ASSESSMENT OF SOIL ORGANIC CARBON STOCK OF CHURIA BROAD LEAVED FOREST

(A Case Study of Bhedawari Community Forest of Nawalparasi District)

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DECLARATION

I hereby declare that this research work entitled "**Assessment of Soil Organic Carbon Stock of Churia Broad Leaved Forest**" *(A Case Study of Bhedawari Community Forest of Nawalparasi District)* is my original work and all the sources of information are duly acknowledged. This work has not been published or submitted elsewhere for any other academic institution for any degree.

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Bharat Mohan Adhikari

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ABSTRACT

Global warming is caused primarily by increase in greenhouse gases such as Carbon Dioxide (CO_2). Soil Organic Carbon (SOC) content significantly influence climate change and a slight change in the SOC stocks can have a considerable effect on atmospheric carbon dioxide concentration. Therefore, it is interesting to investigate how SOC in the profiles varied under different altitude and aspect in community managed Churia broad-leaved forest.

*The research entitled "***Assessment of Soil Organic Carbon Stock of Churia Broad Leaved Forest***" was carried out to assess soil organic carbon stock of Churia broad leaved forest in Bhedawari Community Forest, Nawalparasi. Specific objectives were to assess the soil organic carbon up to 30cm depths of Churia broad leaved forest and to compare the variation of soil organic carbon with altitudes and aspects. To achieve the objectives, Soil samples were collected randomly in five replicates each from the two aspects (North and South) and elevation classes (350m and 550m). Soil samples were taken from 0–10cm, 11-20 cm and 21–30 cm soil depths. Core sampling method developed by Blake and Hartge (1986) was used to determine Bulk Density. Soil organic carbon was determined by the titrimetric method developed by Walkley-Black (1934). Total soil organic carbon was calculated using the formula given by Chabbra et al. (2003).*

The total amount of soil organic carbon stock upto 30cm depth in Bhedawari Community Forest (CF) was found to be 33.91 t/ha. Average SOC at various depth 0-10cm, 10-20cm and 20-30cm were 15.34 t/ha, 9.96 t/ha, 8.61 t/ha respectively. The average bulk density of Bhedawari CF was found to be 1.47 gm/cu.cm. Similarly the average soil organic carbon percent of Bhedawari CF was found to be 0.79. The result of one way ANOVA shows that altitude had made significant impact in total SOC (t/ha) at 95% confidence interval with p value 0.015 ($p<0.05$). While, SOC was found non-significant with respect to aspects at 95% confidence interval with p value 0.278 ($p>0.05$).

Key words: Carbon Sequestration, Soil Organic Carbon, Altitude, Aspect

शोध-सार

Global Warming मुख्य रुपमा हरितगृह ग्यास जस्तै कार्वन-डाइअक्साइड (CO_2) वृद्दि हुदा हुने गर्दछ । माटोको कार्वन संचितीले जलवायु परिवर्तनमा महत्वपूर्ण असर पार्दछ र कार्वन संचितीमा हुने सानो परिवर्तनले वायुमण्डलीय कार्वन-डाइअक्साइडमा असर पुर्याउन सक्छ । तसर्थ, चुरे क्षेत्रको वनमा उचाई तथा वनको मोहडाले माटोको कार्वन संचितीमा कसरी असर पुर्याउछ भनी अध्यनन गर्नु महत्वपूर्ण रहेको पाइन्छ ।

माटोको जैविक कार्वन (SOC) को अवस्था थाहा पाउन चुरे क्षेत्रको भेडावारी सामुदायिक वनमा अध्ययन गरियो । यस अध्ययनको प्राथमिक उद्देश्य ३० से.मी गहिराइसम्म माटोको जैविक कार्वन मात्रा थाहा पाउनु र विभिन्न उचाई तथा वनको मोहडमा माटोको कार्वन संचितीमा हुने भिन्नता हेर्नु हो । यसका लागी प्रत्येक ३५० मिटर र ५५० मिटर उचाई एवं उत्तर र दक्षिणी मोहडाबाट ५/५ ठाउबाट Randomly माटोको नमूना संकलन गरियो। प्रत्येक प्लटमा ३ विभिन्न गहिराइ ०-१० से.मी, ११-२० से. मी र २१-३० से. मी बाट माटोको नमूनाहरु लिइयो । Bulk Density निर्धारण गर्न Blake and Hartge (1986) द्वारा विकसित Core Sampling विधि तथा माटोको जैविक कार्वन Walkley-Black (1934) विधि द्वारा निर्धारित गरिएको थियो । यसै गरि माटोमा रहेको जैविक कार्वन संचिती Chabbra et al. (2003) को सुत्र बाट निकालियो ।

भेडावारी सामुदायिक वनमा ३० से.मी गहिराइ सम्म माटोको कुल कार्वन संचिती ३३.९१ टन/हे. रहेको पाइयो । जुन ०-१० से.मी, ११-२० से. मी र २१-३० से. मी मा क्रमशः १५.३४ टन/हे., ९.९६ टन/हे. र ८.६१ टन/हे.रहेको थियो । साथै भेडावारी सामुदायिक वनको Bulk Density १.४७ ग्राम घन/से.मि. तथा जैविक कार्वन ०.७९ प्रतिशत भेटियो ।

One-way ANOVA को 95% confidence interval मा हेरिएको नतिजा अनुसार, विभिन्न उचाईको असर माटाको जैविक कार्वनमा परेको पाइयो जसमा P0.015 ($P< 0.05$) रहेको थियो । तर, वनको मोहडाले माटोको जैविक कार्वनमा असर नपर्ने जसमा P0.278 ($p>0.05$) पाइयो ।

मुख्य शब्दहरुः कार्वन संचितीकरण, माटोको जैविक कार्वन, उचाई , मोहडा

ACRONYMS

BD	Bulk Density
C	Carbon
CF	Community Forest
cm	Centimeter
CO_2	Carbon Dioxide
COP	Conference of the Parties
CDM	Clean Development Mechanism
CFUG	Community Forest User Group
CIFOR	Center for International Forestry Research
DFRS	Department of Forest Research and Survey
DoF	Department of Forest
FAO	Food and Agriculture Organization
FCTF	Forest Carbon Trust Fund
gm / cm^3	gram per cubic centimeter
GHGs	Greenhouse Gases
Gt	Giga ton
ha	Hectare
ICIMOD	International Centre for Integrated Mountain Development
IPCC	International Panel on Climate Change
MoFSC	Ministry of Forest and Soil Conservation
MoPE	Ministry of Population and Environment
Pg	Penta Gram
REDD	Reducing Emission from Deforestation and Forest Degradation
SOC	Soil Organic Carbon
t/ ha	ton per hectare
UNFCCC	United Nation Framework Convention on Climate Change

CHAPTER: ONE INTRODUCTION

1.1 Background of the Study

The interaction between climate change and the global carbon cycle is an important aspect of the global environmental changes (IPCC, 2007). Soil is the largest pool of terrestrial organic carbon in biosphere, storing more Carbon (C). Therefore, the Soil Organic Carbon stock has an irreplaceable function in mitigating climate change as a key component of the biosphere carbon cycle. Meaning that changes in SOC content significantly influence climate change and a slight change in the SOC stocks can have a considerable effects on atmospheric carbon dioxide concentration, contributing to climate warming (Jobbagy and Jackson, 2000).

Soil, being the largest carbon reservoir of the terrestrial carbon cycle, about three times more carbon is contained in soil than in the world's vegetation and soils hold double the amount of carbon that is present in the atmosphere (Sheikh et al. 2009). The amount of stored SOC is the net balance between C inputs from plant production and losses through decomposition and leaching. Hence, depending upon C fluxes, the soil can either be a source or sink for atmospheric CO_2 (Schrumpf et al. 2011). The stability and distribution of SOC in the soil profile is influenced by biotic controls such as the abundance and vigor of faunal, microbial and plant species as well as environmental controls like temperature, moisture and soil texture (Lorenz and Lal, 2005). Topography (altitude, aspect) through its influence on climate, soil properties, is largely responsible for the spatial and vertical distributions of SOC. The expected decrease in temperature with altitude depresses organic matter decomposition rates more than litter production, and generally favors the accumulation of SOC. However, as the soil becomes shallower at the higher altitudinal zones, the overall SOC storage capacity is limited despite higher SOC content per unit of soil mass. While a number of previous studies reported increased SOC with altitude (Griffiths, 2009; Chen and Chiu, 2000) also, there have been records of decreased in SOC with altitude (Sheikh et. al., 2009; Zhong and Xu, 2009). While many studies have reported higher SOC content (Begum et al. 2010; Egli et al. 2009; Sharma et al. 2010) on the north-facing slopes of the Himalayas, Sidari et al. (2008) reported lower SOC content on the northern aspect direction. In contrast, Han et al. (2010) did not find any significant difference in SOC content between the north and south-facing slopes. SOC is highly heterogeneous because of local-scale variability in soil environment and microclimate. In Nepal, average organic carbon in soil, litter and debris, and tree component (≥10 cm DBH) are 67.14 t/ha, 1.19 t/ha and 108.88 t/ha, respectively. The highest soil organic carbon stock (114.03 t/ha) was estimated in High Mountains and High Himal regions. SOC was the lowest in Churia region with an average of 31.44 t/ha. The results from Middle Mountains region showed an average SOC stock of 54.33 t/ha. SOC stock in the forests of the Terai was found to be slightly higher than in Churia (Department of Forest Research and Survey, 2015). Carbon emissions from deforestation account for an estimated 20% of global carbon emissions (IPCC, 2006), second only to that produced by fossil fuel combustion. To successfully reduce greenhouse gas emissions from land cover change, effective strategies for protecting natural habitats are needed. Thus, assessment of SOC is important for C budgeting, designing appropriate C sequestration strategies and enhancing our understanding of biogeochemical cycles. The aim of this study was therefore to investigate how SOC in the profiles varied under different altitude and aspect in community managed Churia broad-leaved forest.

1.2 Rationale of the Study:

Forest can be a major carbon sink, which can effectively reduce the emitted carbon through sustainable management. As the largest pool of terrestrial organic carbon, soils interact strongly with atmospheric composition, climate, and land cover change. Our capacity to predict and ameliorate the consequences of global change depends in part on a better understanding of the distributions and controls of SOC and how topography affects SOC distributions with depth. It is therefore necessary to estimate clearly and to understand the potential role of forests in the alleviation of global warming. Nepal as being among the most vulnerable countries to climate change (ICIMOD, 2007) and it is the main concern issue to mitigate climate change for the betterment of the environment**.** A/to ICIMOD (2009) report, Current knowledge of forest carbon, carbon budgets and ecosystem change process is especially lacking in highly heterogeneous and diverse mountainous regions such as Hindu Kush Himalayan. In context of Nepal, many researchers have assessed the soil carbon stock in different land use types, forest management regime and species. However, there is very little research conducted yet evaluating the effect of topography (aspect and altitude) on soil carbon stock in Churia broad- leaved forest. This research will help explore whether there is difference in soil carbon stock according to aspect and altitude because it is generally unknown in community managed broad-leaved forest. The study also provides valuable information to forestry sector for planning and policy making by concerned bodies.

1.3 Objectives:

The **general objective** of the study is to assess the soil organic carbon stock in Churia broadleaved forest.

Specific Objectives:

- To determine the bulk density of soil horizon up to 30cm depth with respect to aspect and elevation
- To quantify soil organic carbon stock up to 30cm depth in different elevation and aspect
- To compare the variation of soil organic carbon stock with respect to aspect and altitude

1.4 Hypothesis

H0: There is no significant difference in SOC stock within aspects and altitudes.

H1: There is significant difference in SOC stock within aspects and altitudes.

1.5 Limitations of the Study

The findings of this research were based on a case study and do not necessarily represent the regional or national scenario but the findings can be used as a base line scenario for similar type of forest for further research.

- ✓ Despite maintaining high accuracy in field some error may arise due to human error.
- ✓ This study was undertaken only in one community forest of Churia region. Findings of this research do not necessarily represent the regional or national scenario but the result can be used as a baseline scenario for the future research.
- ✓ For the better understanding of the entitled purpose a national level research is utmost.

CHAPTER TWO: LITERATURE REVIEW

2.1 Green House Gases and its Effect

Greenhouse gases (GHGs) are "Gas molecules that absorb thermal infrared radiation, and are in significant enough quantity, can force the climate system". GHGs include water vapor (36-72%), carbon dioxide (9-26%), methane (4-9%), Ozone (3-7%), traces of nitrous oxide (N_2O) and other gases.

CO_2 and other greenhouse gases act like a blanket, absorbing IR radiation and preventing it from escaping into outer space. Since, the Industrial Revolution in the early 1800s, the burning of fossil fuels like coal, oil and gasoline have greatly increased the concentration of greenhouse gases in the atmosphere, especially CO_2 (National Oceanic and Atmospheric Administration).

Earth is constantly bombarded with enormous amounts of radiation, primarily from the sun. The solar radiation includes visible light, ultra-violet, infrared & other types of invisible light. About 30% of the radiation striking Earth's atmosphere is immediately reflected back to space by clouds, ice, snow, sand & other reflective surfaces, according to NASA. The remaining 70% of incoming solar radiation is absorbed by the oceans, the land and the atmosphere.

There's a delicate balancing act occurring every day all across the Earth. The equilibrium of incoming and outgoing radiation makes the Earth habitable, with an average temperature of about 59 degrees Fahrenheit (15 degrees Celsius), according to NASA. Without greenhouse gases, the average temperature of Earth's surface would be about −18°C (0°F). (https://www.livescience.com/37743-greenhouse-effect.html)

The greenhouse effect is a natural phenomenon however anthropogenic activities are amplifying the natural greenhouse effect in the earth.

2.2 Global Warming

Global warming is the increase of the earth's average surface temperatures due to the effect of GHGs. These GHGs such as carbon dioxide, methane and water vapor absorb heat that would otherwise escape from the earth. Global warming has emerged as one of the biggest environment issues in the last two decades.

According to Environment Protection Agency reports, the earth temperature has increased by 0.8^{0}C over the past century. More than half of this increase has happened in the last 25 years. Natural events and human activities are responsible to global warming adding large amount of heat trapping gases to the atmosphere. Human activities like burning of fossil fuels, deforestation, pollution, industrialization are considered as few of the factors responsible for global warming. Our fossil fuel is the main source of these gases followed by deforestation in the tropics including other land use changes.

The major factor affecting the global warming is high concentration of GHGs in the atmosphere. Chlorofluorocarbon remains the second factor responsible for global warming. Since, the preindustrial times the atmospheric concentration increased by 31%. Over the same period, atmospheric methane has risen by 151%. This increase in the trapped heat changes the climate, causing altered weather patterns that can usually bring unusually intense precipitation or dry spells and more serve storms. (http://www.ucusa.org//globalwarming_science/global_warming)

2.3 Carbon Sequestration

Carbon sequestration is the removal of carbon from the atmosphere by storing in the biosphere (IPCC, 2000).Forest acts as a source of atmospheric C when there is disturbance due to anthropogenic and natural causes and as a sink when re-growth occurs after disturbance, therefore, forest can be managed to alter the magnitude and direction of fluxes. Carbon emission from deforestation account for an estimated 20% of global carbon emissions which is second only to that produced by fossil fuel (IPCC, 2007).The carbon pool in the terrestrial ecosystem can be broadly categorized into vegetative carbon and soil components. Vegetative carbon can further be categorized into above ground and below ground biomass (Hamburg, 2000). As one of the potential soil fertility indicators for tropical soils, the contribution of SOC in tropics need to understand to enable proper soil functioning and sustain yields (Musingunzi et al., 2013).

2.3.1 Forest and Carbon Sequestration

Forest carbon sequestration is a measure that can be taken up to mitigate climate change. But the amount of carbon stored in forests differs according to spatial and temporal factors such as forest type, size, age, stand structure, associated vegetation, and ecological zonation, among other things (ICIMOD, 2016).

The sink capacity of forest increases when tree density and area expand. It stores more CO_2 (4500Gt CO_2) than atmosphere (3000Gt CO_2) (Prentice et al, 2001). In an average, 50% dry weight of the biomass is carbon (MacDicken, 1997). Forest vegetation and soil shares about 60% of the world's terrestrial carbon (Winjum et al, 1992) (Neupane,T. 2017).

Forests are very critical in emission of carbon in atmosphere. When trees are cut down, carbon stored in above and below ground biomass and the soils is liberated back into the atmosphere. In global carbon pool, forest share about 17-20% of the GHGs emission (CO_2) (IPCC, 2007). This is higher than the emission by the whole transport system. Deforestation in tropical forest of developing countries is contributing to accelerate global warming. Nepal's contribution to the global annual GHG emission is 0.025% (MoPE, 2004).

The very simple and least cost effective solution to abate global climate change is afforestation, reforestation, conservation and management of forests (Kyoto Protocal, 1997). Since, forests function as emission sources as well as viable sinks of atmospheric carbon, prudent sustainable community forest management will be milestone steps in trade off the carbon concentration in global mitigating climate change (Banskota et. al., 2007)

2.3.2 Soil and Carbon Sequestration

Soil carbon sequestration is the process of transferring carbon dioxide from the atmosphere into the soil through crop residues and organic solids, and in a form that is not immediately remitted. It refers to the storage of carbon under the ground. Soil carbon sequestration can be accomplished by management systems that add high amounts of biomass to the soil, causes minimal disturbance, conserve soil and water improve soil structure, and enhance soil faunal activity (Sundermeier, 2000, Neupane,T. 2017).

Soil is a major store of organic carbon, especially the forest soil, because these contain higher organic matter in comparison to any other land use. It may be because of continuous litter fall and its decomposition, which release the organic carbon (Jha et. al., 2003). Deforestation, biomass burning, plowing, residue removal, fertilization and single crop cycles have been depleting the earth's soil in most agro ecosystem by 50-70%. Land use change, particularly conversion to agriculture ecosystem depletes the soil carbon stock. Thus afforesting of agriculture soil and management of forest plantations can enhance SOC stock through carbon sequestration. Rate of soil carbon storage in forest depends on the climate variability, dominant tree species with other species, litter composition, management practices, etc. (Lal, 2005).

The effects of forest management on carbon soil storage aren't as clear or as well understood as in agriculture systems. Estimated carbon storage in below ground components is known & has been measured (Brady, 1996), but knowledge is however lacking on how harvesting and management affects the soil carbon. Spatially distributed estimates of SOC pools and flux are important requirements for understanding role of soils in global carbon cycle and for assessing potential biosphere responses to climate change or variation (Schimel et al., 2000, Neupane,T. 2017)

2.3.3 Carbon Studies around the World

FAO (2007) pointed out that the Global forest vegetation stores 283 Gt of carbon in its biomass, and additional 38 Gt in dead wood, for a total of 321 Gt. Soils (down to 30 cm) and litter contain 317 Gt of carbon. IPCC (2000) estimated an average carbon stock of 86 t/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 t/ ha for the year 1990 and to 81 t/ 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. IPCC (2001) estimated that temperate forests were sequestering something in the region of 1.4-2 tons of carbon/ha/yr. Boreal forests were quite variable, depending on forest type. Tropical forests, on the other hand, remained a net carbon source (IPCC, 2001).

2.3.4 Carbon Studies in Forests of Nepal

Shrestha and Singh (2008) have reported that the total carbon stock (vegetation plus soil) in the Mid-hill forests is 139 Mg C ha-1. Similarly, Shrestha (2009) found the total carbon stock in the Schima-Castanopsis forest of Palpa District as 178.5 Mg C ha-1 and Khanal et al. (2010) found the total carbon stock in the two community-managed forests of Palpa District as 168.48 Mg C ha-1 and 146.16 Mg C ha-1 respectively. ANSAB, ICIMOD and FECOFUN (2010) jointly studied at 105 CFs of three different watersheds having an area of 10,266 ha of Chitwan (Khayarkhola Watershed), Dolakha (Charnawati Watershed) and Gorkha (Ludhikhola

Watershed) district. It was found that the carbon stock in dense and sparse forest of Khayarkhola Watershed to be 296.44 and 256.70 t/ha where as it was 228.56 and 166.76 t/ha for Charnawati Watershed of Dolakha and in Ludhikhola Watershed it was 216.26 t/ha and 162.98 t/ha for dense and sparse forest respectively.

The total carbon stock in Nepal is estimated to be 1,157.37 million tons, out of which Forest, OWL and OL constitute 1,054.97 million tonnes (176.95 t/ha), 60.92 million tonnes (105.24 t/ha) and 41.48 million tonnes (7.84 t/ha), respectively. Out of the total forest carbon stock, tree, soil and litter/debris components contribute 61.53%, 37.80 %, and 0.67% of carbon, respectively. The average organic carbon in soil, litter and debris, and tree component (≥10 cm DBH) are 67.14 t/ha, 1.19 t/ha and 108.88 t/ha, respectively. The highest soil organic carbon stock (114.03 t/ha) was estimated in High Mountains and High Himal regions. SOC was the lowest in Churia region with an average of 31.44 t/ha. The results from Middle Mountains region showed an average SOC stock of 54.33 t/ha. SOC stock in the forests of the Terai was found to be slightly higher than in Churia (Department of Forest Research and Survey, 2015)

2.4 United Nation's Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol

The UN conference on the Environment and Development was held in 1992 in Rio de Jenerio. It results in the Framework Convention on Climate Change (FCCC or UNFCCC) among other agreements. In 1995 Parties to the UNFCCC meet in Berlin (the 1st Conference of Parties (COP) to the UNFCCC) to outline specific targets on emissions. In December 11, 1997, the parties conclude the Kyoto Protocol in Kyoto, japan in which they agreed to board outlines of emission target. The Kyoto Protocol is an international treaty which extends the 1992 UNFCCC that commits state parties to reduce GHGs emissions, based on the scientific consensus that a) global warming is occurring and b) it is extremely likely that human induced CO_2 emissions have predominately caused it.

The Kyoto Protocol legally binds developed nation to reduce worldwide emission of GHGs from these countries. It has a provision where developed nations will have to reduce GHGs by 5.2% from its 1990 level over the next decade. The time frame for this protocol was from 2008 to 2012 AD, which is also known as first commitment period. However, emission reduction is not an easy task for the developed nations whose economic backbone is coal and fossil fuels. It would be an expensive activity for many industrialized nations. To simply it, the Kyoto protocol brought three mechanisms: i) Clean Development Mechanism (CDM) ii) Emission trading and iii) Joint Implementation by which Annex I and Non-Annex I countries participate in GHGs reduction. These mechanisms allowed industrialized countries to reduce emissions outside their national boundaries and to count these reductions towards their national target.

2.4.1 Clean Development Management (CDM)

Among the three mechanisms, the most important flexible mechanism of Kyoto Protocol is the CDM, which primarily deals with the interest of developing countries. CDM was established under Article 12 of the Kyoto Protocol adopted by 3rd COP to the UNFCCC to provide cost effective emission reductions for Annex I countries while contributing to sustainable development in developing (Non-Annex I) countries through enabling the transfer of clean technologies and finance. The scheme permits developing countries to sell tradable Certified Emission Reduction generated from approved CDM activities and then permits Annex I countries to use such Certified Emission Reductions to comply with their GHG emission reduction target under Kyoto Protocol.

2.5 Reducing Emission from Deforestation and Forest Degradation (REDD)

As CDM fails to reduce the emissions from deforestation in non-industrialized countries, there was a strong move to find ways to reduce CO_2 emissions from the terrestrial ecosystems by reducing the deforestation rates. Under the policy called ‘Reduced Emissions from Deforestation’ (RED), several approaches have been developed and are being discussed by the parties. REDD+ began life as REDD, a scheme in which developed states would pay developing states to protect their forest to mitigate climate change. The scheme was remodeled as REDD+, which allowed sustainable management of forests and the conservation and enhancement of forest carbon stocks (CIFOR, 2010). To combat the climate change from the degradation and deforestation of forests, a mechanism was proposed under REDD, in Bali 2007, which was later on expanded to REDD+, in Copenhagen 2015, recognizing the role of conservation, sustainable management of forest and enhancement of forest carbon stocks. A flexible, transparent, efficient and effective benefit sharing mechanism has been proposed. According to this, 70% of the benefits are distributed in forms of monetary benefits and 30% in the form of non-monetary benefits (MoFSC, 2015). The benefits in the non-monetary may be in form of support for community development, livelihood generation, capacity and skill development, employment and the like rather than cash distribution at the household level (MoFSC, 2015).

Fortunately, Nepal is first among the developing countries which have been selected by the World Bank as a member of the Carbon Partnership Facility (FCPF).The World Bank, through FCPF program has provided USD 200,000 for REDD 'readiness'. Under the first ever pilot Forest Carbon Trust in Nepal, representatives from three watersheds in Dolakha, Gorkha, and Chitwan districts received a total sum of US$ 95,000 on the behalf of CFUGs (Dhakal, 2006).

2.7 Climate Change and its Impacts

Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2007). It is a long-term change in the statistical distribution of weather pattern, including average temperature and rainfall over periods of time. Climate change is increasingly accepted as the major issue facing the globe. Climate change is a phenomenon due to emissions of greenhouse gases from fuel combustion, deforestation, urbanization a industrialization resulting variations in solar energy, temperature and precipitation (Joshi, 2007).

In case of Nepal, the temperature has been increased by 1.8^0C during last 32 years and the average temperature increase was recorded as 0.06^0C per year with more pronounced 0.08^0C in Himalayan region (DoF, 2008).The rainfall pattern is also experienced as inconsistent with higher intensities of rain and less number of rainy days creating long drought for some time and heavy rain in some other periods (IPCC, 2001). Changes in hydrological cycles and the depletion of water resources are the top challenges facing Nepal in context of climate change. According to FAO (2007) agriculture, forestry, and fisheries are highly sensitive to climate change and climate change is very likely to have a serious impact on their productive functions. As a consequence, production of food, feed, fiber, energy, or industrial crops, livestock, poultry, fish and forest products may decrease (Epstein & Mills, 2005).To control global warming there are many options such as the mitigate option- sequestration of CO_2 and reduction of emission; the adaptive option – adjustment in ways that reduce the negative impacts of temperature changes on the environment; and indirect policies like controlling population growth or changing technologies. Among the options, forestry is one of the most cost-effective mitigating options (IPCC, 2007).

CHAPTER THREE: MATERIALS AND METHODS

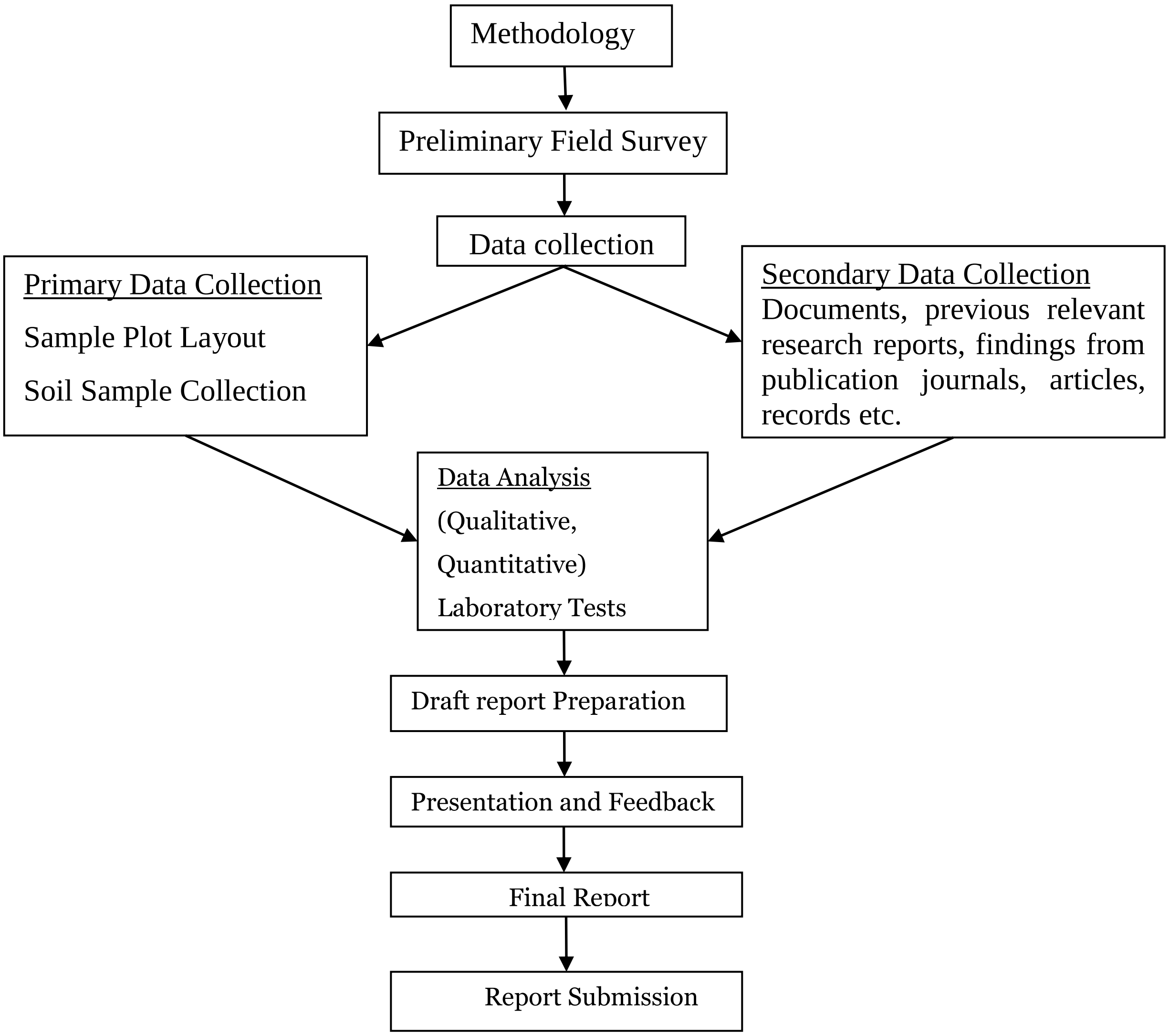

Figure 1: Research Framework

3.1 Study Area:

The research was carried out in Churia region of Bhedawari Community Forest of Nawalparasi district. It is situated in Gaindakot municipality- 11 & 12, an eastern part of Nawalparasi. The detail of CF is given below in Table 1.

Table 1: General Description of the Study Area

Details	Bhedawari Community Forest
Total Area	391.96 hectare
Forest Type	Natural Broad leaved
Dominant Species	Sal, Asna, Karma, Jamun, Valayo
Other Species	Kyamuna, Jamun, Valayo,
Major NTFPs	Harro, Barro, Amala
Soil Type	Reddish- Brown
Aspect	North and South
Elevation	200-730m
Location coordinate (Position format : UTM, Datum : WGS84, UTM Zone : 45, Unit : Metric)	X = 0233710 Y = 3067430

(Source: CF Operational Plan- 2016)

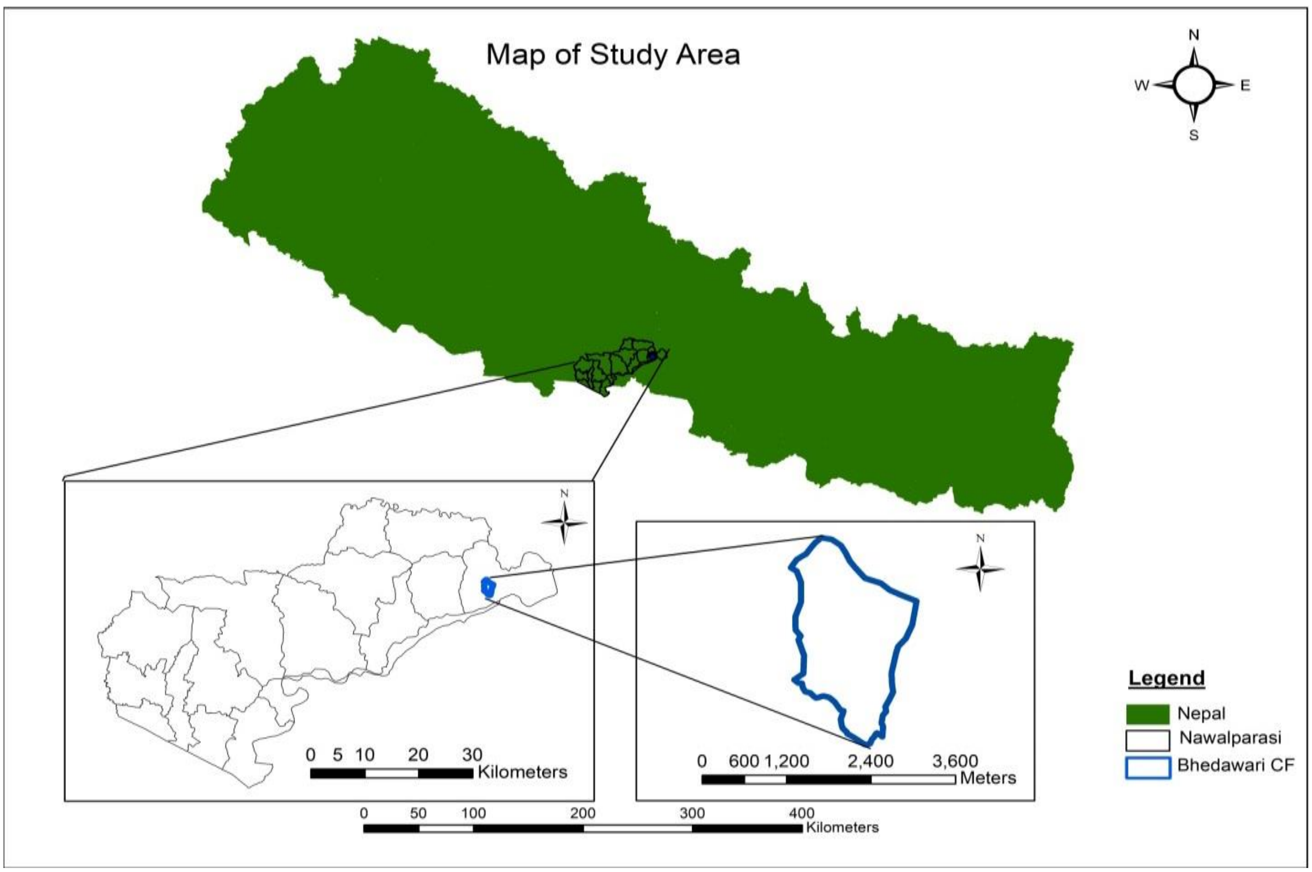

Figure 2: Map of the Study Area

3.2 Data Collection
This includes collection of primary and secondary data.

3.2.1 Primary Data Collection
Primary data was collected through direct field survey. It includes soil sample collection. Two aspect classes: North and South and two elevation classes: about 350m and 550m were used.

Soil samples were collected in five replicates each from the two aspects and elevation classes. Soil samples were taken from 0–10cm, 11-20 cm and 21–30 cm soil depths using a 100mm long cylindrical corer with diameter 30mm so the volume of the each soil sample collected was 70.69 cm^3. Soil sample was collected from 0.56m plot radius such that the designated pit turned out to be a steep slope (>100%), riverbank, rocky area or water body to ensure that sample should be of undisturbed soil. Each sample was bagged, labeled and transported to laboratory for further analysis. The entire process was guided by Guidelines for measuring carbon stock in community managed forest (2010).

3.2.2 Secondary Data Collection
Secondary data sources were gathered from journals, websites and thesis of various individuals and published/unpublished reports of government offices such as Ministry of Forests and Soil Conservation, Department of Forest (DoF), District Forest office, and other concerning NGO's & INGO's and various other concerned agencies, literature from FOF library etc.

3.3 Data Processing and Analysis:
The collected information was analyzed using both qualitative and quantitative methods using software MS Excel and SPSS. The results were interpreted using text, tables and figures. The detail of analysis methods is given below:

3.3.1 Bulk Density
Soil samples were collected from 0-10, 11-20, and 21-30 cm soil depths. Soil bulk density was determined using the core sampling method (Blake and Hartage, 1986). Samples were taken and transferred to pre-weighted sampling bags. Wet weights of soils were recorded in the field. Subsequently, samples were transported to the laboratory and oven dried for 24 hours at the constant temperature of 105^0c and again weight of each samples were recorded. Bulk density was computed as:

Bulk Density (gm. /cm^3) = oven dry weight of soil (gm.)/ volume of soil in the core (cm^3)

3.3.2 Estimation of Soil Organic Carbon

Soil organic carbon percent was determined by the titration method developed by Walkley and Black (1934). For its determination, following procedure was followed:

- Air dried soil samples were passed through a 2 mm sieve to prepare sample for determining soil organic carbon.
- 1 gm of air dried soil was weighed and transferred to the well labeled oven dried 500 ml conical flask.
- 10 ml 1 N potassium dichromate ($K_2Cr_2O_7$) solution and 20 ml concentrated sulphuric acid (H_2SO_4) was added and mixed by gentle swirling.
- The flask was kept for about 30 minutes to react with the mixture.
- After the reaction was over, the mixture was diluted with 200 ml of distilled water and 10 ml of phosphoric acid was added followed by 1 ml of diphenylamine indicator.
- The sample was titrated with 0.4 N ammonium ferrous sulphate [$(NH_4)_2Fe(SO_4)_2.6H_2O$] until end point is marked with changed color from black to the brilliant green.
- The blank was run as followed by above procedure without soil sample.

The Soil Organic Carbon content percent is calculated as:

% C= 3.951⁄g [1 -T/S]   Where,

g= weight of sample in gram,
W= weight of sample in gram
T= ml ferrous solution with sample titration,
S= ml ferrous solution with blank titration.
B & S = ml ferrous solution with Blank and Sample titration

Total soil organic carbon was then calculated by (Chabbra et. al. 2003)

SOC= ρ*d*%C

Whereas,
SOC= soil organic carbon stock per unit area (ton ha^{-1}),
ρ= soil bulk density (Kg/m^3),
d= soil depth (m), and
%C= carbon concentration (%)

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Results

4.1.1 Bulk Density (BD)

There was a gradual increase in the BD with increase in soil depth. Average bulk density of Bhedawari CF was found to be 1.47 gm. / cm^3 with average BD of different soil depths: 0-10 cm, 11-20 cm and 21-30 cm were 1.40 gm. / cm^3, 1.46 gm. / cm^3 and 1.55 gm. /cm^3 respectively (Table 2).

Table 2: Average Bulk density (gm. / cm^3) at various depths

Depth (cm)	Average Bulk density (gm. / cm^3)
0-10	1.40
11-20	1.46
21-30	1.55

(Source: Field Survey, 2018)

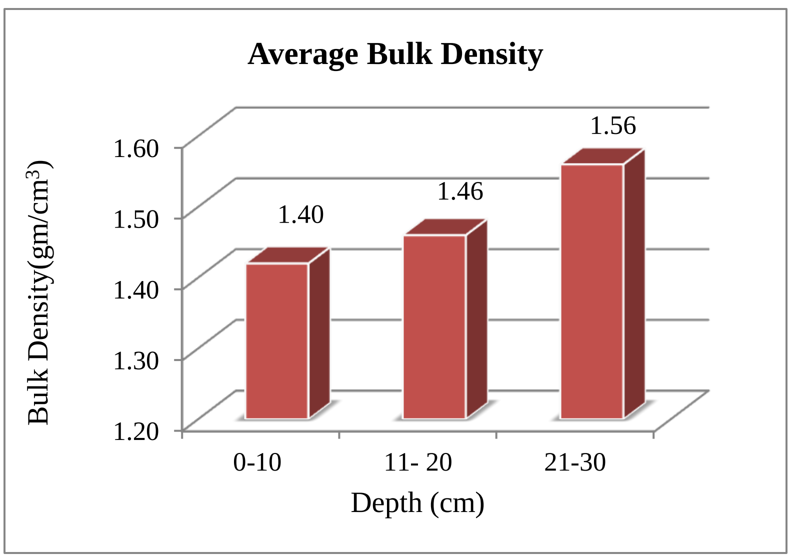

Figure 3: Average Bulk density (gm. / cm^3) at various depths

4.1.1.1 BD with respect to Altitude and Aspect

A) At 350m Elevation

In Southern aspect, the average BD of Bhedawari CF at this elevation was 1.49 gm. /cm^3 with average bulk density of different soil depths: 0-10 cm, 11-20 cm and 21-30 cm were 1.39 gm. / cm^3, 1.46 gm. / cm^3 and 1.64 gm. /cm^3 respectively. While the average BD was 1.36 gm. /cm^3 in Northern aspect with average BD of different soil depths: 0-10 cm, 11-20 cm and 21-30 cm were 1.26 gm. / cm^3, 1.24 gm. / cm^3 and 1.57 gm. /cm^3 respectively (Table 3).

Table 3: Average Bulk density (gm. / cm^3) at 350m

Aspect	Depth			Average
	0-10	11- 20	21-30	
Southern	1.39	1.44	1.64	1.49
Northern	1.26	1.24	1.57	1.36

(Source: Field Survey, 2018)

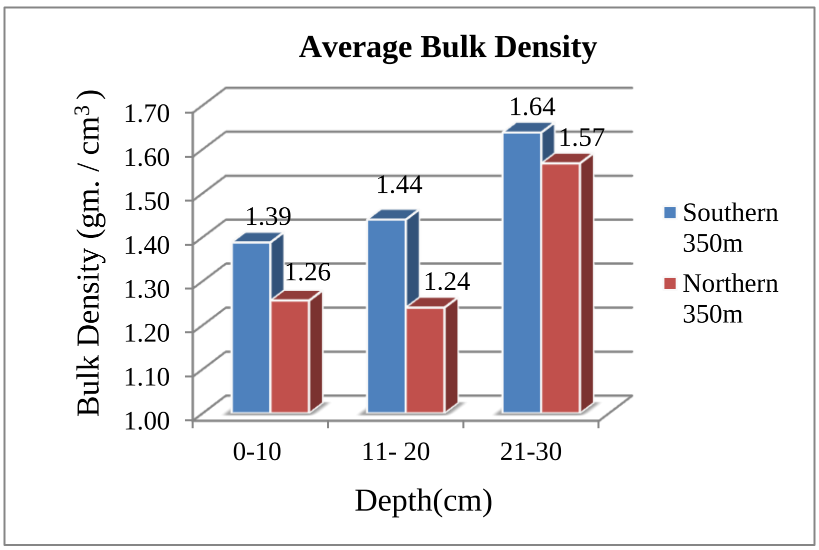

Figure 4: Average Bulk Density (gm. / cm^3) at 350m

BD was found increasing with increase in depths irrespective at 11-20 cm of northern 350m may be due to presence of tree root zone.

B) At 550m Elevation

In Southern aspect, the average BD of Bhedawari CF at this elevation was 1.51 gm. /cm^3 with average bulk density of different soil depths: 0-10 cm, 11-20 cm and 21-30 cm were 1.32 gm. / cm^3, 1.67 gm. / cm^3 and 1.54 gm. /cm^3 respectively. While the average BD was 1.52 gm. /cm^3 in Northern aspect with average BD of different soil depths: 0-10 cm, 11-20 cm and 21-30 cm were 1.61 gm. / cm^3, 1.50 gm. / cm^3 and 1.46 gm. /cm^3 respectively (Table 4).

Table 4: Average Bulk density (gm. / cm^3) at 550m

Aspect	Depth			Average
	0-10	11- 20	21-30	
Southern	1.32	1.67	1.54	1.51
Northern	1.61	1.50	1.46	1.52

(Source: Field Survey, 2018)

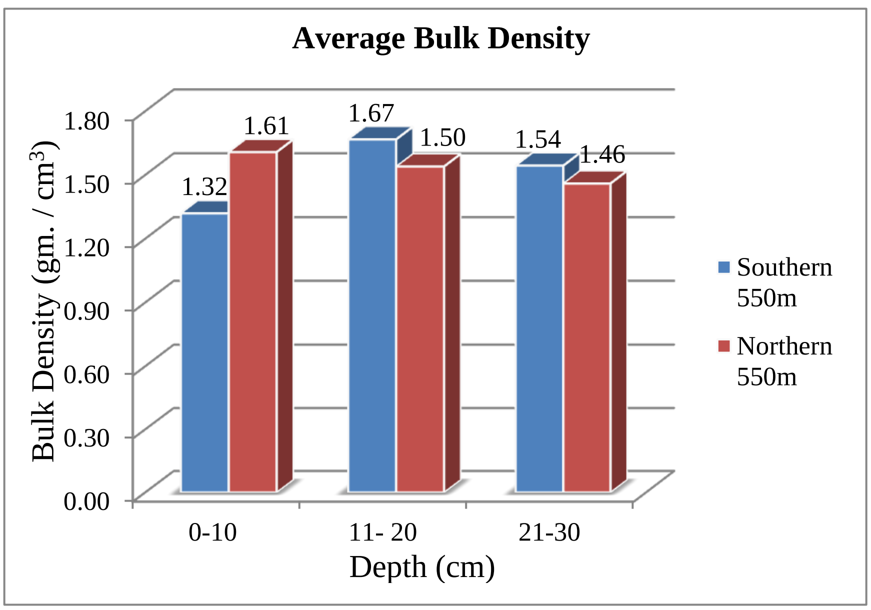

Figure 5: Average Bulk density (gm. / cm^3) at 550m

Here, in Northern aspect BD was found varied irrespective of increasing depth may be due to presence of sedimentary soil and stones.

4.1.2 Soil Organic Carbon Percentage (SOC %)

Average soil organic carbon percent of Bhedawari CF was found to be 0.79 with average soil organic carbon percent of different soil depths: 0-10 cm, 11-20 cm and 21-30 cm were 1.11, 0.70 and 0.56 respectively (Table 5).

Table 5: Average Soil Organic Carbon Percentage at various depths

Depth (cm)	Average Soil Organic Carbon Percent
0-10	1.11
11-20	0.70
21-30	0.56

(Source: Field Survey, 2018)

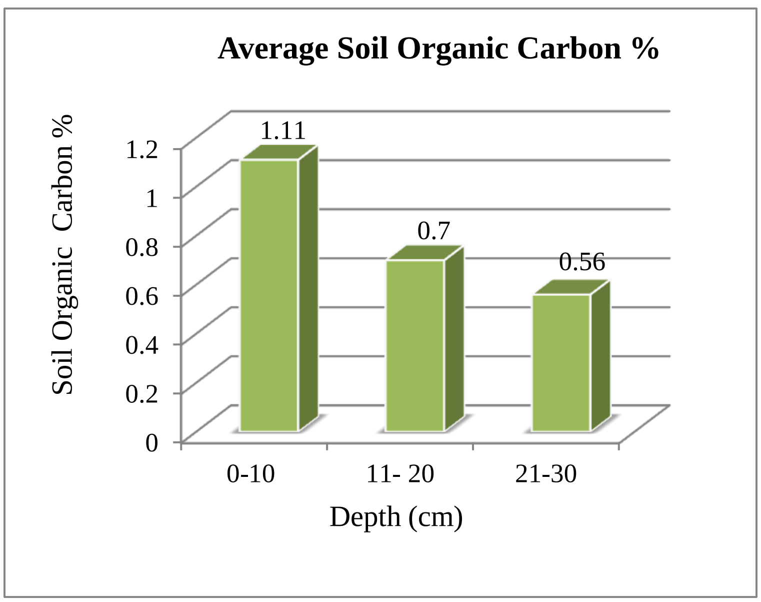

Figure 6: Average Soil Organic Carbon Percentage at various depths

The total SOC% at various depths was found to be decreasing with increasing depths.

4.1.2.1 SOC % With Respect to Altitude and Aspect
A) At 350m Elevation

In southern aspect, the average SOC % at this elevation was found to be 0.82% with average SOC percent of different soil depths: 0-10 cm, 11-20 cm and 21-30 cm were 1.18, 0.79 and 0.50 respectively. Whereas, the average SOC % was found to be 1.16% in Northern aspect with average SOC percent of different soil depths: 0-10 cm, 11-20 cm and 21-30 cm were 1.51, 0.95 and 1.01 respectively (Table 6).

Table 6: Average Soil Organic Carbon Percentage at 350m

Aspect	Depth(cm)			Average SOC %
	0-10	11- 20	21-30	
Southern	1.18	0.79	0.50	0.82
Northern	1.51	0.95	1.01	1.16

(Source: Field Survey, 2018)

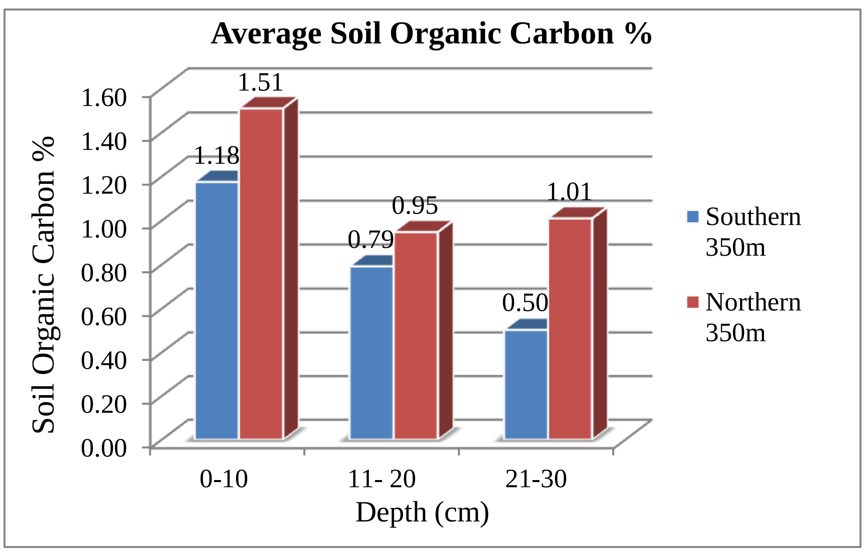

Figure 7: Average Soil Organic Carbon Percentage at 350m

The SOC% at various depths was found to be decreasing with increasing depths irrespective in North.

B) At 550m Elevation

In southern aspect, the average SOC % at this elevation was found to be 0.60 with average SOC percent of different soil depths: 0-10 cm, 11-20 cm and 21-30 cm were 0.83, 0.52 and 0.44 respectively. Whereas, the average SOC % was found to be 0.56% in Northern aspect with average SOC percent of different soil depths: 0-10 cm, 11-20 cm and 21-30 cm were 0.90, 0.52 and 0.27 respectively. (Table 7)

Table 7: Average Soil Organic Carbon Percentage at 550m

Aspect	Depth(cm)			Average SOC %
	0-10	11- 20	21-30	
Southern	0.83	0.52	0.44	0.60
Northern	0.90	0.52	0.27	0.56

(Source: Field Survey, 2018)

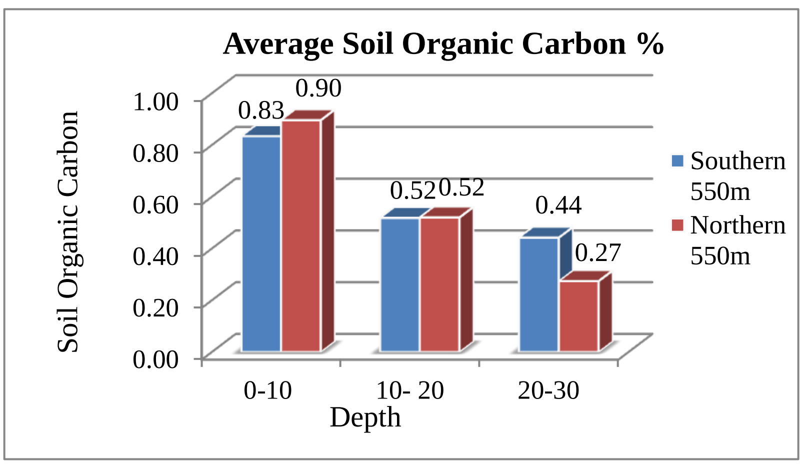

Figure 8: Average Soil Organic Carbon Percentage at 550m

The SOC% at various depths was found to be decreasing with increasing depths.

4.1.3 Soil Organic Carbon Stock

The total SOC stock of Bhedawari CF was found to be 33.91 t/ha. Average SOC at various depth 0-10 cm, 11-20 cm and 21-30 cm were 15.34 t/ha, 9.96 t/ha and 8.61 t/ha respectively. The minimum average SOC stock was found in 21-30 cm with 8.61 t/ha and maximum average SOC was 15.34 t/ha in 0-10 cm depth. The total SOC stock at various depths was found to be decreasing with increasing depths (Table 8).

Table 8: Average Soil Organic Carbon Stock at various depths

Depth (cm)	Average Soil Organic Carbon Stock (t/ha)
0-10	15.34
11-20	9.96
21-30	8.61

(Source: Field Survey, 2018)

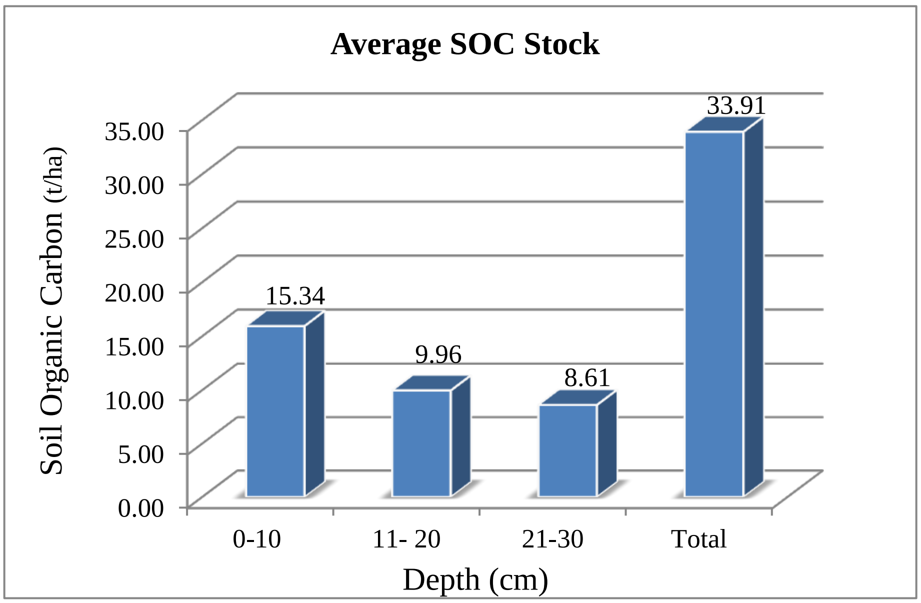

Figure 9: Average Soil Organic Carbon Stock at various depths

4.1.3.1 SOC Stock with respect to Altitude and Aspect

A) At 350m Elevation

In southern aspect, the total SOC at this elevation was found to be 35.29 t/ha with average SOC of different soil depths: 0-10 cm, 11-20 cm and 21-30 cm were 16.02 t/ha, 11.04 t/ha and 8.23 t/ha respectively. Whereas, the average SOC was found to be 46.68 t/ha in Northern aspect with average SOC percent of different soil depths: 0-10 cm, 11-20 cm and 21-30 cm were 18.95 t/ha, 12.30 t/ha and 15.43 t/ha respectively. (Table 9)

Table 9: Average Soil Organic Carbon Stock at 350m

Aspect	Depth (cm)			Total Average (t/ha)
	0-10	11- 20	21-30	
Southern	16.02	11.04	8.23	35.29
Northern	18.95	12.30	15.43	46.68

(Source: Field Survey, 2018)

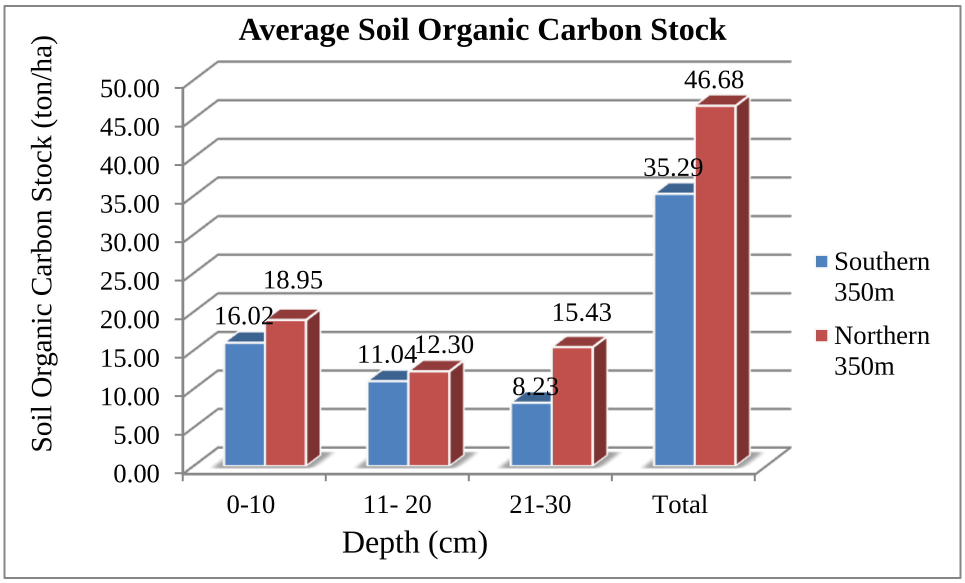

Figure 10: Average Soil Organic Carbon Stock at 350m

The total SOC stock at various depths was found to be decreasing with increasing depths irrespective at 21-30 cm depth of North attributed by increased bulk density of the samples at this depth due to presence of stone.

B) At 550m Elevation

In southern aspect, the total SOC at this elevation was found to be 26.69 t/ha with average SOC of different soil depths: 0-10 cm, 11-20 cm and 21-30 cm were 11.47 t/ha, 8.48 t/ha and 6.74 t/ha respectively. Whereas, the average SOC was found to be 26.99 t/ha in Northern aspect with average SOC percent of different soil depths: 0-10 cm, 11-20 cm and 21-30 cm were 14.93 t/ha, 8.03 t/ha and 4.03 t/ha respectively (Table 10).

Table 10: Average Soil Organic Carbon Stock at 550m

Aspect	Depth (cm)			Total Average
	0-10	11- 20	21-30	
Southern	11.47	8.48	6.74	26.69
Northern	14.93	8.03	4.03	26.99

(Source: Field Survey, 2018)

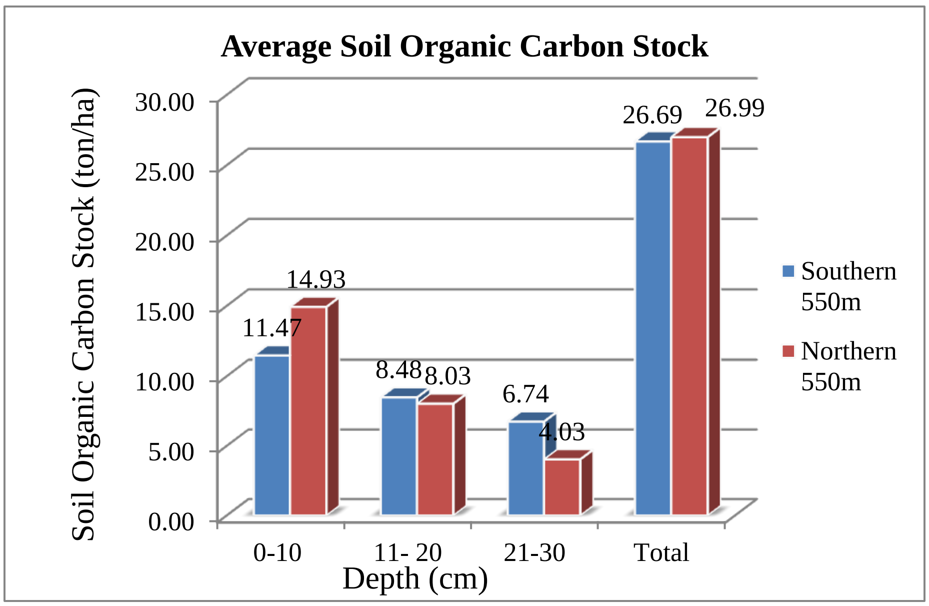

Figure 11: Average Soil Organic Carbon Stock at 550m

The total SOC stock at various depths was found to be decreasing with increasing depths.

One-way ANOVA was used test the significance of altitude and aspect in term of SOC content. The result of one way ANOVA showed that altitude had made significant impact in total SOC (t/ha) at 95% confidence interval with p value 0.015 ($p<0.05$). While, SOC was found non-significant with respect to aspects at 95% confidence interval with p value 0.278($p>0.05$). (Annex 2).

4.2 Discussion

There was a gradual increase in the BD with increase in soil depth (Table 2). The results was justified to Perie and Ouimet (2008) that "With increase in the depth of the soil profile the organic matter content of the soil decreases and which leads to decrease the porosity of soil that leads to increase the BD."

The soil organic carbon in the forest depends upon forest types, climate, moisture, temperature, soil organic matter and types of soil. The SOC percent was found higher at the upper layers. Higher SOC percent in upper layer is due to high soil organic matter content and less degraded organic matter. Top layer of most of the soils contains between 0.3 and 11.5% in the surface 20 cm of mineral soil (Lal, 2005). This supports the result that with increase in the depths soil organic carbon percentage decreases (Table 4).

The SOC generally diminishes with depth regardless of vegetation, soil texture, and clay size fraction (Trujilo et. al., 1997) which relates to the result (Table 8). The total SOC stock in Bhedawari Community Forest (33.91 t/ha) was found to be similar with SOC in Churia region with an average of 31.44 t/ha (DFRS, 2015). Griffiths, R.P. (2009) reported increased in SOC with altitude. Also, there have been records of decreased in SOC with altitude (Sheikh et. al., 2009; Zhong and Xu, 2009). And, the total SOC stock was found to be higher in 350m (40.99 t/ha) than that of 550m altitude (26.84 t/ha). Similarly, total SOC stock was found to be higher in Northern (36.83 t/ha) than that of Southern aspect (30.99 t/ha). This may be due to dense & young vegetation in lower altitude which could be attributed to high inputs of leaf litter, decomposition of fine roots, greater root biomass and returns of vegetative residue. Despite of similarity in vegetation, low light intensity (temperature) may be contributed in higher SOC storage in north.

The result of one way ANOVA shows that altitude had made significant impact in total SOC (t/ha) at 95% confidence interval with p value 0.015 ($p<0.05$). SOC was found non-significant with respect to aspects at 95% confidence interval with p value 0.278 ($p>0.05$) and correlates to Han et al. (2010) that, did not find any significant difference in SOC content between the north and south facing slopes.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1 Conclusions

The following summary and conclusions have been made based on the result of the study:

- Average bulk density of Bhedawari CF upto 30cm depth was found to be 1.47 gm. / cm^3. BD at various depths was found to be increasing with increasing depths.
- SOC % at various depths was found to be decreasing with increasing depths. Where, average SOC % of Bhedawari CF upto 30cm depth was found to be 0.79.
- The total SOC stock of Bhedawari CF upto 30cm depth was found to be 33.91 t/ha. The total SOC stock at various depths was found to be decreasing with increasing depths.
- The total SOC stock was found to be higher in 350m (40.99 t/ha) than that of 550m altitude (26.84 t/ha). Similarly, total SOC stock was found to be higher in Northern (36.83 t/ha) than that of Southern aspect (30.99 t/ha).
- This may be due to dense & young vegetation in lower altitude which could be attributed to high inputs of leaf litter, decomposition of fine roots, greater root biomass and returns of vegetative residue.
- Despite of similarity in vegetation, low light intensity (temperature) may be contributed in higher SOC storage in north.
- The result of one way ANOVA shows that altitude had made significant impact in total SOC (t/ha) at 95% confidence interval with p value 0.015 ($p<0.05$), while the SOC was found non-significant with respect to aspects at 95% confidence interval with p value 0.278 ($p>0.05$).

5.2 Recommendations

Based on the findings the following recommendations have been made:

- In carbon trading policy carbon stored in soil carbon pools should be equally valued with carbon stored in biomass.
- Similar research should be conducted in different vegetation/forest and locality.
- The economic valuation of carbon sequestration must be carried out.
- People participation and their awareness should be increased in REDD+, benefits of REDD+ or carbon trade from community forestry system.

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ANNEXES

Annex 1: Equipment and Materials

For Plot Establishment

S.N	Items	Purpose
1.	GPS	For determining sample plot coordinates
2.	Measuring Tape	To measure distance between plots
	For Soil Sample Collection	
3.	Metal Scale	For measuring soil depth
4.	Soil sample core	For collecting soil samples from various depths
5.	Soil sample hammer	For bearing down on the soil core while collecting sample
6.	Plastic bag	For collecting soil sample
7.	Marker	For marking sample number
8.	Gloves	For soil test in soil lab
9.	Weighing machine	For weighing sample
10.	Kuto	For taking soil core from soil depth
11.	Sickle	For removing grasses and debris
12.	Shawal	For removing soil

Annex 2: ANOVA table of Altitude and Aspect class for SOC stock

	Sum of Squares	df	Mean Square	F	Sig.
Altitude	111.250	1	111.250	7.374	.015
Error	241.395	16	15.087		

	Sum of Squares	df	Mean Square	F	Sig.
Aspect	18.993	1	18.993	1.259	.278
Error	241.395	16	15.087		

Annex 3: Photo Plates

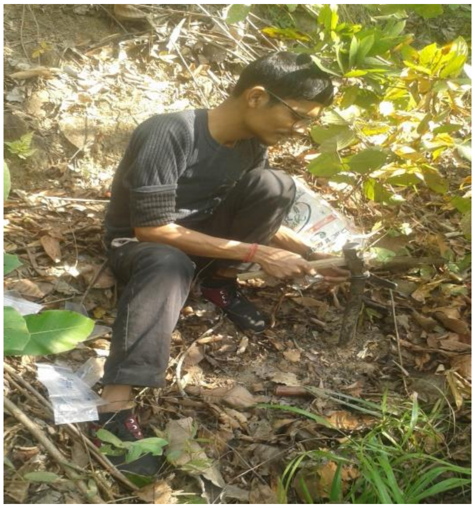

Fig: Drilling of Soil Corer to collect sample

Fig: Labeled Soil Samples

Fig: Sieving with 2 mm mesh

Fig: Sample before titration

Fig: Preparation of Titration Solution

Fig: Titration

BIBLIOGRAPHY

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2.	10+2	HSEB Board	First	Physics, Chemistry & Biology	2067-2069
3.	S.L.C	Government of Nepal	First division with Distinction	English, Math, Science	2066