that, in the temperate zone, impressive growth of forest biomass which was about 10% in a year; largely due to regeneration and protective measures Dahal (2006). The present study compared with Dahal (2006), the increment in the biomass of Mixed Broad Leaf forest would be 10% of the present tree biomass, i.e. the carbon sequestration rate of the Mixed Broad Leaf forest would be 2.59 ton/ha/yr. The mean biomass carbon of the Mixed Broad

Leaf forest in the consecutive year would be 28.54ton/ha for next year and 23.36ton/ha in the previous year. The carbon sequestration rate of Pine Forest was found to be 1ton/ha/yr as this study compared with Adhikaree (2005).

5.1.2. Soil Organic Carbon: Most of the data on soil carbon of central Himalayan forest are based on 20-30cm soil depth (Jobbagy & Jakson, 2000). The present study data on the soil carbon are based on (0-25) cm and (25-50)cm depth.

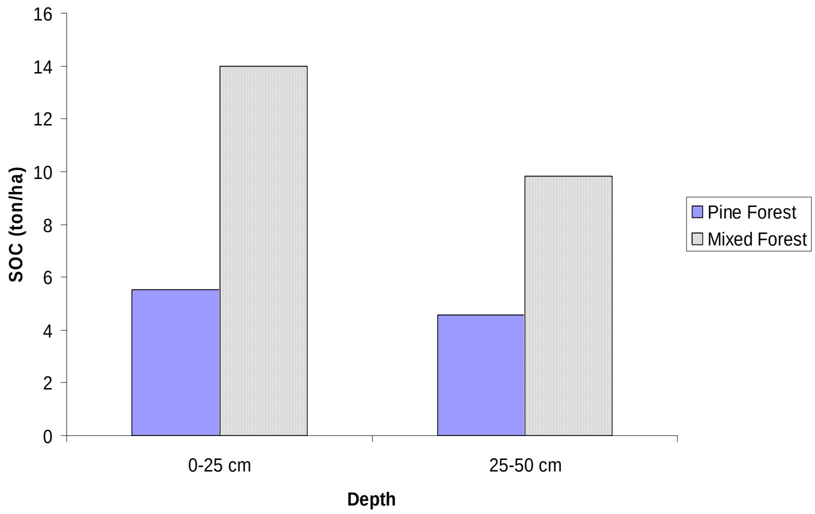

Fig 6: Variation in Soil Organic Carbon with depth. (Annex:8b Graph)

The SOC of two forest types were studied. The range of SOC in the upper layer i.e.(0-25)cm was found to be (7.95±1.18)ton/ha on site 15 to (49.76±1.18)ton/ha on site 12 in Mixed Broad Leaf Forest and in Pine Forest, SOC found to be (5.67±1.03)ton/ha on site 4, to (24.52±1.03)ton /ha on site 14. SOC in the lower layer i.e.(25-50) was found to be (5.56±1.18) ton/ha on site 15 to (30.40±1.18)ton/ha on site 8 in Mixed Broad Leaf Forest and in the Pine Forest the SOC found to be (5.36±1.03) ton /ha in site 6 to (18.38 ±1.03) ton/ha in site 11 (Annex: 1).The carbon content in the upper layer of both forest was found to be higher than that of lower layer (Annex: 1). The average SOC upto depth 50cm was found to be (10.15±1.03) ton/ha and (24.62±1.18) ton/ha in Pine Forest and Mixed Broad Leaf Forest.

5.1.3. Total Biomass and Soil, Organic Carbon Content: The above carbon content in the Pine Forest was found to be 99.79ton/ha and the below carbon content was found to be 21.79ton/ha. The above carbon content in Mixed Broad Leaf Forest was found to be 23.54 ton/ha and below carbon content is found to be 26.22 ton/ha.

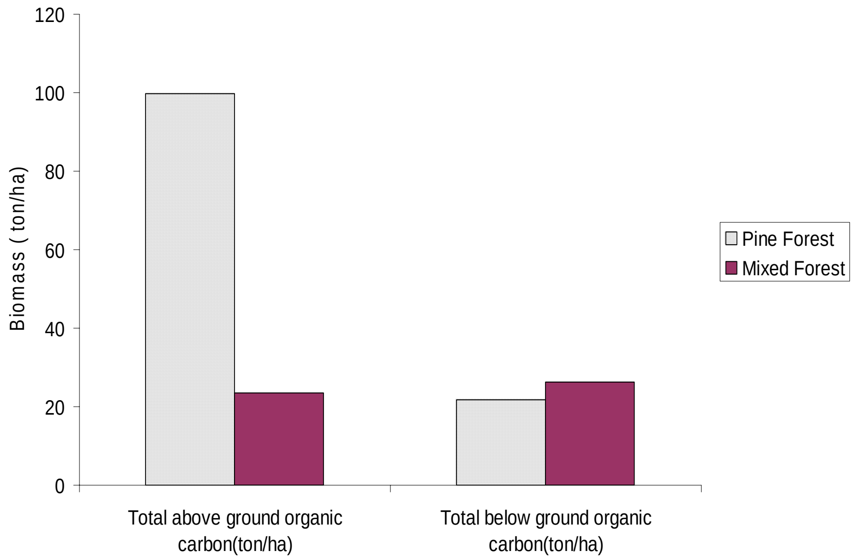

Fig 7: Graph of Above, Below Carbon Content of Pine Forest and Mixed Broad Leaf Forest. (Annex: 8c Graph)

The total above and below carbon content of the Pine and Mixed Broad Leaf forest were found to be 126.58ton/ha and 49.76ton/ha respectively as described in (Annex: 8c)

5.1.4: Carbon Sequestration Rate in Sunaulo Ghaympe Danda Community Forest: Adhikaree (2005) estimated carbon stock of Pine Forest as biomass at Sunaulo Ghyampe Danda Community Forest was 114ton/ha and according to Dahal (2006) carbon stock of Mixed Broad Leaf Forest of the previous year was 23.56 ton/ha.

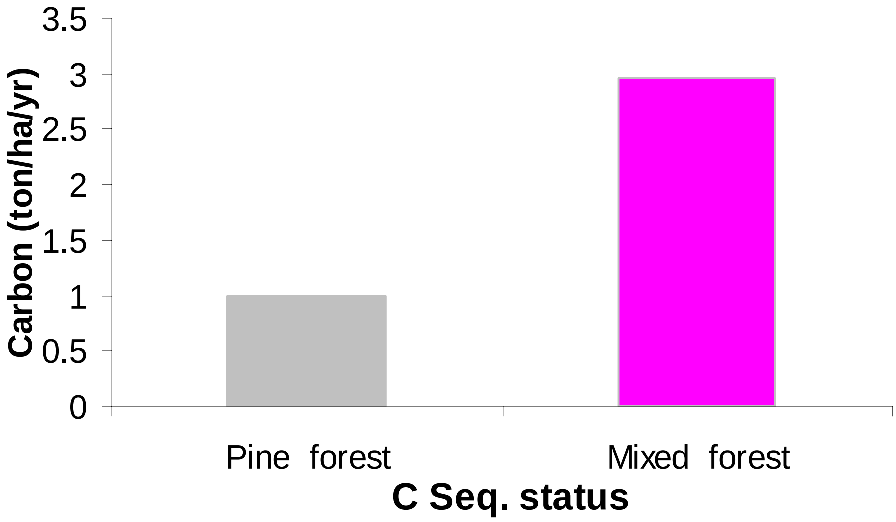

Fig 8**:** Carbon sequestration status of Pine & Mixed Broad Leaf forest (Annex 8d graph)

The rate of carbon sequestration by the Pine Forest and Mixed Broad Leaf Forest was described in (Annex 8d). Carbon sequestration rate of Mixed Broad Leaf forest was found to be higher than Pine forest.

5.1.5. Monetary value of carbon sequestration by Sunaulo Ghaympe Danda Community Forest: Based on the category of the community forest and forest type, the monetary evaluation depends. Depending on the community forest management and types, monetary evaluation of one ton carbon sequestered by the community forest ranges from 5$ to 20$ (Banskota & Karky 2006).

5.2. DISCUSSION

5.2.1. Biomass Carbon Stock: Forest plays the significant role in the climate change as they emit as well sequestrate carbon dioxide. Trees absorbs atmospheric CO_2 for their growth and the carbon content in the soil as well revitalizing degraded forest lands and soil in the global terrestrial ecosystem can sequester 50-70% of the historic losses (Upadhaya *et al*. 2005 cited from Banskota & Karky 2006)**.**

The biomass of the vegetation depends on the diameter and age of the tree. From the socio economic survey, the Pine trees were planted 30 years ago where as the trees on Mixed Broad Leaf Forest were planted 6 years ago, which is still in the growing stage, i.e. regenerative stage. In the present study; the diameter of the Pine trees in the Pine Forest was found to be ranges from 7 cm to 38 cm, where as the maximum tree lies with in the diameter range class above 12cm, but in the Mixed Broad Leaf Forest the diameter of the trees was found to be ranges from 6cm to 60cm where as the maximum tree lies in the diameter class range from (5-12cm). In the Pine Forest, 95.1% of the tree was found to be having diameter greater than 12cm but in Mixed Broad Leaf Forest 80.5% of the tree was found to be having diameter ranges from 5-12 cm i.e. diameter of the Pine tree was found to be greater than that of tree present on the Mixed Broad Leaf Forest.

Banskota & Karky (2006) reported that carbon stock/ha present in the older forest was higher than that of regenerative forest. The present study data reveals with Banskota & Karky (2006) i.e. in Pine Forest biomass organic carbon was found to be higher than Mixed Broad Leaf Forest. According to the stastical analysis; at 95% significance level, the biomass and biomass organic carbon of both forests are independent with each other. The hypothesis based on biomass and biomass organic carbon was accepted.

Nearly ¾ of the trees in Lamatar and about a half in Illam have diameter between (5-10) cm, indicating a relatively young tree. Despite the forest in Manang being much older , with over 40 of the trees having diameter between 21cm-50cm class, the forest still retains about 14 of the trees having diameter >41cm indicating a rich forest ecosystem (Banskota & Karky 2006). In the present study, the result was found to be similar with (Banskota & Karky 2006), i.e. carbon stock of Pine forest was found to be higher than that of Mixed Broad Leaf forest.

5.2.2. Soil Organic Carbon: On average the global survey data indicates that the percentage of carbon in the top 20cm soil relative to that in the first meter soil columns is 50% and the amount in the two meter is 56% of that the first meter (Jobbagy & Jakson, 2000). Top soil shows higher CO_2 flux than subsoil as it is the zone of maximum root and soil flora and fauna activities (Lamander *et al*.1998). The CO_2 flux from soil is closely related to SOC content at each depth. A decreasing trend of CO_2 emission corresponding with decrease in SOC with soil depth is noted from all lands uses (Shrestha 2002). The present data reveal that forest soil in both type of forest have more SOC in the upper layer than in lower. According to the stastical analysis; at 95% significance level, the SOC decreases with depth wise in both forest types. The hypothesis based on SOC was accepted, i.e the SOC in both type of the forest decreases with depth wise.

In Pine forest there is grazing pressure disturbing the soil where as in the Mixed Broad Leaf Forest the land is not disturbed, which causes the high SOC content in Mixed Broad Leaf Forest than in Pine Forest. Minimizing soil disturbances generally lead to SOC accumulation, while high intensity and frequency of cultivation cause SOC decline (Bajracharya *et al*. 1998). High values of SOC were seen for dense broad leaf forest than in pine forest, while very low SOC contents occurred under the degraded condition. The regenerating forest also has less SOC than mixed forest (Baral *et al*. 1999, cited by Bajracharya *et al*. 2004). As, from our analysis, SOC of Mixed Broad Leaf Forest was found to be higher than Pine Forest, similar to result of Baral & Guha (1999) cited from Bajracharya *et al*. (2004).

The south and south west facing slopes tend to notably warm and dry causing depletion in SOC, while north and north east aspects are cooler, more moist , with slower growth and decomposition rates ; hence greater accumulation of organic carbon (Bajracharya *et al* 2004). SOC was found to be higher in Mixed Broad Leaf Forest it might be because of, Pine Forest lies in the south facing slopes where as the Mixed Broad Leaf forest lies in the east facing slopes.

A Mixed Broad Leaf Forest have higher in nutrition (Boral & Jhas 1984) and rich in organic matter such as leaves of *Schima wallichi*, ground vegetation such as *Eupatorium adenophorum*, *Artimisia vulgeris*, *Sapium insignia* and others (Bhandari *et al*. 1982). In the present study area, Mixed Broad Leaf Forest was found to be dominated by the different types of tree species such as *Schima wallichi*, A*lnus nepalensis, Rhododendron arboreum* where as the ground vegetation of Pine forest was found to be covered by pine leaves, lowering the accumulation of SOC, similar with the finding of (Bhandari *et al*. 1982).

Similarly, SOC in (0-50) cm depth of the soil layer at Pakhribas was estimated to be 49.83 toh/ha (DFID & DSS 1997-1999). This estimation is higher than the present study. It might be because of certain perturbations of the system; such as deforestation, some types of fires, tillage and artificial drainage, grazing pressure. It is stated that, certain perturbation of the system causes the net loss of carbon from the soil system (Brady & Weil 2002).The forest soil has good potential for carbon sequestration because more SOC is concentrated in micro aggregates (<1mm), which are more stable and less subjected to organic carbon deposition (Shrestha *et al*. 2003).

5.2.3. **Total Biomass and Soil, Organic Carbon Content:** The total above and below organic carbon of Pine Forest was found to be higher than that of Mixed Broad Leaf Forest. Singh (2005) estimated the total above and below ground net organic carbon sequestration potential in the Kusunde Community Forest was 48.90 ton/ha and 8.82 ton/ ha. Our present data compared with Singh (2005) total above and below ground organic carbon of both types of forest is found to be higher. It might be Kusunde Community Forest was regenerating forest (Singh 2005), but Pine Forest of the study area was not regenerating forest and Mixed Broad Leaf Forest was regenerating forest and these two types of forest were well managed by the Community forest user groups.

5.5.4. Carbon Sequestration Rate in Sunaulo Ghaympe Danda Community Forest: Total carbon sequestration by both forests was found to be 3.95 ton/ha/yr. Maraseni *et.al* (2005) estimated the carbon sequestration by the Nepal's forest was found 1.62 megaton/yr. Carbon sequestration rate of present study is found to be higher than that of Maraseni *et.al* (2005). The total carbon sequestered by Sunaulo Ghyampe Danda Community Forest was found to be 112.63 ton C/yr as described in (Annex 8d).

5.2.5. Monetary value of carbon sequestration by Sunaulo Ghaympe Danda Community Forest: Studies have revealed that carbon stored in community forests can also be considered as non-timber forest products, which when traded in emerging global carbon market, have the potential to bring additional benefits to the people in the form of income (Sharma *et.al*. 2007). The additional benefit can be shared by the user groups of Sunaulo Ghyampe Danda Community Forest from carbon trading. Based on carbon sequestered per annum by the community forest, the additional Benefit to community forest users groups by carbon trading ranges minimum from $563.15 to maximum based on community forest category.

To get the benefit from CDM, every country must be the signatory of the UNFCCC, ratify the Kyoto Protocol. Nepal is a Signatory country of UNFCCCand has ratified the Kyoto Protocol. On Kyoto Protocol Article 12, CDM is the only activity where developing countries like Nepal can participate in the collective action for emission reduction. In general, forest resources utilized by communities under sustainable management practices can be of perpetual use and when using biomass energy from such sources, there is no net atmospheric CO_2 emission as CO_2 released during combustion is compensated by those sequestered during growth of biomass (Watson *et al.* 1996).

Limiting CDM activities to afforestation and reforestation is a major setback to Nepalese community forestry, as this excludes naturally regenerated forests prior to 1990 that were managed by local communities as is common in Nepal. In most cases, degraded forests were rehabilitated not only by planting trees on totally barren land for 50 years or before 1990, but by protecting and managing severely degraded forests. Afforestation and Reforestation do not exclude naturally regenerated forest; in fact they are compatible with community based multi-species plantation (Smith & Scherr 2002).

Community forest is characterized by high transaction cost as it entails negotiating land-use decision with a spatially dispersed large population (Smith & Scherr 2003) in comparison to a large-scale industrial plantation where negotiations are limited to a few large-scale operators. Rural areas of developing countries are also deep pits of market failure. In this case, information on techniques to measure carbon in forests and to manage carbon as a non-timber forest product (NTFP) is not available to the communities managing forests.

Viewing all these scenarios of benefits and conditions of CDM and status of Community forest in Nepal, there are some options that Community forests can benefit once the Kyoto Protocol recognize community forest as eligible activity for CDM project. For that, identification of the area of forests that were planted prior to 1990 is important. Similarly, inventory of these forests to estimate the carbon is essential and this task would seem challenging especially when we do not have allorimetric equations for all the forest tree species in the community forest and the cost would be very high, when the preparation are not made well in advance. Similarly, on the government front, MFSC and other Ministry should be active in the international groundwork for policy lobbying to draw attention towards making community forest activities eligible for CDM, at least beyond the second commitment period. Most of the forests handed over are rehabilitated and regenerated by the local people.

Inadequate information about the status of biomass and carbon stocks in community managed forest of Nepal after 1990 has been a major problem to estimate total contribution of community forest on sequestrating carbon and claming for the compensation from global climate funds.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

- The estimated total biomass organic carbon stock was higher in Pine Forest i.e (116.50±16.39)ton/ha than that of Mixed Broad Leaf Forest (25.93±1.03) tan/ha.

- The estimated SOC of the Mixed Broad Leaf Forest was higher i.e (24.62±1.18)ton/ ha than that of Pine Forest ie. (10.12±1.03)ton/ha. The soil SOC decreases as the depth of soil increases in both type of forest.

- The estimated total above ground organic carbon of Pine Forest was 99.79ton/ha which was higher than that of Mixed Bored Leaf Forest i.e 23.54 ton/ha and the below ground organic carbon of Mixed Broad Leaf Forest was 26.22 ton/ ha which was higher than that of Pine Forest i.e. 21.79 to/ ha .

- The estimated total biomass and SOC of Pine Forest was 126.56 ton/ha which was higher than that of Mixed Broad Leaf Forest i.e 49.76 ton/ ha.

- The estimated carbon sequestration rate of the Pine Forest was lower i.e 1 ton/ ha/ year than that of Mixed Board Leaf forest i.e. 2.95 ton/ ha / year.

- Based on carbon sequestered per annum by the community forest, the additional Benefit to community forest users groups by carbon trading ranges minimum from $563.15 to maximum based on community forest category.

6.2. RECOMMENDATION

- The Carbon Sequestration rate of regenerating forest is higher than old forest. It is strongly recommended to do further plantation in the bare land to regulate the climatic condition and to get benefit from the carbon trading.

- The Nepal Government is recommended to be active in the international groundwork for policy lobbying to draw attention towards making Community Forest activities eligible for CDM, at least beyond the second commitment period.

- Stocks of forests under community managed needs to be identified prior 1990 and give information to Forest users group about possible benefit of carbon sequestration.

- It is recommended to conduct further research on the different forest types, different climatic zones, different soil types and different forest management system to monitor carbon sequestration. So, that the standard carbon management system can be applied to mitigate climate change.

- The allometeic equation for the different tree species of Nepal with different age are recommended to calculate for the estimation of the biomass of trees.

- It is further recommended to study for the estimation of the Carbon sequestration rate of different forest types by using its own allometric equation with different constant value for the estimation of the biomass of trees.

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ANNEX-1
Soil Organic Carbon Content of Pine Forest and Mixed Broad Leaf Forest

Site -	Depth (cm)	P.F	MBLF	P.F	MBLF	P.F	MBLF	P.F	MBLF
		% C		Bulk Density(gm/cc)		Carbon (kg/m2)		Carbon con.(ton/ha) (±1.18)	(±1.03)
1	0-25	0.47	1.37	0.74	0.69	0.87	2.39	8.76	23.90
	25-50	0.36	1.21	0.76	0.76	0.69	2.29	6.90	22.99
2	0-25	0.38	1.12	0.65	0.71	0.62	1.99	6.24	19.93
	25-50	0.3	1.06	0.70	0.72	0.52	1.92	5.28	19.23
3	0-25	0.39	1.53	0.66	0.63	0.64	2.40	6.47	24.09
	25-50	0.34	1.38	0.71	0.69	0.60	2.38	6.05	23.80
4	0-25	0.36	1.84	0.63	0.71	0.56	3.27	5.67	32.75
	25-50	0.32	1.3	0.69	0.76	0.55	2.47	5.52	24.76
5	0-25	0.38	2.8	0.63	0.64	0.60	4.50	6.07	45.01
	25-50	0.33	2.4	0.65	0.67	0.53	4.02	5.36	40.20
6	0-25	0.53	1.12	0.69	0.68	0.91	1.91	9.15	19.15
	25-50	0.42	0.62	0.80	0.72	0.84	1.12	8.48	11.22
7	0-25	0.35	1.37	0.81	0.74	0.71	2.55	7.10	25.55
	25-50	0.29	0.87	0.85	0.80	0.62	1.75	6.20	17.57
8	0-25	0.49	2.82	0.77	0.60	0.94	4.24	9.46	42.44
	25-50	0.43	1.75	0.83	0.69	0.89	3.04	8.97	30.40
9	0-25	0.5	1.66	0.65	0.66	0.81	2.73	8.12	27.39
	25-50	0.39	1.46	0.72	0.68	0.70	2.49	7.07	24.96
10	0-25	0.46	1.41	0.615	0.72	0.70	2.55	7.07	25.59
	25-50	0.4	1.21	0.65	0.68	0.65	2.08	6.58	20.84
11	0-25	1.13	1.33	0.65	0.80	1.85	2.68	18.56	26.86
	25-50	1.02	0.95	0.72	0.81	1.83	1.92	18.38	19.28
12	0-25	1.14	2.91	0.68	0.68	1.94	4.97	19.49	49.76
	25-50	0.49	1.42	0.70	0.76	0.86	2.69	8.63	26.98
13	0-25	0.99	1.06	0.71	0.73	1.77	1.93	17.79	19.39
	25-50	0.85	0.63	0.78	0.82	1.67	1.29	16.72	12.93
14	0-25	1.34	2.14	0.73	0.56	2.45	3.00	24.52	30.01
	25-50	0.91	1.24	0.82	0.58	1.88	1.80	18.83	18.04
15	0-25		0.52		0.61		0.79		7.95
	25-50		0.35		0.63		0.55		5.56
						Total(ton/ha		283.56	738.63
						average(ton/ha)		10.12	24.62

ANNEX-2

Biomass and Carbon content of Pine Forest.

site	No. of pine species	Stem (ton/ha)	Branch (ton/ha)	Foliage (ton/ha)	Root (ton/ha)	Total (ton/ha)	C.content (ton/ha) (± 16.39)
1	4	209.1	62.68	6.88	31.35	310.02	155.01
2	6	127.51	38.00	4.20	19.13	189.10	94.55
3	1	19.62	5.88	0.64	2.94	29.08	14.55
4	12	36.57	10.97	1.20	5.48	54.23	27.11
5	19	113.31	40.00	4.40	17.97	197.90	98.85
6	24	158.96	47.68	5.24	23.84	235.74	117.87
7	38	160.36	48.11	5.30	24.03	237.82	118.97
8	22	166.08	49.82	5.48	24.91	246.29	123.14
9	23	264.92	79.47	8.74	39.74	392.89	196.44
10	30	353.81	106.14	11.67	53.08	524.71	262.35
11	38	160.36	48.11	5.29	24.06	237.82	118.91
12	12	87.14	26.14	2.87	13.08	129.24	64.62
13	14	198.74	39.62	6.56	29.80	294.72	147.35
14	6	123.17	36.95	4.07	18.48	182.66	91.33
TOTAL	249	155.69	45.68	5.20	23.42	233.00	116.50

ANNEX-3

Biomass and carbon content of Mixed Broad Leaf Forest.

site	No. of species	Stem (ton/ha)	Branch (ton/ha)	Foliage (ton/ha)	Root (ton/ha)	Total (ton/ha)	C.content (ton/ha) (± 8.09)
1	26	23.02	7.74	6.85	3.45	41.07	20.53
2	21	14.86	5.14	3.76	2.23	26.01	13.00
3	20	8.18	3.53	2.47	1.22	15.42	7.712
4	18	44.24	20.10	9.19	6.63	80.17	40.08
5	27	118.91	43.40	22.8	15.18	200.31	100.15
6	10	20.29	14.08	4.45	3.04	41.87	20.93
7	30	19.47	10.20	6.92	2.92	39.52	19.78
8	20	14.02	7.15	4.62	2.10	27.90	13.95
9	15	24.95	10.15	5.68	3.74	44.53	22.26
10	21	16.18	7.32	5.72	2.42	31.66	15.83
11	14	115.77	80.59	22.64	3.39	3.39	111.20
12	25	33.217	13.71	7.36	4.98	59.27	29.63
13	07	1.77	0.86	0.30	0.26	3.21	1.60
14	13	7.71	2.18	1.24	1.24	12.38	6.19
15	15	18.82	6.30	5.85	2.82	33.80	16.90
TOTAL	276	32.09	7.66	7.33	4.81	51.90	25.95

ANNEX-4

Soil pH, Moisture Content, Conductivity and Temperature of Pine Forest and Mixed Broad Leaf Forest

Site -	Depth (cm)	pH P.F	pH MBLF	Moisture content P.F	Moisture content MBLF	conductivity P.F	conductivity MBLF	Soil temp P F	Soil temp MBLF
1	0-25	6.2	5.0	14.76	17.00	22	21	17.0	22.0
	25-50	6.0	4.9	16.30	12.00	16	09	15.5	20.0
2	0-25	5.7	5.1	17.91	14.14	15	06	17.0	23.0
	25-50	5.6	5.0	18.80	13.29	14	05	16.0	21.0
3	0-25	5.7	4.8	14.83	15.99	15	09	19.0	25.0
	25-50	5.6	4.7	17.50	21.49	14	07	17.0	23.0
4	0-25	5.7	4.6	22.53	18.33	17	09	12.5	23.0
	25-50	5.7	4.7	22.17	07.23	16	06	12.0	24.0
5	0-25	5.8	5.5	20.01	12.49	19	15	15.5	23.0
	25-50	5.7	5.6	19.91	12.19	18	11	15.0	21.0
6	0-25	5.9	5.0	14.66	15.40	28	06	17.0	25.0
	25-50	5.9	5.1	16.11	15.45	22	04	16.0	23.0
7	0-25	5.5	4.7	09.87	14.20	23	20	17.0	20.0
	25-50	5.5	4.7	07.95	18.94	21	12	15.0	18.0
8	0-25	5.8	5.9	14.46	21.07	22	47	17.0	16.5
	25-50	5.8	5.8	12.56	19.56	20	23	16.5	15.0
9	0-25	5.8	4.6	16.60	27.33	20	09	16.0	21.0
	25-50	5.5	5.6	15.20	24.68	21	07	15.5	20.0
10	0-25	5.7	5.0	18.12	16.70	20	06	17.0	18.0
	25-50	5.6	4.7	17.10	15.00	19	05	15.5	17.0
11	0-25	5.4	5.0	23.00	13.42	05	18	23.0	19.5
	25-50	5.3	4.7	22.00	12.27	04	14	22.0	19.0
12	0-25	5.8	4.5	20.30	22.14	23	14	23.0	22.5
	25-50	5.7	4.8	20.20	18.00	13	06	22.0	21.5
13	0-25	5.7	4.5	24.00	21.67	26	12	24.0	24.5
	25-50	5.6	4.7	23.00	22.24	13	07	23.0	20.5
14	0-25	5.5	4.6	20.00	25.87	08	07	20.0	26.5
	25-50	5.4	4.5	18.50	24.21	04	07	18.5	22.5
15	0-25		4.7		18.90		09		24.0
	25-50		5.0		19.92		04		21.0

ANNEX-5

% and mg/100g of Available Phosphorous of Pine Forest and Mixed Broad Leaf Forest Soil

Site -	Depth (cm)	P.F	MBLF	P.F	MBLF
		% of available Phosphorus		mg/100g	
1	0-25	0.002	0.005	2.079	5.737
	25-50	0.000	1.402	0.899	0.014
2	0-25	0.001	0.008	1.253	8.038
	25-50	0.000	0.000	0.663	0.694
3	0-25	0.000	0.000	0.368	0.899
	25-50	0.000	0.001	0.663	1.548
4	0-25	0.001	0.005	1.135	5.088
	25-50	0.001	0.033	1.017	3.113
5	0-25	0.003	0.001	3.082	1.076
	25-50	0.002	0.003	2.492	3.731
6	0-25	0.004	0.000	4.085	0.132
	25-50	0.001	0.002	1.135	2.256
7	0-25	0.002	0.006	2.433	6.622
	25-50	0.002	0.002	2.315	2.374
8	0-25	0.006	0.004	6.091	4.911
	25-50	0.008	0.001	8.215	1.725
9	0-25	0.006	0.000	6.917	0.576
	25-50	0.006	0.000	6.858	0.899
10	0-25	0.004	0.002	4.675	2.551
	25-50	0.004	0.001	4.321	1.548
11	0-25	0.004	0.004	4.707	4.348
	25-50	0.003	0.003	3.875	3.747
12	0-25	0.006	0.003	6.576	3.952
	25-50	0.003	0.003	3.900	3.516
13	0-25	0.004	0.003	4.016	3.632
	25-50	0.002	0.005	2.044	5.091
14	0-25	0.005	0.003	5.436	3.785
	25-50	0.007	0.004	7.356	4.028
15	0-25		0.005		4.800
	25-50		0.004		4.784

ANNEX-6

Soil Nitrate content of Pine Forest and Mixed Broad Leaf Forest

Site	Depth (cm)	P.F	MBLF	P.F	MBLF	P.F	MBLF
		NO3-Nmg/l of soil extract		Moisture Content(%)		% Nitrate –N {10*E^(-5)}	
1	0-25	0.39	0.25	14.76	17.00	1.32	7.11
	25-50	0.33	0.26	16.37	12.00	1.02	1.09
2	0-25	0.49	0.40	17.91	14.14	1.38	1.36
	25-50	0.74	0.42	18.80	13.29	1.97	1.58
3	0-25	0.72	0.36	14.83	15.99	2.45	1.32
	25-50	0.41	0.28	17.50	21.49	1.20	6.56
4	0-25	0.46	0.33	22.53	18.38	1.02	6.59
	25-50	0.30	0.24	22.17	07.23	6.79	1.65
5	0-25	0.48	0.38	20.01	12.49	1.21	1.50
	25-50	0.46	0.38	19.91	12.19	1.16	1.56
6	0-25	0.73	0.24	14.66	15.40	2.49	7.66
	25-50	0.69	0.37	16.11	15.45	2.15	1.19
7	0-25	0.56	0.34	09.87	14.00	2.88	1.19
	25-50	0.54	0.34	07.95	18.94	3.42	8.89
8	0-25	0.50	0.30	14.46	21.07	1.73	6.89
	25-50	0.59	0.38	12.56	19.56	2.73	9.96
9	0-25	0.68	0.30	16.60	27.33	2.09	5.31
	25-50	0.60	0.29	15.20	24.68	1.97	5.72
10	0-25	0.62	0.37	18.21	16.70	1.71	1.10
	25-50	0.58	0.33	17.10	15.00	1.70	1.08
11	0-25	0.03	0.05	23.00	13.42	0.68	1.64
	25-50	0.04	0.02	22.00	12.27	1.01	5.08
12	0-25	0.03	0.17	23.00	22.14	0.76	0.38
	25-50	0.05	0.06	22.00	18.00	1.14	1.70
13	0-25	0.05	0.07	24.00	21.67	1.18	1.68
	25-50	0.08	0.08	23.00	22.24	1.89	1.80
14	0-25	0.054	0.06	20.00	25.87	1.35	1.18
	25-50	0.058	0.07	18.50	24.21	1.57	1.50
15	0-25		0.05		18.90		1.31
	25-50(5-timesdil.)		0.09		19.92		2.30

ANNEX-7

Soil Nitrogen content of Mixed Broad Leaf Forest

site	Depth (cm)	P.F	MBLF	P.F	MBLF
		Total vol. of acid used (ml)		Nitrogen %	
1	0-25	3.00	3.8	1.19	0.25
	25-50	2.10	3.1	1.33	0.20
2	0-25	2.60	2.2	1.68	0.14
	25-50	2.20	2.5	1.40	0.16
3	0-25	2.70	2.4	1.75	0.15
	25-50	2.70	2.2	1.75	0.14
4	0-25	2.80	2.6	1.82	0.17
	25-50	2.25	2.1	1.43	0.13
5	0-25	2.30	2.5	1.47	0.16
	25-50	2.10	2.8	1.33	0.18
6	0-25	2.45	2.9	1.57	0.19
	25-50	2.65	2.3	1.71	0.15
7	0-25	2.75	2.5	1.078	0.16
	25-50	2.50	2.3	1.61	0.15
8	0-25	2.50	3.2	1.61	0.21
	25-50	2.75	2.9	1.78	0.19
9	0-25	3.75	2.5	2.48	0.16
	25-50	2.50	2.3	1.61	0.15
10	0-25	2.50	2.8	1.61	0.18
	25-50	2.30	2.6	1.47	0.17
11	0-25	3.50	4.1	2.12	0.16
	25-50	2.70	3.2	1.06	0.10
12	0-25	2.40	2.0	1.04	0.02
	25-50	1.70	3.2	1.01	0.10
13	0-25	3.40	3.2	1.11	0.10
	25-50	2.10	3.1	1.02	0.10
14	0-25	2.20	2.9	1.03	0.07
	25-50	2.90	3.1	1.06	0.09
15	0-25		3.1		0.09
	25-50		2.5		0.05

ANNEX-8

Biomass and SOC estimation

ANNEX-(8a): Total stock of biomass carbon (ton/ha) of both type of forest:

S. N	Forest Type	Stem biomass (ton/ha)	Branch biomass (ton/ha)	Foliage biomass (ton/ha)	Root biomass (ton/ha)	Total biomass (ton/ha)	Total carbon. (ton/ha)
1	Pine forest	155.69	45.68	5.20	23.42	233.0	116.50
2	Mixed forest	32.097	7.6626	7.334	4.8145	51.9081	25.95

ANNEX-(8b): Total soil organic carbon stock. (ton/ha).

S.N	Forest type	SOC(ton/ha) (0-25)cm	(depth) (25-50) cm	Total soil organic carbon(ton/ha)
1	Pine forest	5.51	4.56	10.083
2	Mixed forest	13.99	9.83	23.82

ANNEX-(8c) Total stock of organic carbon (ton/ha) showing above and below organic carbon.

S.N	Forest type	Total above ground organic carbon(ton/ha)	Total below ground organic carbon(ton/ha)	Total carbon (ton/ha)
1	Pine forest	99.79	21.79	126.58
2	Mixed forest	23.54	26.22	49.76

ANNEX-(8d): Carbon sequestration status in Pine forest and Mixed Broad Leaf forest

S.N	Forest type	C storage of this year as biomass (ton/ha)	C storage of previous year as biomass (ton/ha)	C seq. rate (ton/ha/yr)	Area (ha)	Total C seq. (ton/ha/yr)
1	Pine forest	166	144	1	20	20
2	Mixed forest	25.95	23.5	2.95	31.4	92.63

ANNEX-9

GPS located sampling point of Pine Forest and Mixed Broad Leaf Forest.

SAMPLING PLOT	P.F	MBLF	P.F	MBLF
	latitude	longitude	latitude	longitude
1	27.6276	27.62978	85.27715	85.28581
2	27.6273	27.62974	85.27755	85.28511
3	27.62735	27.62931	85.27877	85.28611
4	27.62708	27.62931	85.28020	85.28611
5	27.62675	27.62859	85.28163	85.28588
6	27.62644	27.6275	85.28207	85.2816
7	27.62593	27.63123	85.28227	85.28427
8	27.62559	27.62832	85.28187	85.28537
9	27.62433	27.62805	85.28042	85.27697
10	27.62628	27.62992	85.28018	85.28297
11	27.62652	27.632	85.28087	85.28242
12	27.624	27.63163	85.2803	85.28386
13	27.62391	27.62826	85.28058	85.28236
14	27.62706	27.62994	85.28355	85.28224
15		27.62913		85.28432