DYNAMICS IN LAND COVER AND CARBON STOCK OF FORESTS IN CHEBERA-CHURCHURA AND BORENA-SAYINT NATIONAL PARKS, ETHIOPIA

M.Sc. THESIS

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A THESIS SUBMITTED TO

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Approval Sheet I

This is to certify that the thesis entitled "*Dynamics in Land Cover and Carbon Stock of Forests in Chebera - Churchura and Borena - Sayint National Parks*, *Ethiopia* " submitted in partial fulfillment of the requirement for the degree of Master of Sciences with specialization in *Forest Resource Assessment and Monitoring* of the Graduate Program of the *School of Forestry*, Wondo Genet College of Forestry and Natural Resources, is a record of original research carried out by *Negash Hailegiorgis Sirneisa* Id.No.*MSc/ FRA&M/ R0013/09*, under my supervision; and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the courses of this investigation have been duly acknowledged. Therefore I recommended that it be accepted as fulfilling the thesis requirement.

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Dr. Yemiru Tesfaye	____________________	____________________
Name of Co-advisor	Signature	Date

Approval Sheet II

We, the under signed, members of the Board of examiners of the final open defense by *Negash Hailegiorgis* have read and evaluated his thesis entitled "*Dynamics in Land Cover and Carbon Stock of Forests in Chebera - Churchura and Borena - Sayint National Parks, Ethiopia*" and examined the candidate. This is there fore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science.

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Dedication

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LIST OF ABBREVATIONS AND ACRONYMS

GHG	Green House Gas
NMSA	National Metreological Services Agency
CRGE	Climate Resilient Green Economy Initiative
CSA	Central Statistical Agency
FAO	Food and Agriculture Organization of the United Nation
IPCC	Intergovernmental Panel on Climate Change
UNFCCC	United Nations Framework Convention on Climate Change
UNESCO	United Nations Educational, Scientific and Cultural Organizations
$REDD^+$	Reducing Emissions from Deforestation and Forest Degradation
WBISPP	Woody Biomass Inventory and Strategic Planning Project
GIS	Geographic Information system
RS	Remote Sensing
SNNPR	Southern Nations, Nationalities and People's Region
Gt C	Giga tone of Carbon
CBD	Convention on Biological Diversity
EWCA	Ethiopian Wildlife Conservation Authority
BSNP	Borena Sayint National Park
CCNP	Chebera Churchura National Park
C	Carbon
LULCC	Land Use Land Cover Change
TCSD	Total Carbon Stock Density
MEFCC	Ministry of Environment, Forest and Climate Change
EBI	Ethiopian Institute of Biodiversity
MCT	Ministry of Culture and Tourism
QGIS	Quantum GIS Soft ware
DBH	Diameter at Breast Height
GPS	Global Positioning System Receiver
EMA	Ethiopian Mapping Agency
AFOLU	Agriculture, Forestry and other land use

USGS	United States Geological Survey
ANOVA	Analysis of Variance
SPSS	Statistical Package for Social Survey
AGB	Above Ground Biomass
BGB	Below Ground Biomass
DW	Dead Wood
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
BD	Bulk Density
Wav.dry	Average dry weight
ETM+	Enhanced Thematic Mapper
TM	Thematic Mapper
NASA	National Auerotic Space Agency
OLI	Operational Land Imager
TIRS	Thermal Infrared Sensor
DOS	Dark Object Subtraction Method
GCP	Ground Control Point
EFAP	Ethiopian Forest Action Programme
MoPED	Ministry of Planning and Economic Development
EWNHS	Ethiopian Wildlife and Natural History Society
IUCN	International Union for Conservation of Nature
KSWARDO	Konta Special Woreda Agriculture and Rural Development Office
FDRE	Federal Democratic Repablic of Ethiopia

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Abstract

Forests play a significant role in climate change mitigation by sinking and storing more carbon. The main objective of the study was estimating the role of protected area forests in the reduction of atmospheric carbon dioxide by conducting studies on two national parks: Chebera-Churchura(CC) and Borena- Sayint(BS). The study includes exploring vegetation characterstics, estimation of total carbon stock density and assessment of land cover changes for the periods of 1990,2003 and 2017. Stratified random sampling design was used in this study.The stratified lands are Moist afromontane forest,Combretum terminalia,Wooded grass land and Wet land land cover types for CCNP while, Dry afromontane forest, Afro alpain wood land and Afro alpain grass lands are those land cover types for BSNP. Data was collected for Above ground biomas, Dead wood biomass, Litte biomass, Soil organic matter and Land cover change analysis. Biomass data was collected from 130 and 63 big plot of 2000m^2 for CC and BS respectively. Litter biomass data was collected from all the 1m x1m small sub plots framed with in the big plot on the field and an evenly mixed 100g of sample was taken for laboratory analysis. Dead wood data was collected from the big plot for woods with DBH ≥ 10cm. For SOC analysis, from the two 1m x 1m small sub plot with two layers of soil depth(0-30cm and 30-60cm), 60 and 40 samples of 150g were collected for soil composite in CC and BS respectively.Similarly,,for soil bulk density determination 60 and 40 samples from the 1mx1m small sub plot with two layers were collected by core sampler for CC and BS respectively. For above and below ground biomass estimation, DBH and height of trees in the big plot with DBH ≥ 5 cm were measured. Above ground biomass was estimated by using allometric models of chave etal(2014) while below ground biomass was taken 26 % of Above ground biomass. Litter biomass was analyised by the loss on ignition method. However, soil organic carbon were analyised by Walkley & Black (1934) while soil bulk density was analyised by wet oxidation method. For data summarization and analysis microsoft excell 2016, SPSS software version 23, Q GIS version 2.1.8 and 3.2.3 as well as Arc GIS 10.3 were used in this study.The mean and standard deviation were used to test the relation between variables. One way ANOVA was used to test the effect of land cover variation on biomass carbon stock. But,Univariat analysis of the generalized linear model was used to test the effects of land cover and soil depth on soil carbon stock. The mean total carbon stock in CCNP was 854.41 t ha $^{-1}$ (Table : 6). Similarly, The mean total carbon stock in BSNP was 950.59 t ha $^{-1}$ (Table : 6). The result of LCC analysis showed that in both study sites the grass land has been increased at an average rate of 1,089.18 ha/year; while the woodland, forest land and COGL area in the same sites were decreasing at an average rate of 1,604.36, 181.21 and 73.38 ha/year, respectively; during the last 27 years. Despite the rapid decline in the wood land and forest land coverage,the present study points out forests in BS and CCNP have the potential to sequester plenty of CO_2 with a considerable variation in land use type and soil depth.

Key words : *Forests, Climate change mitigation, Carbon sinking, Carbon storing, carbon pools, Biomass carbon, Soil organic carbon, Protected area.*

1. INTRODUCTION

1.1 Back ground

Earth's climate is rapidly warming due to the anthropogenic green house gas emissions, mainly carbon dioxide (CO_2), from burning of fossil fuel for energy, deforestation and land degradation. The average earth temperature is set to increase by 3 - 5ºC by the end of this century under a business-as-usual scenario (IPCC, 2013a). To date, about 64 % of the additional CO_2 emissions in the atmosphere are from fossil fuel and 36 % from depletion of land carbon stocks (Mackey *et al*. 2013). As, enhanced green house gas effect is a serious global problem now a days, the effect of Climate change on earth is one of the greatest threats that the world faces. Global warming due to increasing of atmospheric temperature and variability in the rain-fall pattern are an indicator for climate change in different parts of the world. The remedy for this problem is climate change mitigation and adaptation that is a combined set of actions in an overall strategy to reduce green house gas emissions. (IPCC, 2007).

Protected areas play a vital role in contributing to climate change mitigation and adaptation by reducing green house gas emissions and helping society cope with impacts of climate change by maintaining essential services on which people depend, both on global and local scales. (CBD, 2009).

Protected areas contribute to alleviate climate change causes and effects through mitigation and adaptation measures included in their management. Protected areas can prevent the loss of carbon that is already present in vegetation and soil. For example, in 39 national parks of Canada 4,432 million t of carbon is sequestrated; in Madagascar, new protected areas covering 6 million ha are responsible for preventing 4 million t of CO_2 emissions annually. In total, about 15 % of the world's terrestrial carbon is stored in the world's protected area net work. Protected areas can be an effective land management strategy that prevents conversion of land uses and loss of carbon (Dudley *et al*., 2010).

Ethiopian Protected Area System comprise National Parks, Sanctuaries, Wildlife Reserves, Forest Priority Areas and Controlled Hunting Areas covering 14 % of its land mass, forming the corner stones of the national conservation strategy (Vreugdenhi *et al*., 2012). Ethiopian protected areas are one of the most effective land use types used to mitigate climate change as well as to adapt to the negative implication caused by climate change (EWCA, 2008).

Ethiopian Climate-resilient green economy is one of the green economy strategy developed by the Ethiopian government to protect the country from the adverse effects of climate change and to build a green economy that will help realise its ambition of reaching middle income status before 2025.

This strategic plan document was prepared basically based on the following four pillars

- **Agriculture**: Improving crop and livestock production practices for higher food security and farmer income while reducing emissions
- **Forestry**: Protecting and re-establishing forests for their economic and ecosystem services, including as carbon stocks
- **Power**: Expanding electricity generation form renewable energy for domestic and regional markets
- **Transport, industrial sectors and buildings**: Leapfrogging to modern and energy efficient technologies (FDRE, 2011).

Forestry is one of the AFOLU sectors which has a unique capability in building green economy through the provision of goods and services of forest ecosystem. Furthermore, it has the potential for carbon sink in its forest ecosystem which is an additionality for this sector. Unlike others, forestry has the potential to avoid further emissions from the source and to sequester GHGs emission from the atmosphere (IPCC, 2006). Therefore, Protecting and re-establishing forests for their economic and ecosystem services, including as carbon stocks is an essential thing.

More over, exploring the carbon stock potential and land cover dynamics in Chebera-Churchura and Borena-sayint national parks through this study are important to determine their contribution for climate change mitigation and helps to conduct further research on the area.

1.2 Statement of the Problem

Protected areas in Ethiopia render various environmental services (e.g. climate stabilization, carbon sequestration, provision of clean water, erosion control, etc.) than the value of direct benefits through tourism and employment (EWCA, 2012). Particularly the vegetation and soils in protected area play a significant role in sequestering GHGs and avoiding further emissions. However, human-induced pressures on protected-areas such as extractive use of forest resources, overgrazing by a large livestock population, anthropogenic fire, expansion of agriculture and human settlement are increasing (Girma Kelboro and Till,2012). These in turn have caused degradation, fragmentation and loss of natural habitats in protected areas hampering their contribution for ecosystem services and goods such as carbon change mitigation and adaptation measures. Particularly, deforestation and fire causes the emission of GHGs stored in a vegetation and soil (Saatchi *et al.*, 2011). On top of that deforestation, fire and over grazing reduces the carbon sequestering potential of the vegetation and soil (Ensermu Kelbessa and Teshome Soromessa, 2008). Furthermore, the contribution of Ethiopian protected areas in responding to climate change is insufficiently recognized.

Chebera-Churchura and Borena-Sayint national parks are among the protected areas threatened due to the above mentioned factors. However, as the two protected areas have inter-complex ecosystem and diversified vegetation types, they can serve as an important carbon sink. Even through, these parks are serving as a refuge for a number of animals and plant species, their contribution for climate change mitigation has not been studied so far.

1.3 Objectives

1.3.1 General Objective: -

The general objective of the study is to investigate the potential of carbon stock storage and changes of land cover in Chebera-Churchura and Borena-Sayint National parks as a proxy for climate change mitigation measures.

1.3.2 Specific Objectives:

The specific objectives of this study are,

- To explore vegetation characterstics of both study sites.
- To determine the total carbon stock density of both national parks .
- To investigate the spatio-temporal trends of land cover change in both study areas for the years between 1990 and 2017.

1.4 Research Questions

- Does the vegetation show similar characterstics for each study sites ?
- Does the carbon stock density differ for the two study sites ?
- What is the trend of land cover change over the past 27 years on both National parks?

1.5 Significance of the Study.

The study quantifies the magnitude of carbon sink and stock of forest, grass land and aquatic ecosystems that are essentially needed for carbon trading and forest carbon project. Particularly, it attempts to determine the carbon stock of the different ecosystems representing two dominant vegetation types in Ethiopian namely; Moist evergreen Afro-montane Forest (MAF) and Dry evergreen Afromontane Forest and grassland complex (DAF). As a result, it provides important base line information to predict the potential of carbon sequestration of other similar protected areas.

Further more, the study contributes significantly for sustainable conservation of the national parks through economic valuation of the national parks as carbon sink. This in turn generates revenues to the parks through systems such as carbon trading which sustainably supports the conservation effort of the parks.

2 LITERATURE REVIEW

2.1 Climate Change and Its Causes

Climate Change is : Any significant change in measures of climate (such as temperature or precipitation) lasting for an extended period of time (typically decades). According to UNFCCC, Climate Change can be defined as: ‘a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere’

Climate change has now been proved by scientific evidences and unequivocally accepted by the global community as a common issue of interest. Since the industrial revolution, the burning of fossil fuels and the destruction of forests have caused the concentrations of heat-trapping green house gases to increase significantly in our atmosphere, at a speed and magnitude much greater than natural fluctuations would dictate. If concentrations of green house gases in the atmosphere continue to increase, the average temperature at the Earth’s surface will increase from 1.8 to 4^0C above 2000 levels by the end of this century (IPCC 2007).

Impacts of climate change, many of which have already been seen, include temperature increase, sea level rise, melting of glaciers and sea ice, increased coral bleaching, changes in the location of suitable habitat for plants and animals, more intense droughts, hurricanes and other extreme weather events, increased wild fire risk and increased damage from floods and storms. (Meehl *et al.* 2007). People living in marginal poverty-stricken areas are most at risk of being severely and negatively impacted by climate change, as their livelihoods are closely tied to ecosystems which provide water for drinking, wildlife for hunting, fishing and medicinal plants (Gobosho Amaja, 2015). The impact of climate change is more sever in tropical ecosystems where there are diverse but fragile ecosystems.

2.2 Green house Gases and Climate Change

Guided by the United Nations Frame work Convention on Climate Change (UNFCCC), global leaders have started global negotiations aiming at 'stabilization of green house gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system' (UNFCCC, 2000). The first major attempt to curb or at least stabilize green house gas (GHG) emissions was made with the Kyoto Protocol in 1997, the first commitment period which has ended in 2012.

The Kyoto protocol (KP) has identified six GHGs and put targets of reduction of those GHGs for the first commitment. To enable achieve those targets, KP has identified developed countries which are the main emitters as annex 1 countries, and less developed countries which have insignificant contribution to the global emission, but have a shared responsibility, as non-annex 1 countries. As stated by the KP, the six GHGs are carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Sulfur hexafluoride (SF_6), Hydrofloro carbons (HFC) and Perflorocarbons (PFC).

i) Carbon dioxide (CO_2): uptake through plant photosynthesis, release via respiration, decomposition and combustion of organic matter

ii) Nitrous oxide (N_2O): primarily emitted from ecosystems as a by-product of nitrification and denitrification

iii) Methane (CH_4): emitted through methanogenesis under anaerobic conditions in soils and manure storage, through enteric fermentation, and during incomplete combustion while burning organic matter.

However, there are other gases that directly or indirectly contribute to greenhouse gas accumulation in the atmosphere, although their contribution is relatively too small. These gaseous compounds include Nitrogen oxides (NO), Ammonia (NH_3), non-methane organic volatile compounds (NMVOC) and carbon monoxide (CO) (precursors for the formation of GHG in the atmosphere).

2.3 Global Carbon Stock Balance

The total global carbon stock is distributed in different forms of reserves. Carbon is normally found in diverse forms (in living things, air, water bodies, rocks etc.), in different forms of organic and inorganic compounds. The natural global carbon stock in the different carbon reserves is estimated as (Canadell *et al*., 2007):

Carbonated rocks 65,000,000 Gt

Fossil fuel reserves 4,000 Gt

Deep Ocean 38,000 Gt

Surface Ocean 1,020 Gt

Terrestrial ecosystems 2,070 Gt (vegetation 610 Gt, soils 1,400 Gt & litter 60 Gt)

Atmospheric ecosystem 750 Gt

While the natural carbon stock in the atmosphere is estimated as 750 Gt, there is a gradual increase of over 3Gt carbon per annum (Nair *et al*., 2009). This un natural shift of the carbon stock from the terrestrial ecosystem to the atmosphere is the main reason for climate change and related chaos on the environment, terrestrial and aquatic ecosystems, temporal socioeconomic disturbances and threats to the long term existence of humans and other living things on the planet.

From the global carbon reserves, fossil fuel and the terrestrial ecosystem are currently primary sources of carbon that is released to the atmosphere as other reserves are not easily accessible. Carbonated rocks, although they are the biggest carbon reserves, only coal is being used as source of energy and are technically difficult to be easily accessed and converted in to energy (Canadell *et al*. 2007). The terrestrial carbon stock is distributed in three basic pools as vegetation (above ground and below ground), soil (as SOC) and litter. Un like fossil fuels, terrestrial ecosystems naturally serve as both source and sink to carbon, though generally it is regarded as net sequester as there is more annual sequestration than emission (release) of carbon. However, the increasing rate of deforestation, particularly that in the tropics is leveling the carbon flux of the terrestrial ecosystem, and if this is continued, the rate of emission may surpass the rate of sequestration that aggravating the climate change problem to a point of no return.

According to IPCC (2006) GL, the terrestrial carbon stock in vegetation and soils is assessed by considering the five forest carbon pools namely; (1) Above ground biomass: carbon stocked in live and standing vegetation (trees, shrubs, under growth and regeneration) (2) Below ground biomass: carbon stored in roots (3) Dead wood: carbon stored in standing and fallen dead trees and stumps (4) Litter: carbon in shed leaves and fine branches (5) Soil: carbon stored as soil organic matter.

2.4 Protected Area System

In order to combat Green house Gas emissions from land use change and sustain ecosystem services which are vital to climate change adaptation, various land use management strategies are important. In this regard, protected areas are in a unique position to support national climate change mitigation and adaptation strategies, as they are already established as efficient, successful and cost effective tools for ecosystem management. Protected areas cover about 12.2 % of the world's land surface containing the only remaining large natural habitats in many areas (IUCN,1994).

According to IUCN, protected area defined as a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values. Based on the management objectives, IUCN classify protected areas in to six management categories (one with a sub-division), as (IA). Strict nature reserve: Strictly protected for biodiversity and geological/ geomorphological features, where human visitation, use and impacts are controlled and limited (IB). Wilderness area: Usually large unmodified or slightly modified areas, retaining their natural character and influence, with out permanent or significant human habitation, protected and managed to preserve their natural condition (II). National Park: Large natural or near-natural areas protecting large-scale ecological processes with characteristic species and ecosystems, which also have environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities (III). Natural monument or feature: Areas set aside to protect a specific natural monument, which can be a land form, sea mount, marine cavern, geological feature such as a cave, or a living feature such as an ancient grove (IV). Habitat/species management area: Areas to protect particular species or habitats, where management reflects this priority. Many will need regular, active interventions to meet the needs of particular species or habitats, but this is not a requirement of the category (V). Protected land or sea scape: Where the interaction of people and nature over time has produced a distinct character with significant ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values (VI). Protected areas with sustainable use of natural resources: Areas which conserve ecosystems, together with associated cultural values and traditional natural resource management systems (Dudely, 2008). The management of protected areas are applied with a typology of governance types. Accordingly, IUCN defines governance types as :- (A) Governance by government: Federal or national ministry/agency in charge; sub-national ministry/agency in charge; government-delegated management (e.g. to NGO) (B) Shared governance: Collaborative management (various degrees of influence); joint management (pluralist management board; transboundary management, various levels across international borders) (C) Private governance: By individual owner; by non-profit organizations (NGOs, universities, cooperatives); by for-profit originations (individuals or corporate) (D) Governance by indigenous peoples and local communities: Indigenous peoples' conserved areas and territories; community conserved areas – declared and run by local communities. Ecosystem degradation, loss of habitat, wild fire and expansion of invasive species are some of the mentioned threats for protected areas globally.

Protected areas provide a wide range of ecosystem services for the sake of human populations. There are four general categories of ecosystem services: (1) Provisioning services (food, water, minerals, pharmaceuticals, energy) (2) Regulation services (carbon sequestration and climate regulation, waste decomposition, water and air purification, crop pollination, pest and disease control) (3) Supporting services (nutrient dispersal and cycling, seed dispersal, primary production) and (4) Cultural services (cultural and spiritual inspiration, recreation, scientific discovery) (Campbell *etal*.., 2008). Protected areas maintain essential ecosystem services to increase resistance, resilience and reduce the vulnerability of livelihoods against climate change. For example, 33 of the world's largest cities receive drinking water from catchments in forest protected areas. Protected areas are source of sustainable food for communities and help to rebuild fish stocks in marine and fresh water areas (IUCN, 1974).

Carbon accounting is the practice of making scientifically robust and verifiable measurements of net GHG emissions. Accounting for carbon is a more recent addition to forest inventories. It followed the growing need to quantify the stocks, sources and sinks of carbon and other GHGs in the context of anthropogenic impacts on the global climate (IPCC, 2006). Forest carbon accounting identifies the carbon-density of areas, providing information for low-carbon-impact land use planning. It prepares territories for accounting and reporting of emissions from the forestry sector. It allows comparison of the climate change impact of the forestry sector relative to other sectors, as well as allowing comparison between territories. Finally, it enables trade off project emission reductions on carbon markets and for emission reductions to be included in policy targets (IPCC, 2003).

The Role of Protected Area for Climate Change Mitigation and Adaptation

Well managed protected areas are inspirational models for the management of natural ecosystems. They can provide a cost-effective option to implement climate change response strategies. However, protected areas can face a number of challenges. For example, ecosystem degradation and loss are one of the main causes of Greenhouse Gas emissions, accounting for 20 % of global Green house Gas emissions (Dudley, *et al*., 2010). Because of habitat destruction and degradation, ecosystems can switch from carbon sinks to carbon sources. Degradation of protected area system contributes for the significant increase of floods, wild fires, storms, tidal surges and droughts. Besides intensifying shortages of potable water, food and traditional medicines climate change exacerbate the spread of diseases, such as malaria, leishmaniasis and yellow fever.

Protected area plays an important role in climate change mitigation and adaptation by reducing green house gas emissions and helping society cope with impacts of climate change. Protected areas contribute to alleviate climate change causes and effects through mitigation and adaptation measures included in their management and prevent the loss of carbon that is already present in vegetation and soil. For example, in 39 national parks of Canada 4,432 million t of carbon is sequestrated; in Madagascar, new protected areas covering 6 million ha are responsible for preventing 4 million t of CO_2 emissions annually. In total, about 15 % of the world's terrestrial carbon is stored in the world's protected area net work (Dudley *et al*., 2010).

2.5 Ethiopian Protected Areas and their Role to Climate Change Mitigation.

Ethiopia's protected area system is larger than the global average, covering 14 % of its land mass. In Ethiopia protected areas comprise National Parks, Wildlife Sanctuaries, Wildlife Reserves, Community Conservation Areas, Wildlife Rescue Centers, Controlled Hunting Areas, Community Managed and Eco-tourism Areas, Open Hunting Areas, Commercial Ranches, Botanical Garden and Herbarium, Bio-reserves and Sanctuaries, Forest Priority Areas and Controlled Hunting Areas (EWCA,2012). The currently designated protected areas (PAs) including 21 national parks (44,611km^2), three wild life sanctuaries (9,532km^2), 11 wildlife reserves (24,810km^2), 20 controlled hunting areas (131,820km^2) and 80 national forest priority areas (Young, 2012).

The Ethiopian Wildlife Conservation Authority (EWCA) administers some of those protected areas, while others including a number of National Parks, Forest Priority Areas and Controlled Hunting Areas, are managed by various regional authorities in the nine states of the federation. Protected areas act as refuge for many species and ecological processes and provide protection to wider landscapes and watersheds. Protected areas are primarily designated for the purpose of biodiversity conservation, but have a substantial additional value in maintaining ecosystem services; including climate regulation through carbon storage. They assist in reducing green house gas emissions by sequestering carbon dioxide from the atmosphere. They serve as effective natural barriers against the impact of climate change, mitigating flooding, changing precipitation patterns, land slides and storm surges and keep natural resources healthy and productive by protecting natural processes (Yitebitu *et al*., 2010).

Protected areas are one of the most effective ways to mitigate climate change as well as to adapt to the negative implication caused by climate change (EWCA, 2008).

For example, in the three national parks of Ethiopia namely Awash National park, Semen Mountain National park and Gambela National park 2,775 million tonnes, 4,239 million tones and 20,927 million tons of carbon is sequestered respectively. (Zerihun Aserat and Habtamu Assaye, 2016; Abreham Berta, 2016). On the other way, different study revealed that the carbon storage potential of Deneba community forest and Gedo forest in Oromia and Tara gedam forest in Amhara regions are 507.29 t/ha, 505.07 t/ha and 643.1 t/ha as reported by (Muluken Nega *etal*.,2015 ; yohannes Hamere *etal*, 2015 and Mohammed Gedefaw, 2015) respectively. According to WBISPP, (2004) the largest store of carbon in the country is found in the wood lands (45.7%) and the shrub lands (34.4%).

2.6 Ethiopian Climate Reseilent Green Economy strategic plan (CRGE).

Ethiopian Climate - resilient green economy is one of the economic strategy developed by the Ethiopian government to protect the country from the adverse effects of climate change and to build a green economy that will help realise its ambition of reaching middle income status before 2025.

This strategic plan document was prepared basically based on the following four pillars

1. **Agriculture**: Improving crop and livestock production practices for higher food security and farmer income while reducing emissions

2. Forestry: Protecting and re-establishing forests for their economic and ecosystem services, including as carbon stocks

3. **Power**: Expanding electricity generation form renewable energy for domestic and regional markets

4. Transport, industrial sectors and buildings: Leapfrogging to modern and energy efficient technologies (FDRE, 2011).

2.6.1 Current Contributions of Forestry Sector for GHGs Emission

Forestry sector has a unique potential in supporting economic growth. But, due to deforestation and forest degradation problem they have lost this potential. According to the report on CRGE document the main drivers of deforestation and forest degradation are clearing of forests for expansion of agricultural lands of large scale agricultural investment and encroachment by small holder farmers which accounts half (50%) of total deforestation and forest degradation due to fuel wood consumption which accounts (46%) of total degradation of forests while informal logging accounts (4%) of the total degradation of forest in this sector. This indicates from 150 Mt CO_2e GHGs emission in 2010 at national level, forestry sector currently accounts (37%) or 55 Mt CO_2e

GHGs emission. If the rate of deforestation and forest degradation in Ethiopia is continuing in this manner, Emissions are projected to grow from around 55 Mt CO_2e in 2010 to almost 90 Mt CO_2e in 2030. Therefore deforestation and forest degradation must be reversed to support the continued provision of economic and ecosystem services and growth in GDP.

2.6.2 The role and potential of forestry sector on building green economy

Forestry is one of the AFOLU sectors which has a unique capability in building green economy through the provision of goods and services of forest ecosystem. Furthermore, it has the potential for carbon sink in its forest ecosystem which is an additionality for this sector. Unlike others, forestry has the potential to avoid further emissions from the source and to sequester GHGs emission from the atmosphere (IPCC, 2006). Therefore, Protecting and re-establishing forests for their economic and ecosystem services, including as carbon stocks is an essential thing. For instance from the sector of Forestry in 5 million ha of forest and 2 million ha of woodland alone around 50% of the total domestic abatement potential (or 130 Mt CO_2e) will be expected to gain and, as a sector, can even yield ‘negative emissions through sequestration, i.e. Storage of carbon in the form of wood, at a level that exceeds emissions from deforestation and forest degradation. In addition, afforestation (2 million ha), reforestation (1million ha) forest management (2 million ha) and woodlands (2 million ha) of forests can help to increase sequestration by more than 40 Mt CO_2e and hence even exceed any remaining emissions from the forestry sector.

3 MATERIALS AND METHODS

3.1 Description of the Study Areas

The two national parks representing different eco regions/vegetation types were selected for this study. Particularly, Chebera-Churchura and Borena-Sayint National parks representing moist evergreen Afro-montane Forest and Dry evergreen Afro-montane Forest and grass land complex vegetation types were selected purposively.

A) Geographic location.

Chebera Churchura National park (CCNP) is located in the inter boundary region of Dawro zone and Konta special district in the Southern Nations, Nationalities, and Peoples' Region (Figure 1). Borena-Sayint National Park (BSNP) is found in South Wollo Zone (Amhara Regional State) (Figure 1). Chebera Churchura National Park is located at about 590 kms SW of Addis Ababa, while Borena-Sayint National Park is located at about 600 km north of Addis Ababa. BSNP is situated among three Woredas namely Borena to the south, Sayint to the north and Mehal Sayint (a newly established Woreda) to the north and north- west. Borena Woreda on south (with its seven Kebeles) and south west (with its two Kebeles), Sayint on the north (with one Kebele) and Mehal Sayint on the north (with its two Kebeles) and on the west with one Kebele. Legambo Woreda is located bordering the two Woreda Borena and Sayint (Meseret Chane, 2010 and Ayenew Biset, 2017). CCNP is bordered by Konta special district to the north, Omo River to the south, Dawro zone to the east and south eastern Agare High Mountain and Omo River to the west (Woldeyohans, 2006).

Chebera Churchura national park is situated between 6^0 56’ 05’’N - 7^0 08’ 02’’N latitude and 35^0 55’ 00’’E - 36^0 57’ 17’’E longitude with in the western side of the central Omo Gibe Basin while, Borena-Sayint National Park (BSNP) lies between 10^o 50’ 45.4” N - 10^o 53’ 58.3” N latitude and 38^{o} 40’ 28.4” E -38^{o} 54’ 49”E longitude (Fig.1). CCNP was established in 2005 by Southern nation and nationality regional state (SNNPRS) up on the request and participation of the local communities.Where as BSNP was established in 2009 by Amhara regional state with the request and participation of the local communities. The total area of Chebera Churchura and Borena-Sayint National Parks are 127,850 ha and 4375 ha respectively (Young, 2012; Gizachew Girma, 2016 and Ayenew Biset, 2017).

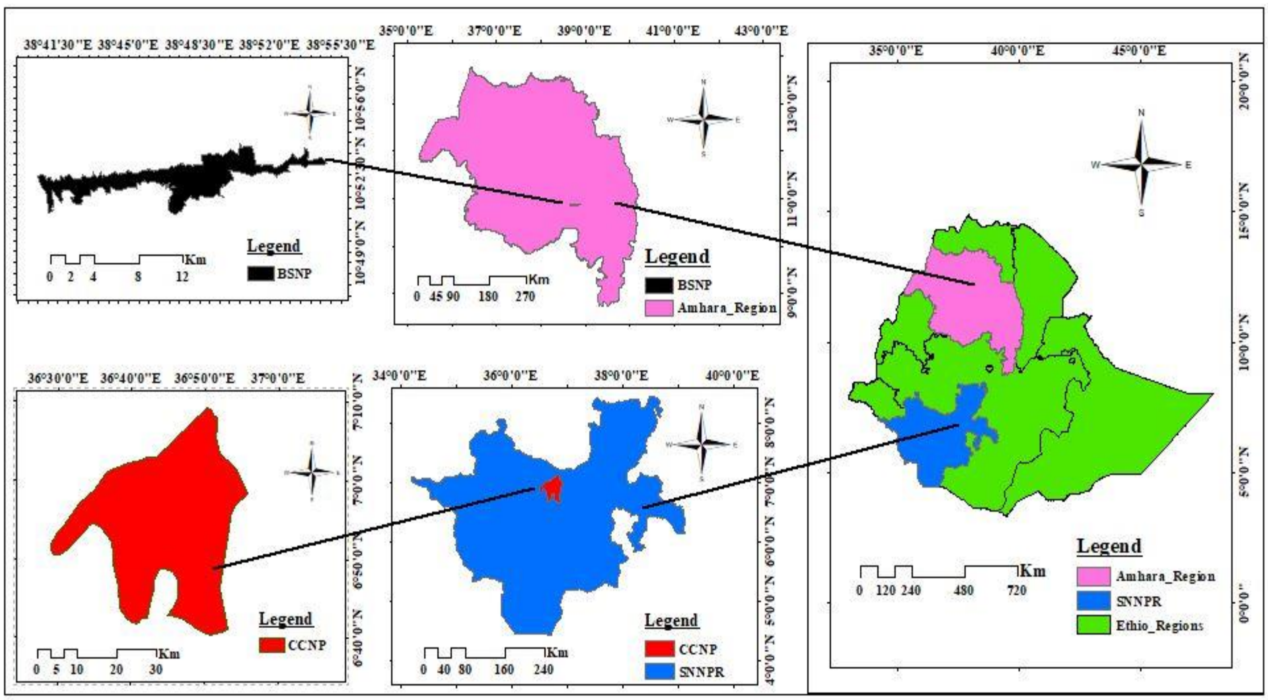

Figure 1: Location Map of study sites.

B) Topography

The topography of the two national park is characterized by rough topography with mountains, deep incised valleys, escarpments and plateaus. The altitudinal range of Chebera-Churchura and Borena-Sayint National Parks are 550 to 1700, and 1900 to 3699 m.a.s.l respectively.

Chebera – Churchura National park possesses numerous rivers, streams and small creator lakes which are reason for the rich wild life resources of the area. Zigina River rises from the north east high lands of the area and cross the central part of the park and feeds the Omo River. Borena-Sayint National park is generally characterized by rough topography with mountains, deep incised valleys, escarpments and plateaus. Denkoro River, which joins the Nile River in its western end after crossing the park and many ponds and water holes are found inside and surrounding the Park (Yirmed Demeke and A. Bekele, 2000 ; Gizachew Girma , 2016 and Ayenew Biset , 2017).

C) Climate

BSNP exhibit bimodal rainfall pattern, while CCNP exhibit unimodal rainfall pattern. The long rainy season in BSNP occurs from June to September, locally known as “Kiremt” and a short wet season occurs between March and April locally known as “Belg”. However, in CCNP unimodal rainfall pattern exist with uniform distribution of rainfall, from March through September with the peak in July. The mean annual rain fall of the area varies between 1000 to 3500 mm and 950 to 2350 mm at CC and BS National Parks respectively. The mean minimum and maximum temperature is 21^0C - 27.5^0C in CC and 9.5^0C - 24.4^0C in BS National Parks respectively (National metriological service Agency).

D) Geology and Soil

The major soil types in South Wollo are Cambisols, Arenosol, Lithosols and Vertisols (MoPED, 1993). Almost 80 % of the area has a soil depth less than 20 cm due to excessive erosion which brings about low soil productivity and low water holding capacity during periods of irregular rainfall (Henerickson *et al*., 1983). BSNP lies on Tertiary volcanic deposits, which are extremely thick, and the soils are mainly Lithosoils (McGinley, 2008). Most parts of the area are covered by volcanic rocks mainly basalts of Tertiary age (Anonymous, 1988). CCNP is characterized by three soil types namely, Alisols, Leptosols, Nitosols, Where Nitosols are the dominant soil types in the park area (Aramde Fetene, (2016) ; un published preliminary field observation report). However, the Soil analysis result in the present study revealed that the major textural classes in CCNP are Clay Loam, Clay, Sandy Loam and Sandy Clay Loam while Loam, Sandy Loam and Clay Loam Soil types are the dominant one in BSNP.

E) Flora and Fauna

The two parks are known as homes for diverse flora and fauna, including some of endangered and endemic species. In CC and BS National Parks there are 120 and 174 species of vascular plants; respectively found in herbs, climbers, shrubs and tree growth forms (Girma Timer ,2005 and Abate Ayalew *etal*., ,2006). The composition of vegetation diversity forms different habitat types in the national parks. In CCNP Wooded grass land, Wood land, Moist Afro-montane forest and Riverine Forest are dominant habitat types, while in BSNP riverine forest, Erica wood land and open grass land comprises the dominant habitat types (Meseret Admasu , 2006 and Abate Ayalew *et al*., ,2006). In CCNP the proportion of habitat types for wooded grass land, wood land, montane and riverine forest were (62.5 %), (8 %), (29.5 %) and (3 %) respectively ; Meseret Admasu, (2006). On the other hand, BSNP comprises Riverine forest (55 %), Erica wood land (18 %) and Open grass land (27 %) Meseret Chane, (2010). The two National Parks were known by elephant, African buffalo, leopard, lion, spotted hyena and African wild dog (CC) and Gelada baboon, Ethiopian wolf and Menilk’s bush buck species of large mammals (BS) respectively. The parks also support diverse species of birds.

F) Land Use and Livelihoods

The major land use of the parks are riverine and mountain forest, wood land and wooded grass land, open grass land, bare land and water bodies like lake & wetlands. However, it is surrounded by agriculture dominated land scape followed by human settlements often influencing the forest land scape with severe human inhabitations and livestock encroachments.

Most people around CC and BS National Parks are engaged in mixed farming. Fuel wood collection, livestock grazing and fire are common activity in the area that led to deforestation and habitat destruction. Poaching of large mammals are also known to occur in both national parks. This has led to decline of the population of the many wildlife species (Gizachew Girma , 2016 ; Meseret Admasu , 2016 ; Meseret Chane , 2010 and Yirmed Demeke and A. Bekele , 2000).

3.2 Sampling and Data Collection Methods

3.2.1 Sampling Design

A. Carbon Stock Assessment.

A stratified sampling design across dominant habitat types in each national park has been used. The stratification was done with considering vegetation differences and land covers in each study area. All informations obtained from secondary data, field survey and satellite images were intensively used to stratify the study sites. The classified lands were Moist Afromontane Forest (MAF), Combretum Terminalia wood land (CTWL), Wooded grass land (WGL) and Wet land land cover types for CCNP while Dry Afro-montane Forest (DAF), Afro alpain wood land (AAWL) and Afro-alpain grass land (AAGL) were the land cover types stratified in BSNP. The approximate area of each strata in each national park were identified using Google Earth Tools and field based collected training samples.

Sampling plots and transects were systematically generated on a map in a geographic information system (GIS) with the aid of field based collected Ground verification, Google earth tools and Quantum GIS software version 2.18. Based on this, sample plots were proportionally allocated for each strata at each study area. Sample plots have been distrbuted on the map with a 100 m buffur zone from the park boundary towards the center to avoide the edge effects for each study areas.

Accordingly, for biomass carbon estimation, a total of 193 sample plots (distributed over 29 transects) with 20m x 100m size had been established in the two study sites; 63 plots (Over 25 transects) for Borena-sayint (Figure 2) and 130 plots (Over 4 transects) for Chebera-churchura (Figure 3) National parks. Transect lines and sample plots were systematically laid on the map for each habitat type and each sampling points were placed on the transect line following the topography of the study areas in an attempt that represent subtle ecotones and capture the greatest number of plant species. The number of sample size required for each strata in the present study of both study sites was determined by the following Pearson *et al*., (2005)formula

$$n = \left[\frac{CV\% \text{ x } t}{E\%} \right]^2$$

Where : n = number of sample plot, CV % = Coefficient of variation (%)

t = student statistics , E % =The standard precision required

The number of sample plots allocated for each strata were 29 (DAF), 23 (AAWL) and 11 (AAGL) in BS while 33 (MAF), 28 (CTWL), 59 (WGL) and 10 (WeL) in CC study site. In all stratum of the two study areas, the distance between each transect lines and each plots over the transect line were 10,000 m and 1000 m for CC and 1000 m and 500 m for BS National parks respectively. The distance between transect lines and plots over transect line were designed with the intention to cover the entire study site based on the size of the area. Each plot consists of nested plot design framed within an outer 2000-m^2 plot (100 x 20m) with one 100-m^2 (10 x 10 m) medium subplot in the center of the big plot and five 1-m^2 small sub plots (1 x 1m^2) positioned along the four corner and center of the medium plot (Figure 4), which was adopted from Hairiah *et al*., (2001).

For soil carbon stock estimation, a total of 300 soil samples from 50 plots have been established with in the 10m x 10m medium plot of the two study sites. From each 10m x10m medium subplot, the three 1m x1m small sub plot traversing from left to right was used for soil sample collection. The two 1m x1m small sub plot located at the corner of the medium sub plot were used for soil composit collection while the middle one 1m x 1m was designed for the collection of soil bulk density. In both study sites of different stratum, each medium plot used for soil sample collection were taken one after the other from the big sample plots of 20m x 100m.

In general, a total of 120 soil samples (20 plots x 1 pit x 2 soil depth = 40 samples for soil bulk density) and (20 plots x 2 pits x 2 soil depth = 80 samples for soil composite) were designed for BSNP while a total of 180 soil samples (30 plots x 1 pit x 2 soil depth = 60 samples for soil bulk density) and (30 plots x 2 pits x 2 soil depth = 120 samples for soil composite) were planned for CCNP. The number of soil samples designed and allocated for each strata based on the size of the area and the significance of the land cover types were 60 (DAF), 36 (AAWL) and 24 (AAGL) for BS while 48 (MAF), 54 (CTWL), 42 (WGL) and 36 (WeL) for CC study site.

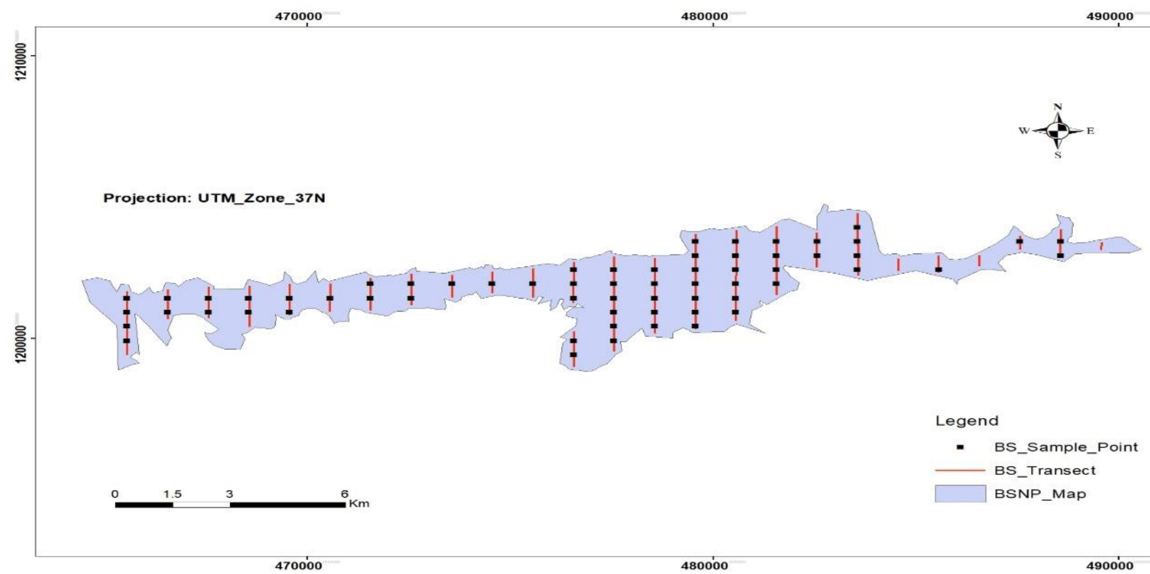

Figure : 2 Sample plot distribution ove transect line for BSNP.

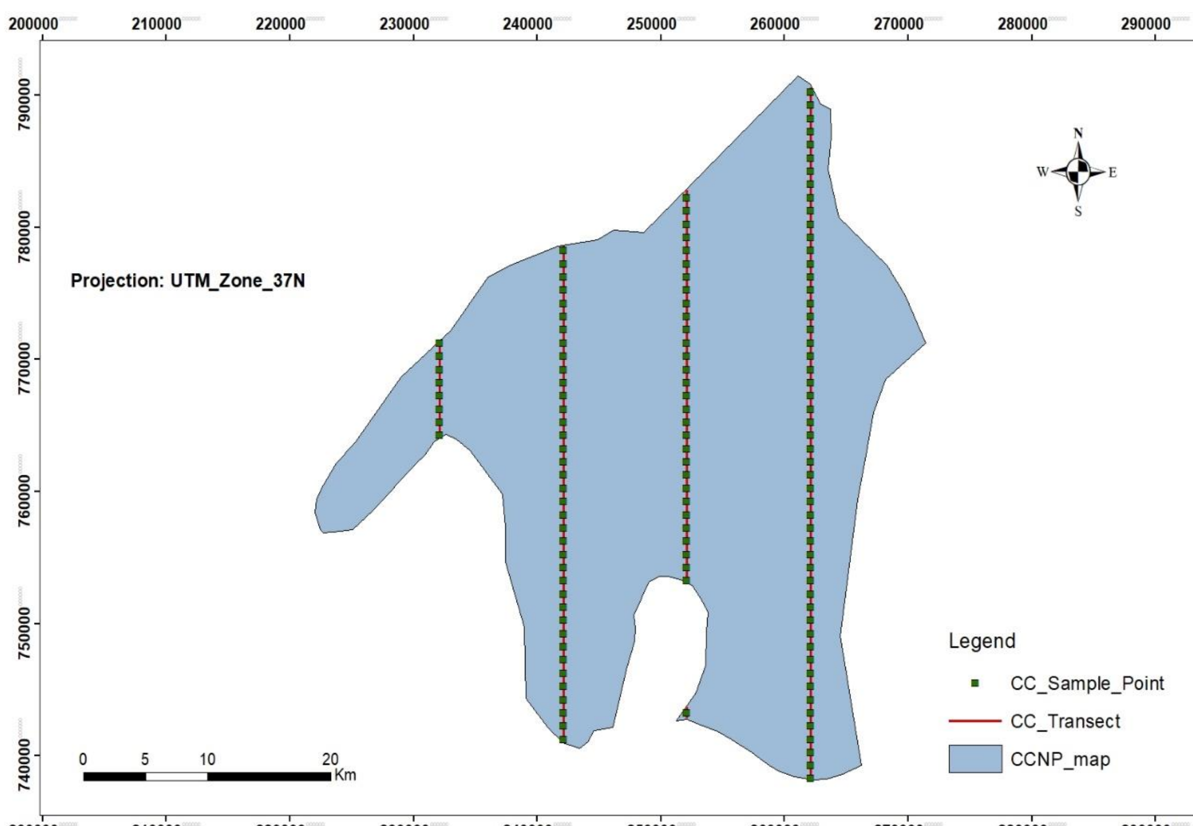

Figure : 3 Sample plot distribution ove transect line for CCNP.

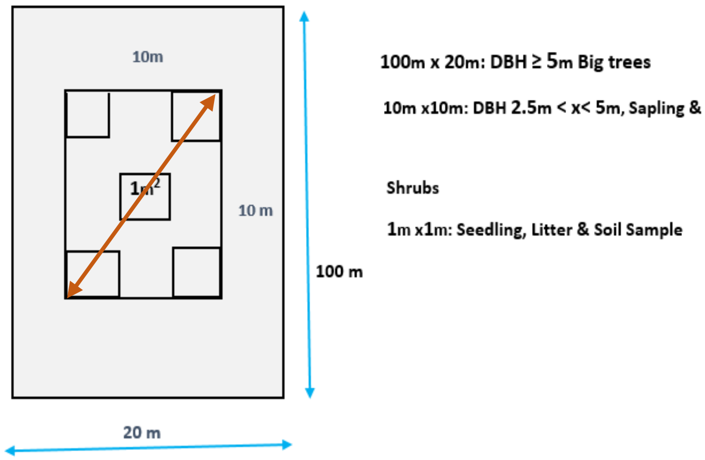

Figure 4 : Nested sample plot design for vegetation and soil survey.

B). Land Cover Change Analysis

The three Geo spatial technologies , Geographic information system (GIS), Remote sensing (RS) and Global positioning system receiver (GPS) were intensively used to investigate the pattern of land cover change on each study area's over the past three decades. For this study, three periods (1990, 2003 and 2017) Landsat satellite imagery data were used by down loading from NASA website. (Http: //glovis.usgs.gov). Besides, based on proximity to the park a total of sixty key informants (Ten from each kebele) and six focuse group (Two from each kebele) from Communities of three rural kebeles for both study sites were purposefully selected and interviewed (Churchura, Seri and Shita kebeles for CC site and Anferfra, Kotet and Miskabi kebeles for BS site) to get the back history and trends of land cover change on the study areas.

3.2.2 Data Collection

A) Carbon Stock Assessment.

All data's were collected from field in between March 23 and July 11, 2018. Biomass data was collected from 193 sample plots through field observation and measurments at different levels with in the limits of sampling units or plots and in smaller sub plots with in each plot.

In the 100 x 20 m quadrat all live trees with diameter at breast height (DBH) greater than or equal to 5cm and a height (H) greater than or equal to 2 m were measured. Similarly, for dead wood trees the diameter and the status of the tree were recorded in each main plot. For standing dead wood measurement, trees with diameter at breast height (DBH) greater than or equal to 5cm and a height (H) greater than or equal to 2 m including the tree status were recorded. But for the fallen dead wood, mid point diameter measurement were under taken in the main plot for all trees with DBH more than 10cm. The measurement includes the status of the wood (sound or rotten), mid point diameter (cm) and the length of the tree in meter (De Vries, 1986).

In the 10 ×10 m quadrat shrubs and saplings in all of the sub plots with a diameter at breast height (DBH) 2.5 ≤ x ≤ 5 cm and a height (H) greater than 1.3 m above the surface level were counted. Similarly, in all the 1 x 1 m quadrats regenerated seedlings with a diameter at breast height (DBH) ≤ 2.5 cm and a height 0.3 ≤ x ≤ 1.3 cm were counted (Mehari Alebachew, 2015). But small trees and shrubs that have DBH less than 5 cm were not used for carbon estimation in this study.

All trees that have (DBH) greater than or equal to 5cm with in the quadrat were measured by metallic caliper (DBH ≤ 50 cm) and diameter tape (DBH ≥ 50 cm) while a height (H) was measured by hypsometer instruments. Tree species information, including vernacular and scientific names of the trees, were collected and identified. The identification was done by using local guides who know species in local language, experience of researcher and from plant identification manuals of Azene Bekele (1993) and Woldemichael Kelecha (1980).

On the other way, litter samples were collected in a 1 m × 1 m sub-plots at all corner and middle position of each small plots. The samples of herbs, fallen leaf and fine branches with in all 1 m x 1 m quadrats of each small plot were collected and weighed on the field, and 100 g of evenly mixed sub samples have been brought to the laboratory to determine dry biomass and percentage of carbon. Then it was oven dried at 70°C till constant weight (Jina *et al*., 2008). The sub-sample dry weight was extrapolated to sub-plot, ha and project level.

For SOC determination, a total of 150 pits were dug for soil sample collection in each land use types of both study sites, 90 and 60 pits for CC and BS national parks respectively. Soil samples were collected from the three 1 x 1 m diagonal subplots traversing the 10 x10 m plot from left to right. The samples were taken from the layers of two soil depth (0–30 and 30–60 cm) using a calibrated soil auger. The composite samples were collected by mixing soil sample taken from the respective layers of the two 1 x1m small sub plots located at the corner of the middle plot. Soil bulk density samples were taken by metallic auger of 4.5 cm diameter and 30 cm height from the two layers of the middle 1 x1 m sub plots separately. Bulk density was estimated after drying the core samples of soil at 105^{o}C. For the layers of each sub plot about 150 g of soil samples were collected for both study sites accordingly.

Ingeneral, a total of 200 soil samples from both areas 120 (60 for SBD and 60 for SOC) for CC and 80 (40 for SBD and 40 for SOC) for BS representing different land cover types were collected, labeled, packed and brought to Hawassa University WGCF Soil Testing Laboratory. Before conducting the analysis work, the soil samples were air-dried, well mixed and sieved through a 2 mm size mesh sieve and analyzed following Walkley & Black (1934).
Core sampler and auger were instruments used to collect soil sample from field. Besides, other instruments like compass for determining direction, measuring tape for measuring distance, digital camera for taking photo, clinometer for measuring slope (%) and GPS for searching plot

location and taking coordinates of each quadrat were used during field data collection. Furthermore, secondary data's like shape file, socio-economic and metreological data's were collected from published and un published documents, CSA, EMA, NMA and EWCA while DEM and Satellite images of land sat_ 5, 7 & 8 for the respective periods were down loaded from glovis.usgs.gov. (Lst. 1990, 2003 and 2017).

B) Land Cover Change Analysis

Relevant information about changes in land cover pattern of both study areas for the years between 1990 to 2017 were extracted after satellite images of land sat_ 5, 7 & 8 for the respective periods were down loaded from glovis.usgs.gov. (Lst.1990, 2003 & 2017), (Table: 1). The images were selected carefully and down loaded with keeping its better quality i.e. with minimum cloud cover and haze. Each land cover types were identified by using google Earth Tools and field based collected reference points.

For this study, a total of 280 representative reference data's were collected from field and Google earth to support accuracy of supervised classification (Table: 2). On average a minimum of 40 reference points were collected for each land cover types of both study sites. Besides, a total of sixty key informants (KI) and six focuse groups (FG) were interviewed to obtain the back history and trends of land cover change on each study areas. The individuals involved in key informants and focuse group discussion includes Elders, Kebele chair man, Development agents, women, scout and Experts from park.

Table 1 : Land sat data acquaired from NASA

Sensors	NB	GR (m)	TR (days)	ICD	SC (km)	A (km)	CCR (%)
Landsat [4,5] TM	7	30 x 30	16	1982	170 x 185	705	0 - 2
Lansat [7] ETM^+	8	30 x 30	16	1999	180 x 185	705	0 - 1
Landsat[8], (OLI &TIRS)	11	30 x 30	16	2013	180 x 185	705	0 -1

(NB = Number of bands, GR = Ground resolution, TR = Temporal resolution, ICD = Image capture date, SC = Spatial coverage, A = Altitude , CCR = Cloud cover range, TM = Thematic Mapper, ETM^+ = Enhanced Thematic Mapper, OLI = Operational Land Imager, TIRS = Thermal Infrared Sensor, Km = Kilometer, m = meter.)

Table 2 : Reference data collected from field.

SN.	Study Site	LULC Type	Training Data	Validation Data	Total
1	BSNP	DAF	28	14	42
		AAWL	26	14	40
		AAGL	11	5	16
		COGL	8	4	12
2	CCNP	MAF	26	14	40
		CTWL	26	14	40
		WGL	40	20	60
		WeL	10	5	15
		COGL	10	5	15
3	Total		185	95	280

(Remark. DAF = Dry Afromontane forest, MAF = Moist Afromontane forest, AAWL = Afro alpain woodland, AAGL = Afro alpain grass land, CTWL = Combretum Terminalia woodland, WGL = Wooded grass land, WeL = Wet land and COGL = Cultivated and over grazed land.)

3.3 Data Analysis

3.3.1 Carbon Stock Estimation Analysis

Data's collected from field were organized and summarized on excel spread sheet version 2016. For this study, the amount of carbon stock in vegetation and soils of the two study sites were assessed by considering the five forest carbon pools, which is in accordance with the IPCC 2006 GL (Estrada 2011). The total forest carbon pools were the summation of carbons at aboveground biomass, belowground biomass, dead wood biomass, litter biomass and soil organic matter.

3.3.1.1 Above Ground Tree Biomass (AGB) Carbon

Above ground tree biomass and respective carbon stock were calculated using an improved allometric equations developed by Chave *etal*., (2014). Since Chave *etal*., (2014) involves wood specific density, diameter at breast height (DBH) and total tree height (H), the inclusion of specific wood density in the equation significantly improves biomass estimation hence, it was selected as an improved biomass regression model for this study. DBH and H of the trees were obtained from field measurments. But, measuring H of whole trees in the plots of both study sites in the field were difficult due to undulating topography and closed canopy cover of forests in the area, hence H of twenty trees for each plots were measured from field with a great care and then the H of the rest trees in each plots were computed with H- diameter curve on the excel spread sheet. On the other hand, for the estimation of AGB of species that have specific wood densities, (Genuse, family and species), the specific wood densities were obtained from the ICRAF wood density data base (www.world agroforestry.org) and the Global wood density data base (Zanne *et al*., 2009). Accordingly, of species recorded 72% in BS and 77% in CC have got specific wood density from ICRAF data base. However, for those species that do not have wood specific density, country specific wood density developed for species in Ethiopia was used for this study. The over all average wood density for Ethiopan species is 0**.**612g/cm^3 (Ethiopia FRL, 2016).

The estimation of AGB in forests of both study sites were done based on plot based forest inventory that involves the following three steps (Brown *et al*., 1989; Houghton *et al*., 2001; Chave *et al*., 2005 and Chave *et al*., 2014).

1. A single tree biomass was calculated with the selection and application of appropriate tree biomass model.

2. Plot based AGB was estimated by the summation of an individual tree biomass with in the plot.

3. Hectar based AGB was estimated by the conversion of Plot based average AGB to hectar.

The general biomass model that was used to calculate the above ground biomass for this study is Chave *et al*., 2014) and given as:

AGB = 0.0673*(WD*DBH^2*H)^0.976…………………………………………Equation (1)

Where,

AGB = above ground biomass (kg/tree)

WD = Spesific wood density (g/cm^3)

DBH = diameter at breast height (cm).

H = Total tree height (m)

The carbon stock of above ground biomass is 47% of above ground biomass.

The Equation was:

AGC = AGB x 0.47……………………………………………..Equation (2)

3.3.1.2 Below Ground Tree Root Biomass (BGB) Carbon

Below ground tree root biomass was estimated using root to shoot ratio which varies from 20 to 50% depending on species. Since conservative values are recommended for carbon accounting purposes, 26% was used as a conversion factor for above ground biomass to belowground biomass as recommended by other authors (Cairns *et al*., 1997; Ciais *et al*., 2011).

BGB = AGB x 0.26………………………………………………………… Equation (3)

Where,

AGB = Above Ground Biomass (kg/tree)

BGB = Below Ground Biomass (kg/tree) and the carbon stock of root biomass is 47% of below ground biomass.

The Equation was**:**

BGC = BGB x 0.47 …………………..…………………………………………Equation (4)

Where,

BGC = Below Ground Biomass carbon

BGB = Below Ground Biomass

3.3.1.3 Dead Wood Biomass Carbon

For standing dead wood with branches the allometric equation used was similar to the one that was used for live trees above ground biomass estimation. But for standing dead wood do not have leaves, needs to subtract 5-6 percent for conifer species while 2-3 percent for broad-leaved species (Pearson *et al*., 2005). Since most of the existing species in both study sites were broadleaved, 2.5 percent reduction was used from the total above ground biomass of each standing dead tree.

Accordingly, based on their decomposition status for this study, dead woods were categorized in to two classes namely sound and rotten. If the dead wood was fresh and did not well decomposed, then it was taken as sound, otherwise it was rotten. Generally, as a rotten wood contains less biomass carbon than sound wood, the wood density of dead wood is scaled down using lower wood densities than for standing live trees as follows;

Sound dead wood biomass **:** Volume*90%*Default WD,

Rotten dead wood biomass **:** Volume*50%* Default WD

The default wood density for species is 0**.**612g/cm^3

$BSDW_1$ = 0.0673*(WD*DBH^2*H)^0.976 …………………………………………Equation (5)

$BSDW_2$ = 0.0673*(WD*DBH^2*H)^0.976 - 2.5% …………………………………Equation (6)

Where, BSDW = Biomass of Standing Dead Wood (kg).

DBH = Diameter at Breast Height of Standing Dead Wood (cm)

WD = Spesific wood density (g/cm^3)

H = Total height of Standing Dead Wood (m)

Since both study sites were conserved protected areas, no data was recorded regarding logged trees with the assumption that logging activity was in significant in such areas.

The volume of fallen dead trees were calculated using the midpoint diameter and height measurements. It was then estimated using Huber's Formula: as indicated below

$V = g_m L$ .... Equation (7)

Where, V = Volume of the Log

g_m = Cross-Sectional Area at Log mid-Point

L = Log Length

Volume was converted to dry biomass using average wood density available in Ethiopia FREL (2016):

$BFDW = V \times WD$ .... Equation (8)

Where, $BFDW_2$ = Biomass of fallen Dead Wood (kg)

V = Volume of the Dead Wood (m^3)

WD = Wood Density of the Dead Wood ($g\ cm^{-3}$) = 0.612 $g\ cm^{-3}$

The total biomass of the dead wood was estimated by summing up the standing and fallen dead wood as follow:

$TBDW = BSDW_1 + BSDW_2 + BFDW$ .... Equation (9)

Where, $TBDW$ = Total Biomass of Dead Wood in a given Plot

$BSDW_1$ = Biomass of Standing Dead Wood which have Branches

$BSDW_2$ = Biomass of Standing Dead Wood which haven't Branches

$BFDW$ = Biomass of fallen Dead Wood

The total carbon stock in dead wood was computed by multiplying the total biomass of the dead wood by 0.47 (IPCC 2006).

TCDW = TBDW x 0.47……………………………………………………………Equation (10)

3.3.1.4 Litter Biomass Carbon Estimation

Litter biomass and % carbon content are the two parameters required to estimate the carbon stock stored in litter biomass. The loss on ignition (LOI) method was used to estimate the % carbon content in litter biomass. In this method, fresh weight of samples collected from field were placed in an ovendry and dried at 65^0c for 48 hours to get dry weight Allen *et al*., (1986). From the dry weight 3.00g samples were taken in pre-weighted crucibles, then after placed it in the furnace at 550^0c for one hour to ignite (Ullah and Al-Amin, 2012). The crucibles were cooled slowly inside the furnace. After cooling, the crucibles with ash were weighted and % carbon content was calculated according to Allen *et al*,. (1986).

$$\text{Ash} = \frac{(W3 - W1)}{(W2 - W1)} \text{ x } 100$$

C (%) = (100 - %Ash) x 0.58 (Considering 58% carbon in ash-free litter material).

Where; C = Biomass carbon stock

W_1 = weight of crucible

W_2 = weight of the oven-dried grind sample and crucible

W_3 = weight of ash and crucible

The carbon content was considered to be 50% of the biomass (Liu *et al.*, 2014). For the forest floor (litter), the amount of bio mass per unit area was estimated according to Persson *et al*,. (2005):

$$\text{LB (kg)} = \frac{\text{Wt field}}{A} \text{ x } \frac{\text{Wt Sub Sample Dry (kg)}}{\text{Wt Sub Sample Fresh (kg)}} \text{ x } \frac{1}{10,000} \text{..............................Equation (11)}$$

Where ; LB = Litter biomass

Wt field = Weight of the fresh field sampled litter with in an area of A(g)

A ═ Size of the area in which litter was collected

Wsub-sample (fresh) ═ Weight of the fresh sub-sample of litter taken to the laboratory to determin the moisture content (g).

Wsub-sample (dry) ═ Weight of the oven-dry sub-sample of litter at the laboratory.

3.3.1.5 Soil Organic Carbon

For this study, a total of 200 soil samples (120 from CC and 80 from BS) from different stratum were collected and brought to soil laboratory for carbon analysis. Prior to analysis the samples were air-dried, well mixed, ground and sieved through a 2 mm mesh size sieve and analyzed following Walkley & Black (1934). Similarly, Bulk density for each soil depth was determined by drying the soil sample in an oven at 105^0c for 24 hours. The samples were analized by the wet oxidation method (Huq and Alam, 2005), for the estimation of organic carbon percentage.

The soil organic carbon stock was calculated following (Pearson *et al.*, 2005) formula given as:

SOC = BD x d x % C ……………………………………………………………..Equation (12)

Where, SOC = Soil Organic Carbon [t ha-^{1}]

BD = Bulk Density [g cm-^{3}]

d = Depth of the Soil Sample [cm]

% C = Carbon Concentration [%]

The bulk density required for soil organic carbon determination was calculated as:

$BD = \frac{Wav.dry}{V}$...Equation (14)

Where: BD = bulk density of the soil sample per the quadrant, Wav.dry = average dry weight of soil sample per the quadrant, V = volume of the soil sample in the core sampler auger in cm^3

3.3.1.6 Estimation of Total Carbon Stock

The total carbon stock density of each study site has been calculated by adding all the carbon stock densities in each pool in all land cover types using the following formula:

CT = AGC + BGC + DWC + LC + SOC…………………………………………..Equation (15)

Where: CT = Total Carbon stock for all pools (t ha^{-1}), AGC = above ground carbon stock (t ha^{-1})

BGC = below ground carbon stock (t ha^{-1}), DWC= dead wood carbon stock (t ha^{-1})

LC = litter carbon stock (t ha^{-1}) and

SOC = soil organic carbon (t ha^{-1}). Then total carbon stock was converted to tons of CO_2 equivalent by multiplying it by 3.67 (Pearson *et al*., 2007).

3.3.2 Land Cover Change Analysis

Image processing such as; geometric correction, radiometric correction, image enhancement, image classification, accuracy assessment and change detection were the procedures carried out to analyze the given land cover data.

A) Image Processing :- Processing involves operations such as corrections for geometric and radiometric errors and enhancing an image that are normally required prior to the main data analysis and extraction of information.

Geometric correction :- is the correction that was achieved by establishing the relationship between the image coordinate system and the geographic coordinate system using calibration data of the sensor and measured data of position and attitude of ground control points.

Radiometric correction :- was under taken to remove errors on an image due to : - the sun's azimuth and elevation, atmospheric conditions (Fog, Aerosols) and sensor's response. Errors due to atmospheric effect were corrected by using correction methods like the radiative transfer equation/ correction models, ground truth data, data from special sensor, Haze reduction and Dark Object Subtraction method (DOS) (Campbell, James B., 2011).

Image Enhancement :- The image was enhanced to improve the visual interpretability of an image by increasing the apparent distinction between features in the scene (Lillesand and Kiefer, 2000). Image enhancement was used to increase the details of the image by assigning the image maximum and minimum brightness values, it was done on pixel values, and this makes visual interpretation easier and assists the human analyst. Prior to the actual classification work image inhancement, proper layer stacking with 4 - 3 -2 band combination and extraction of the study area were under taken carefully. The original low dynamic range of the image was stretched to full dynamic range which is from 0 to 256 by using histogram equalization. Moreover, spatial enhancement of convolution of Kernel 5 by 5 of high pass filtering were done on the images of the respective years.

B) Image Classification

For this study, both types of digital image classification methods (unsupervised and supervised) were used. Supervised image classification is a method in which the analyst defines small region of interest (ROI) on the image, which is representative of the desired land cover category. The delineation of training area (region of interest) was most effective when an image analyst has knowledge of the geography of a region and experience with the spectral properties of the cover classes. However, the unsupervised classification technique was performed when there is little or no knowledge about the geography of the region where classification is needed. Therefore, first the satellite image was classified with the unsupervised classification for identification of the features in a pixel form. Then supervised classification was done by using the training samples collected from field and points collected from Google Earth. Identification of the land cover classes required a number of field visits and discussions with the local communities, inorder to have a clear understanding of the existing main land cover types as well as also to predict the changes happened over time. Ingeneral, the classification work was done by the combination of visual image interpretation of human eyes and creating region of interest (ROI) on an image of land sat TM, ETM+ and OLIS and TIRS satellite imagery for the three respective years to investigat the land cover change and deforestation rate on the area. In supervised classification image processing was done with minimum distance classifier algorithm. Post processing like accuracy assessment and change detection were done with semi-automatic classification plugin installed on Q GIS soft ware.

C) Accuracy Assessment

Land cover classification maps generated from remotely sensed data always contain some sort of errors due to many factors, which range from satellite data acquisition to image classification technique. In order to accept or reject a classification result at a certain confidence level the errors must be quantitatively evaluated in terms of classification accuracy and was intended to produce information that describes ground reality. Therefore, an accuracy classification assessment was carried out to verify to what extent the produced classification was compatible with what actually exists on the ground (Congalton, 1991). It involves the production of references (training samples and validation points) to evaluate the produced classification. These references were obtained (15) from Google Earth and (80) from GCP collected field data, which was independent of the ground truths used in the classification.

A widely used method to describe the relative accuracy of classification was the confusion matrix. It requires ground truth reference data and the classification data which was done based on simple ratios that provides class and overall accuracy.

This method was determined from two point of views: users' point of view (users' accuracy) and producers' point of view (producers' accuracy). Finally the matrix result was verified by conducting Kappa coefficient statistics.

D) Matrix of Land Cover Change

The change matrixe was done simply by using the semi- automatic classification plugin installed on Q GIS soft ware. The area converted from one class to the other class was computed automatically by Q GIS softwares. But for this study QGIS software version 2.8.1 and 3.2.3 were used interchangably to compute the change matrix of two periods land cover maps. The rate of change was calculated for each land cover using the following formula:

Rate of change (ha/year) = (A-B)/C

Where, A = Recent area of the land cover in ha

B = Previous area of the land cover in ha

C = Time interval between A and B in years

It should be noted that the negative values indicated the magnitude of decline in that particular land cover type.

3.3.3 Statistical Test

In this study, the relationship between different variables were tested using mean and standard deviation while one way ANOVA was used to test the effect of land cover variations on biomass carbon stocks (Appenices: 1B and 3A). More over, univariate analysis of variance following the generalized linear model(GLM) procedure of SPSS version 23 was employed to test the effects of land cover and soil depth variations on soil organic carbon stocks and concentrations in this study (Appenices: 2 C & D and 4 A & C).

Further more, the presence of significant differences in means between each land cover type and soil depth on carbon stock of the biomass as well as soil organic carbon were tested using Tukey's Honest Significance Difference (HSD) test.

The statistical mean differences were considered significant when P-value is less than 0.05. Finally, the data has been calculated, analyzed, interpreted and presented as a report using descriptive statistics, frequencies, percentiles, graphs, table’s and histograms.

4 RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Vegetation Characterstics

In the study, a total of 124 tree species (88 and 36) were recorded in CC and BS study areas respectively. Important variables such as tree diameter and total tree height which required for biomass carbon estimation were also identified. From the identified all tree species, a total of 11,205 individual stems were recorded in both study areas.

Accordig to the data presented on table 3 : below, the average number of stem per hectar was 309 and the average basal areas in m^2 per hectar was 12.28 for CC study site. Similarly, for BS study site the average number of stem per hectar was 295 and the average basal area was 7.05 in m^2 per hectar. As it was observed on table 3: below, in both study sites the wood land vegetation was characterized by high stem density as compared to other land cover types but, the highest average basal area was estimated for the Afromontane forests as compared to other land cover types.

However, the Afro alpain Grass land complex (AAGL) land cover was characterized by the lowest average stem density as well as the lowest average basal area as compared to other land cover types on both study sites while, no trees were recorded in wet land land cover of CCNPs. The maximum and minimum number of trees recorded per hectare per strata in CC study site were 585 and 40 (MAF), 910 and 160 (CTWL), 475 and 40 (WGL) and no trees were recorded for Wet Land land cover. Similarly, the maximum and minimum number of trees recorded per hectare per strata in BS study site were 810 and 50 (DAF), 1250 and 90 (AAWL) and 100 and 0 (AAGL) in BS study area. When compared forest land with woodland vegetation types, the average DBH and height of montane forests were higher than that of wood land vegetations on both study area.

Accordingly, as it was computed with an improved allometric model of (Chave *et al.*, 2014), the mean Above ground biomass (AGB) (t ha^{-1}) of MAF > CTWL > WGL in CCNP. Similarly, the mean AGB (t $ha-^{1}$) of DAF > AAWL > AAGL complex land cover types in BSNP respectively (Table 3).

Table 3 : Mean stand characterstics of trees in CC and BSNPs.

NP	Stratum	DBH(cm)	H(m)	BA(m^2) ha^{-1}	TDha^{-1}	AGB(tha^{-1})
CC						
	MAF	23.33	20.89	17.78	278	218.67
	CTWL	17.29	17.72	12.13	420	110.19
	WGL	16.79	14.64	6.93	229	56.18
	WeL	0	0	0	0	0
BS						
	DAF	19.37	18.93	14.60	314	201.18
	AAWL	11.38	13.45	6.52	536	29.86
	AAGL	2.64	2.66	0.014	35	1.03

(NP = National park, CC = Chebera Churchura, BS = Borena Sayint, MAF = Moist Afromontane forest, DAF = Dry Afromontane forest, CTWL = Combretum Terminalia wood land, AAWL = Afro alpain wood land, AAGL = Afro alpain grass land complex, WGL = Wooded grass land, WeL = Wet land , DBH = Diameter at breast height, H = Height, BA = Basal area, TD = Tree density, AGB = Above ground biomass, tha^{-1} = Tone per hectare.)

DBH size class distribution of trees on both study areas.

For both study sites, the distributed tree species in five DBH classes were shown in figure 3 and 4 below. In both cases, most of the woody plants were located in the two lower DBH classes where as the least number of plants were recorded in the third, fourth and fifth DBH classes with a decreasing order. The result of the present study indicated that the number of stems for class 1, 2, 3, 4 and 5 were found to be 1935, 1698, 600, 78 and 12 in BSNP respectively.

Similarly, the tree density per DBH class in CCNP were found to be 2083, 3037, 1581, 154 and 31 for Class 1, 2, 3, 4 and 5 respectively. The above figure indicated as on both study areas, the highest number of individuals were found at relatively lower DBH classes with gradual decline towards the higher DBH classes.

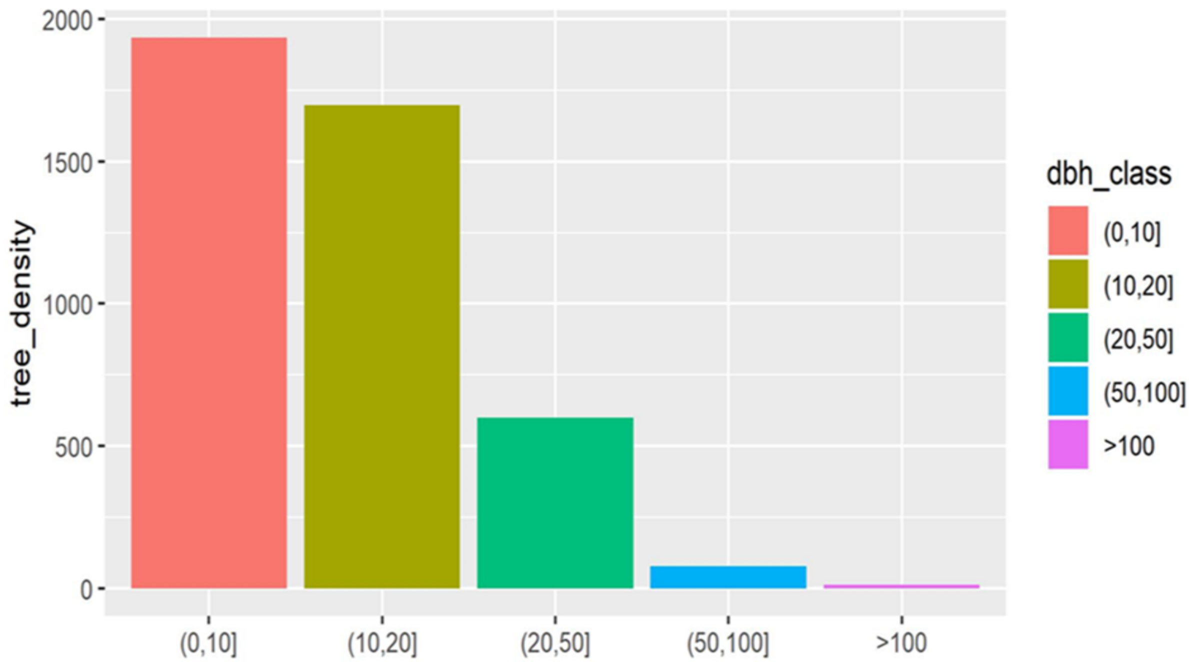

Figure 5 : Diameter size class distribution (cm)of the entire trees in BSNP.

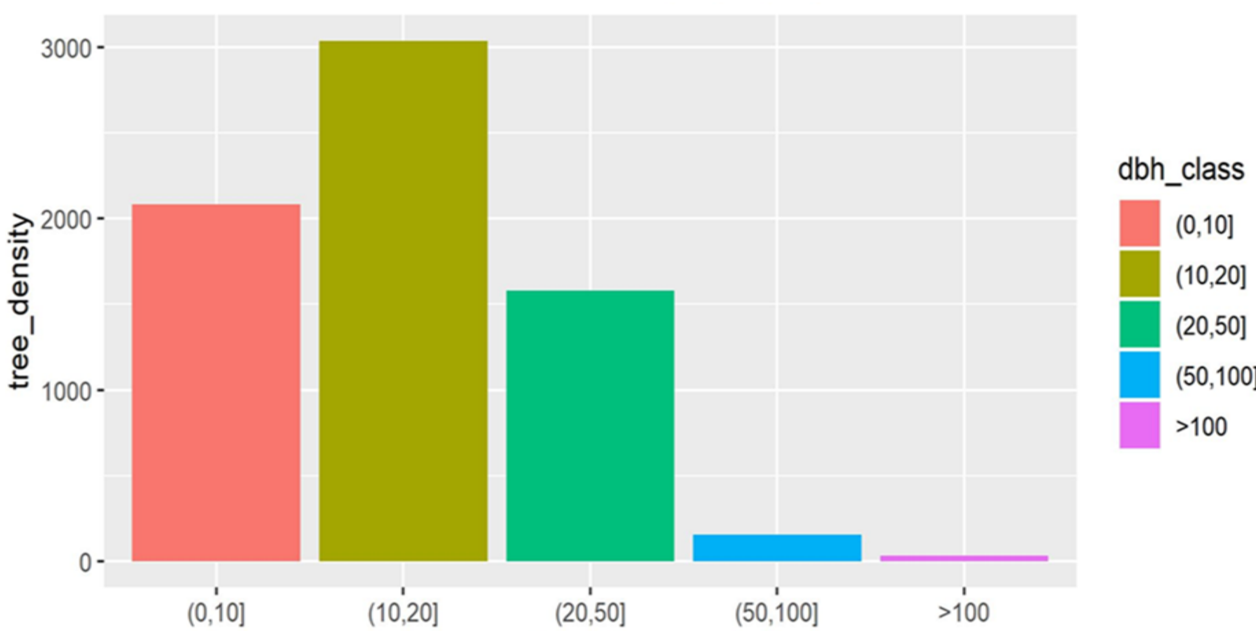

Figure 6 : Diameter size class distribution(cm) of the entire trees in CCNP.

4.1.2 Carbon Stocks in Different Carbon Pools at Both Study Areas.

4.1.2.1 Above Ground Carbon Stock.

The result of this study revealed that the mean carbon stock density across different land cover types in both study areas were significantly varied. The amount of Above ground carbon (AGC) recorded in Afromontane Forests were by far greater than that of wood land and grass land land cover types of similar study sites. As it was observed on table : 4 below, the mean AGC recorded in MAF of CC was by two fold greater than the CTWL Carbon stock and almost by four fold higher than the mean carbon stock of WGL land cover types. Similarly, the mean AGC of DAF in BS was almost by seven times higher than the mean AGC of AAWL and almost by 100 % greater than the mean AGC of AAGL land cover types.

4.1.2.2 Below Ground Carbon Stock

Since the carbon stocks in below ground carbon pools were directly derived from the above ground carbon pools, the variations in BGC of different land covers at each study area had similar trend with that of the above ground carbon pools. The details were indicated in table :4 below.

4.1.2.3 Dead Wood Carbon Stock

For this study, the dead wood carbon pool consists of all non living woody biomass including standing and fallen dead trees with the exclusion of stumps was employed on both study areas. The finding of the present study showed that the mean carbon stocks in dead wood carbon pools of MAF, CTWL and WGL land cover types were indicating a decreasing trend in the order of MAF > CTWL > WGL for CC site. Simlarly, in BS the mean dead wood carbon stocks of DAF > AAWL land cover type. However, as compared to the carbon stored in AG and BG carbon pools, the mean carbon stored in dead wood carbon pool was very low (Table 4).

4.1.2.4 Litter Carbon Stock

The result of this study revealed that, the estimated mean carbon stocks in carbon pool of litter biomass was significantly declined for MAF, CTWL and WGL land cover types in the order of MAF > CTWL > WGL in CC site respectively. However, no litter carbon was found in the AAWL, AAGL and Wetland land cover types except a few mean carbon stocks (0.01tha^{-1}) found in DAF of BS. Ingeneral, as it was indicated on table 4 : below, the least mean carbon storage was obtained from the litter biomass as compared to other biomass carbon pools.

Table 4: Summary of mean biomass carbon (t ha $^{-1}$)

Summary of Biomass carbon (tha^{-1})												
NP	Stratum	N	AGC	SE	BGC	SE	DWC	SE	LC	SE	TBC	SE
CC												
	MAF	33	103	11.1	26.72	2.9	5.02	2.67	0.022	0.003	134.76	16.72
	CTWL	28	51.79	3.83	13.47	1	2.00	0.54	0.013	0.004	67.27	5.37
	WGL	59	26.41	2.96	6.87	0.77	1.05	0.44	0.0061	0.002	34.34	4.18
	F	120	36.488		36.488		1.939		8.745		78.79**	
	P		0.000*		0.000*		0.127		0.000*			
BS												
	DAF	29	94.55	13.5	24.584	3.52	3.25	0.96	0.0079	0.003	122.39	18.01
	AAWL	23	14.03	2.5	3.65	0.65	0.56	0.22	0.00	0.000	18.24	3.38
	AAGL	11	0.221	0.13	0.057	0.03	0.00	0.00	0.00	0.000	0.28	0.16
	F	63	22.621		22.622		5.085		5.026		46.97**	
	P		0.000*		0.000*		0.009*		0.010*			

*values are statistically significant at $\alpha = 0.05$ (95%) ; ** shows total average values.

As it was seen in table 4 above, most of the carbon stock was concentrated in AG and BG carbon pools on both study areas. The contribution of the two carbon pools on aggregate was 228.26 and 137.10 t ha^{-1} for CC and BS respectively. Similarly, the contribution of DW and LB carbon pools on aggregate was 8.11 and 3.82 t ha^{-1} in CC and BS respectively. From the total biomass carbon pools, AG and BG on aggregate holds 96.84 % carbon stocks while the DW and LB holds only about 3.16 % in both study sites. The result of the study indicated that prior to conducting any carbon inventory, identifying and deciding on the pools that hold high stock as well as the one that is highly dynamic and sensitive is very important concern. Further more, the study revealed that the tree component holds more carbon stocks than other bio-masses carbon pools and the removal of trees implies the removal of bulk of carbon stock. So this implies conserving the forest enables sustaining the existing carbon stock as well as enhancing future sequestering potential.

4.1.2.5 Soil Carbon Stock

Table 5 : Summary of mean soil carbon stock (t ha $^{-1}$) and soil bulk density (gcm $^{-3}$).

NP	Stratum	Depth (cm)	OC(%)	SD	BD (gcm^{-3})	SD	SOC (tha^{-1})	SD
CC	MAF	0-30	4.05	(1.045)	1.04	(0.181)	127.00	(41.392)
		30-60	1.85	(0.613)	1.21	(0.151)	68.00	(25.446)
	CTWL	0-30	2.43	(1.542)	1.15	(0.108)	82.36	(46.080)
		30-60	1.30	(0.870)	1.31	(0.172)	50.75	(31.882)
	WGL	0-30	3.22	(2.116)	0.98	(0.158)	102.00	(63.783)
		30-60	1.27	(0.569)	1.20	(0.218)	46.52	(25.145)
	WeL	0-30	3.53	(2.325)	0.98	(0.105)	102.00	(60.695)
		30-60	1.35	(0.830)	1.18	(0.112)	46.68	(26.648)
		F	27.76		22.11		21.16	
		P	0.00**		0.00**		0.00**	
BS	DAF	0-30	5.75	(2.160)	0.77	(0.129)	131.03	(51.136)
		30-60	2.84	(1.115)	1.02	(0.157)	85.47	(36.615)
	AAWL	0-30	9.15	(1.376)	0.58	(0.077)	158.56	(32.093)
		30-60	5.54	(1.985)	0.78	(0.072)	128.34	(43.830)
	AAGL	0-30	8.36	(1.355)	0.66	(0.166)	166.62	(44.704)
		30-60	5.73	(2.102)	0.82	(0.223)	139.66	(50.439)
		F	15.17		10.15		4.37	
		P	0.00**		0.00**		0.02**	

** Values are statistically significant at $\alpha = 0.05$ (95%)

(Numbers in bracket refers standard deviation (SD) : F tests the effect of soil depths on each dependent variables such as; bulk density (BD), percent of organic carbon content (OC) andsoil organic carbon (SOC).

NP = National park, CC = Chebera-churchura, BS = Borena-sayint, DAF = Dry evergreen afromountane forest, AAWL = Afroalphain wood land, AAGL= Afroalphaine grass land complex, MAF = moist evergreen afromountane forest, CTWL = Combretum Terminalia wood land, WGL = Wooded grass land vegetation, WeL = wetland habitat.)

The study result showed that the average soil bulk density on different land covers with a total depth of 60 cm at both study sites in (g cm-^{3}) were 1.125, 1.233, 1.091 and 1.081 for MAF, CTWL, WGL and WeL land cover types in CC while, 0.894, 0.679 and 0.743 were estimated for DAF, AAWL and AAGL land cover types in BS respectively.

As it was observed on table 5 : above, the soil bulk density was increasing with soil depth at all levels for all land cover types on both study sites. In the contrary, the concentration of soil organic carbon stock was decreasing with increasing soil depth at all levels. The SOC in the first layer (0-30 cm depth) was higher than that of the second layer for all land cover types of both study site. This implies that soil depth has a direct relation ship with soil bulk density but, has inverse relation ship with soil organic carbon stock.

4.1.2.6 Total Carbon Stock Density (TCSD)

For this study, the mean total carbon stock densities were obtained by summing the carbon values in all carbon pools (AGC, BGC, DWC, LC and SOC) at all land cover types assessed in both study areas. Accordingly, the total mean of AGC, BGC, DWC, LC and SOC estimated at CC study site in percent were 21.03, 5.46, 0.94, 0.005 and 73.19 respectively. Similarly, in BS study area the estimated mean carbon stocks in each carbon pools were 11.45, 2.98, 0.4, 0.001 and 85.17 for AGC, BGC, DWC, LC and SOC pools respectively. As it was indicated in table 6 : below, the study result depicted that soil carbon pool was found to be the principal storage of carbon stock among other carbon pools in both study sites. Next to soil carbon pool which holds 73.19 and 85.17 % in CC and BS study areas, the second and the third largest carbon reservoir were AGC and BGC pools which holds 21.21 and 5.51 % in CC and 11.45 and 2.98 % in BS study sites respectively. The least carbon stocks were recorded in dead wood and litter carbon pools which holds only about 0.945 and 0.005 % in CC and 0.4 and 0.001 % in BS respectively. The study result showed the mean carbon stock stored (t ha-1) in different carbon pools were decreased in the order of SOC > AGC > BGC > DWC > LC for all land cover types on both study sites.

On the other hand, when the total mean carbon stock density (t ha^{-1}) was estimated from land cover point of view, more than one third of the total carbon stock was stored in MAF (38.60 %), followed by CTWL (22.60 %), WGL (21.40 %) and WeL (17.40 %) land cover types as a second, third and fourth carbon reservior in CC respectively. Similarly, the highest carbon stock was stored in DAF (35.65 %) followed by AAGL (32.25%) and AAWL (32.10 %) as a second and third carbon resrvior in BS respectively.

Table 6 : Summary of total mean carbon stock (t ha $-^{1}$)

Carbon stock density of each carbon pool (tha^{-1}) across different land covers

NP	Carbon Pools									
CC	Stratum	N	AGC	BGC	DWC	LC	TBC	SOC	TC (tha^{-1})	TC (%)
	MAF	33	103	26.72	5.02	0.02	134.76	195	329.76	38.60
	CTWL	28	51.79	13.47	2.00	0.01	67.27	133.11	193.11	22.60
	WGL	59	26.41	6.87	1.05	0.01	34.34	148.52	182.86	21.40
	WeL	10	0.00	0.00	0.00	0.00	0.00	148.68	148.68	17.40
BS										
	DAF	29	94.55	24.584	3.25	0.01	122.39	216.5	338.89	35.65
	AAWL	23	14.03	3.65	0.56	0.00	18.24	286.9	305.14	32.10
	AAGL	11	0.221	0.057	0.00	0.00	0.28	306.28	306.56	

4.1.3 Land Cover Change

In the present study, the over all areas were classified in to eight land cover classes based on the dominant habitat types. The major land cover types observed on the areas were dry Afromontane forest (DAF), afro alpain woodland (AAWL) , afro alpain grass land (AAGL), cultivated and over grazed land (COGL), moist Afromontane forest (MAF), comberetum terminalia wood land (CTWL), wet land (WeL) and wooded grass land (WGL) on both study sites. The land cover maps produced in this study were presented in figures below 7, 8, 9,10, 11 and 12 for the respective periods respectively.

Table 7 : Description of the identified land cover (LC) classes.

LC Types	Description of land cover types.
DAF	Dry ever green montane forest is forest found in between an elevation of 1,900 up to 3,400 m.a.s. in the Central, eastern, south-eastern and northern highlands .eg. Juniperus procera, Podocarpus falcatus, Prunus Africana (Mulugeta Lemenih and Frans Bongers,2017).
MAF	Moist ever green montane forests are forests that corresponds semi-deciduous low land forests, which have a precipitation of approximately 1550 – 3500 mm per year with an elevation of 1500 and 2600 m.a.s. which located in the SW and SE highlands (Feyera Senbeta, 2006).
CTWL	Combretum–Terminalia (broad-leaved deciduous species) are woodlands found in an elivation of 500 – 1,800 m.a.s. in the Western, north-western and parts of the

	south-western lowlands. Eg. Boswellia papyrifera, Terminalia glaucescens (Mulugeta Lemenih and Frans Bongers,2017).
AAWL	Afro-alpain wood land is a vegetation type dominated by Erica arborea species situated in the adjacent area of dense forest and open grass land lies between 2990 to 3340 m.a.s.l.
AAGL	Afro-alpain grass land is an open grass land vegetation situated at high altitude of 3340 to 3665 m.a.s.l.
WGL	Wooded grass land is the vegetation type covers the largest part of CC park and belongs to the Sudanian-Biome regional center of endemism.
WeL	Wet land is a vegetation type found in areas of open grass land sparsely distributed in the park along the plain area and near to lakes and rivers.
COGL	Cultivated and over grazed land is land use land cover types that include farm lands, grazing lands, degraded lands, bare lands and lands ocupied by on going development activities such as roads and mining works in the area.

4.1.3.1 Land Cover in Borena-Sayint National Park.

As indicated on Table : 8 and Figure 7 below, the land cover type occupied by AAWL (50.99 %) was greater than DAF (24.29 %) and AAGL (21.84 %) by more than two folds. Where as the least share was observed in the COGL land cover type which was about 125.55 ha (2.89 %) for the year 1990 in BS study site. More over, the above figure indicated as in the year 1990 more than (75 %) of the area was covered by natural vegetations of afro-alpain wood land and afro-montane forests while, the remaining land 1072.71 ha (24.64%) was occupied by afro-alpain grass land, cultivated and over grazing land.

On the other hand , for the year 2003, the land cover of AAGL (37.21%), AAWL (33.42%) and DAF (20.87%) showed the largest areal coverage. Where as the least area was covered by COGL which was about 369.81 ha (8.53%),(Table : 8 and Figure :8).

In the year 2017, as it was indicated in (Table : 8 and Figure : 9) below the largest area was covered by AAWL (40.51%) followed by DAF (26.54 %) and AAGL (23.36%) as a second and third largest classes respectively. The least area coverage was indicated for COGL land cover class which was about 416.07 ha (9.59%). In general, the result of the study showed the area covered by natural vegetations of AAWL and DAF were declined by 8.23 % in the years between 1990 and 2017. Where as the AAGL and COGL land cover classes showed an increasing trend by 1.52 and 6.7 % in between 1990 and 2017 respectively.

Table : 8 Area of land cover in BSNP for the years 1990, 2003 and 2017.

	1990		2003		2017	
LC_Type	Area(ha)	Area (%)	Area(ha)	Area (%)	Area(ha)	Area (%)
DAF	1052.91	24.29	905.24	20.87	1151.11	26.54
AAWL	2211.75	50.99	1448.35	33.39	1757.03	40.51
AAGL	947.16	21.84	1613.97	37.21	1013.26	23.36
COGL	125.55	2.89	369.81	8.53	415.97	9.59
	4,337.37	100	4,337.37	100	4,337.37	100

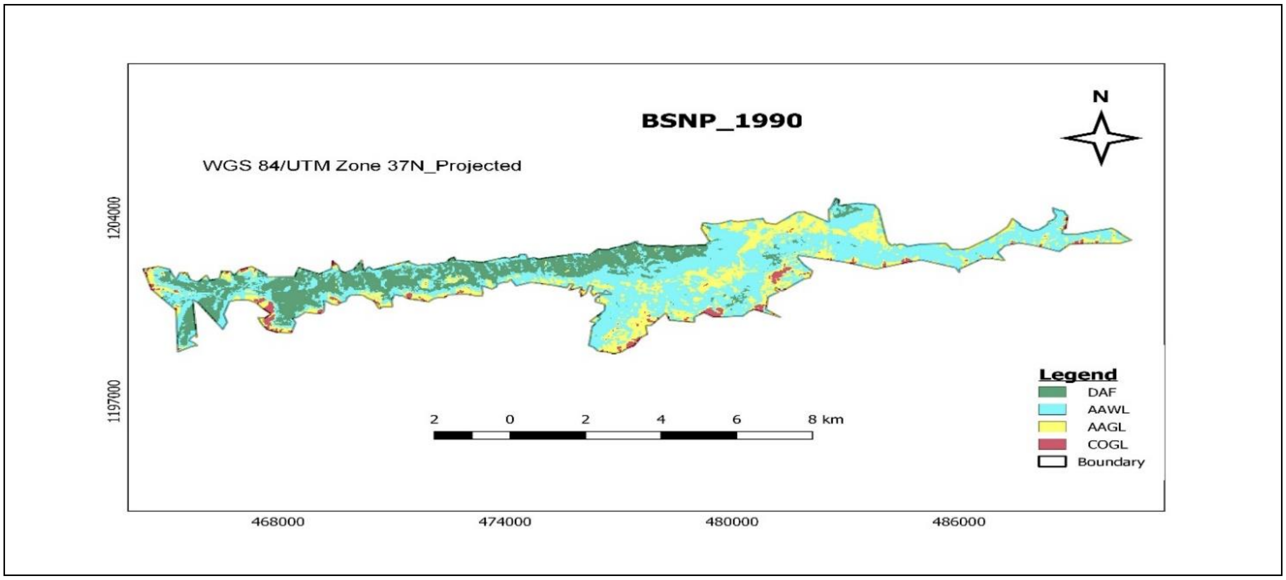

Figure : 7 Land cover Map of BSNP for the year 1990

DAF = Dry afromontane forest, AAWL = Afroalpain woodland,

AAGL = Afroalpin grassland, COGL = Cultivated and over grazed land

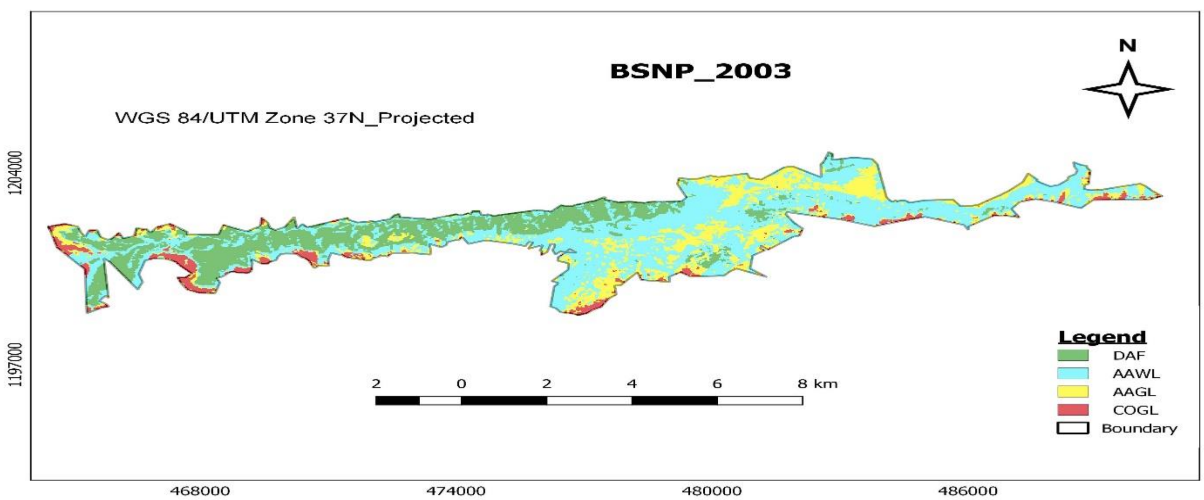

Figure 8 : Land cover Map of BSNP for the year 2003.

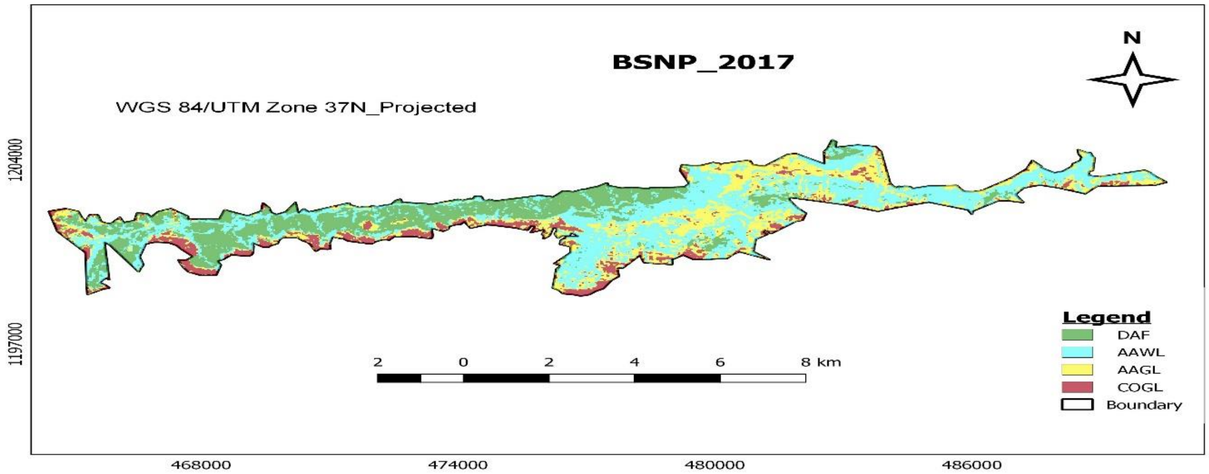

Figure : 9 Land cover Map of BSNP for the year 2017.

DAF = Dry afromontane forest, AAWL = Afroalpain woodland, AAGL = Afroalpin grassland, COGL = Cultivated and over grazed land

4.1.3.1.1 Land Cover Change Matrices of Borena-Sayint National Park

The land cover change matrices shows the direction of change in the years between 1990 and 2003 (Table : 9).

Table : 9 Land cover Change Matrices of BSNP (1990 - 2003)

	LCC_2003 (ha)					
LCC_1990 (ha)	LC_Type	DAF	AAWL	AAGL	COGL	Total
	DAF	**822.43**	65.28	165.20	0.000	1052.91
	AAWL	77.41	**1317.54**	788.49	28.31	2211.75
	AAGL	5.40	65.35	**627.21**	249.20	947.16
	COGL	0.000	0.18	33.07	**92.3**	125.55
	Total	905.24	1448.35	1613.97	369.81	4337.37

As indicated on (Table : 9) above between the year 1990 and 2003 both DAF and AAWL land cover types revealed a declining trend while AAGL and COGL land cover types on contrast showed an increasing trend for similar period. There was a decreasing of dry afro-montane land from 1052.91 ha in 1990 to 905.24 ha in 2003 while, a small portion of the land was converted to AAWL (65.28 ha) and AAGL (165.20 ha). Similarly, the AAWL was declined from 2211.75 ha in 1990 to 1448.35 ha in 2003 while 77.41 ha, 788.49 ha and 28.31 ha of the land were converted to DAM, AAGL and COGL land cover types in the same periods respectively. On the other hand, the AAGL was increased from 947.16 ha in 1990 to 1613.97 ha in 2003 while, 5.4 ha, 65.35 ha and 249.20 ha of this land were changed to DAF, AAWL and COGL land cover types for the same period respectively. Similarly, COGL land cover type was increased by almost three folds from 125.55 ha in 1990 to 369.81 ha in 2003 while a small part of it was converted to AAGL (33.07 ha) and AAWL (0.18 ha).

Table : 10 Land cover Change Matrices of BSNP (2003 -2017)

	LCC_2017 (ha)					
LCC_2003 (ha)	LC_Type	DAF	AAWL	AAGL	COGL	Total
	DAF	**806.12**	97.31	1.80	0.0000	905.24
	AAWL	74.16	**1151.14**	182.64	40.41	1448.35
	AAGL	266.95	495.97	**706.60**	144.45	1613.97
	COGL	3.88	12.61	122.22	**231.1**	369.81
	Total	1151.11	1757.03	1013.26	415.97	4337.37

In similar manner, as it was observed on (Table :10) above, in between the years 2003 and 2017 the land cover types DAF, AAWL and COGL showed a remarkable increase while, AAGL was indicated a decreasing trend. The DAF was increasing from 905.24 ha in 2003 to 1151.11 ha in 2017 as 97.31 ha and 1.80 ha of the land was converted to AAWL and AAGL for the same years respectively. Similarly, AAWL was increased from 1448.35 ha in 2003 to 1757.03 ha in 2017 and COGL was also increased from 369.81 ha in 2003 to 415.97 ha in 2017. For AAWL a small portion of the land was converted to DAF (74.16 ha), AAGL (182.64 ha) and COGL (40.41 ha). Where as, DAF (3.88 ha), AAWL (12.61 ha) and AAGL (122.22 ha) area was the land converted from COGL land cover types in the mentioned period. On contrary, AAGL was decreased from (1613.97 ha) in 2003 to (1013.26

ha) in 2017 while, a small part of the land was converted to DAF (266.95 ha), AAWL (495.97 ha) and COGL (144.45 ha).

4.1.3.1.2 Rate of Land Cover Change in BSNP

According to (Table : 11) below, in between the years 1990 and 2003, both the DAF and AAWL land cover types were declined with a rate of 11.36 ha/yr and 58.72 ha/yr respectively. However, in between the years 2003 and 2017, both DAF and AAWL land cover types were increased with a rate of 17.56 ha /yr and 22.05 ha /yr respectively.

On the other way, in between 1990 and 2003 both the AAGL and COGL were remarkably increased with a rate of 51.29 ha /yr and 18.79 ha /yr respectively. Where as in between the year 2003 and 2017, the AAGL was declined with a rate of 42.91 ha /yr while, the COGL was further increased with a rate of 3.3 ha /yr.

Table : 11 Rate of changes in land cover Classes (1990 - 2017)

	1990 to 2003		2003 to 2017	
LC_Type	ha/yr	% per year	ha/yr	% per year
DAF	(-11.36)	(-)1.08	17.56	1.94
AAWL	(-58.72)	(-)2.66	22.05	1.52
AAGL	51.29	5.42	(-)42.91	(-)2.66
COGL	18.79	14.97	3.30	0.89

4.1.3.1.3 Accuracy Assessment of Borena-Sayint National Park

For all maps , the accuracy assessment was conducted via a standard method. producer accuracy, user accuracy and Kappa statistics were computed. Overall, all the three maps met the minimum 85% accuracy (Appendix 6).

4.1.3.2 Land Cover in Chebera- Churchura National park

According to (Table : 12 and Figure : 10) in 1990 CTWL (44.78 %) cover the largest area followed by WGL (26.25 %) and MAF (21.15 %) as a second and third class while, WeL

1505.52 ha (1.18 %) covers the least area among other land cover classes in CCNP. In addition, in 1990 more than 65 % of the park was covered by natural vegetation while the remaining part were covered by grass land, water body, bare land and cultivated land.

However, in 2002 (Table : 12 and Figure : 11) the largest area was covered by WGL (39.88 %) followed by CTWL (36.12 %) and MAF (15.91 %) as a second and third largest class while, COGL 9633.07 ha (7.53 %) and WeL 713.23 ha (0.56 %) covered the least part as compared to other classes. In between 1990 and 2002 the natural vegetations were declined from 65.93 % in 1990 to 52.03 % in 2002.

Similarly, as observed on (Table :12 and Figure : 12) in 2017 the largest area was occupied by WGL (48.30 %) followed by CTWL (28.56 %) and MAF (18.13 %). Where as the least portion were covered by COGL 5669.87 ha (4.44%) and WeL 731.22 ha (0.57 %). The study result indicated that the natural vegetations including wetland showed remarkably declined while, WGL and COGL land cover types exibited an increasing trend in between 1990 and 2017.

Table : 12 Area of land cover in CCNP for the years 1990,2002 and 2017

	1990		2002		2017	
LC_Type	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
MAF	27039.78	21.15	20345.51	15.91	23184.11	18.13
CTWL	57258.45	44.78	46180.32	36.12	36512.7	28.56
WGL	33562.35	26.25	50982.68	39.88	61756.91	48.30
WeL	1505.52	1.18	713.23	0.56	731.22	0.57
COGL	8488.71	6.64	9633.07	7.53	5669.87	4.44

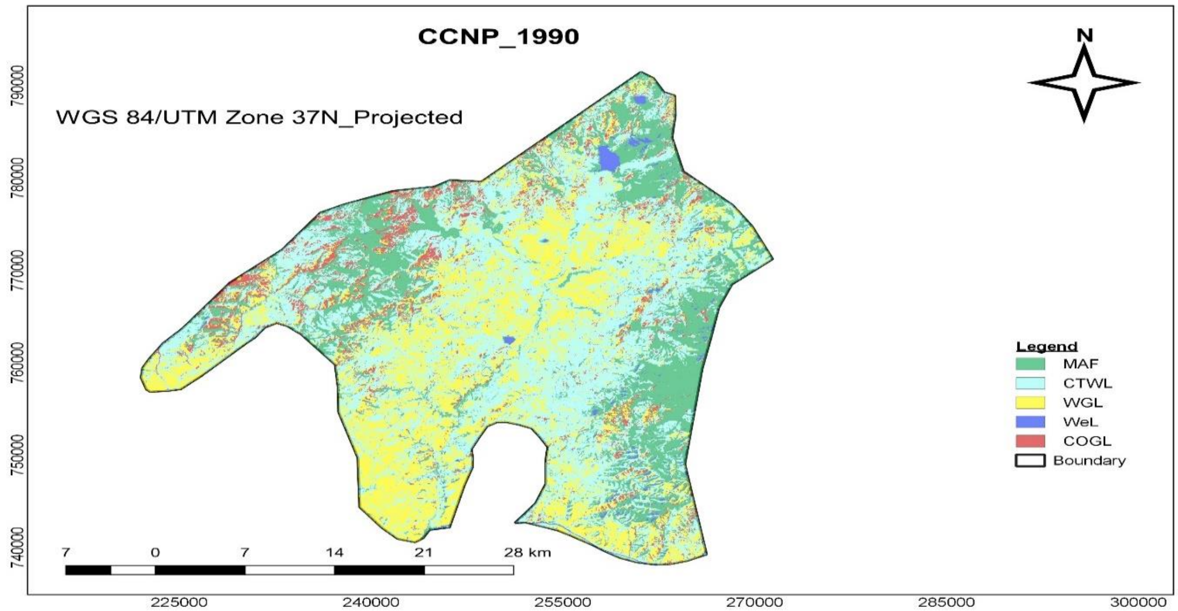

Figure : 10 LC Map of CCNP for the year 1990.

MAF = Moist afromontane forest, CTWL = Combretum terminalia woodland, WGL = Wooded grass land, WeL = Wetland, COGL = Cultivated and overgrazed land

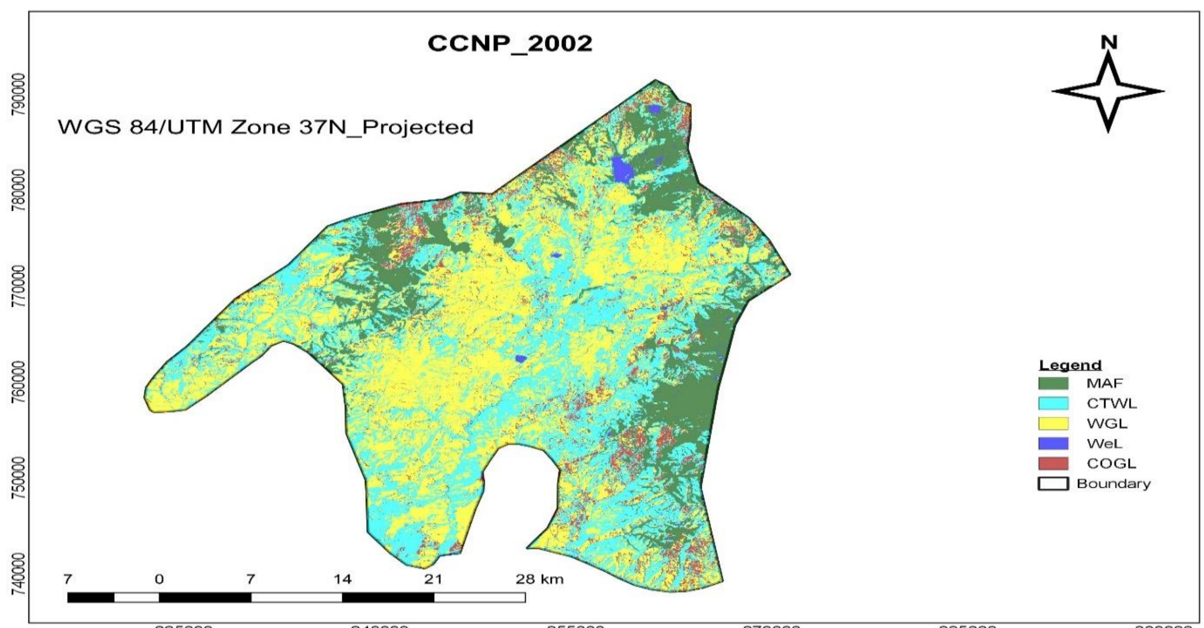

Figure : 11 LC Map of CCNP for the year 2002.

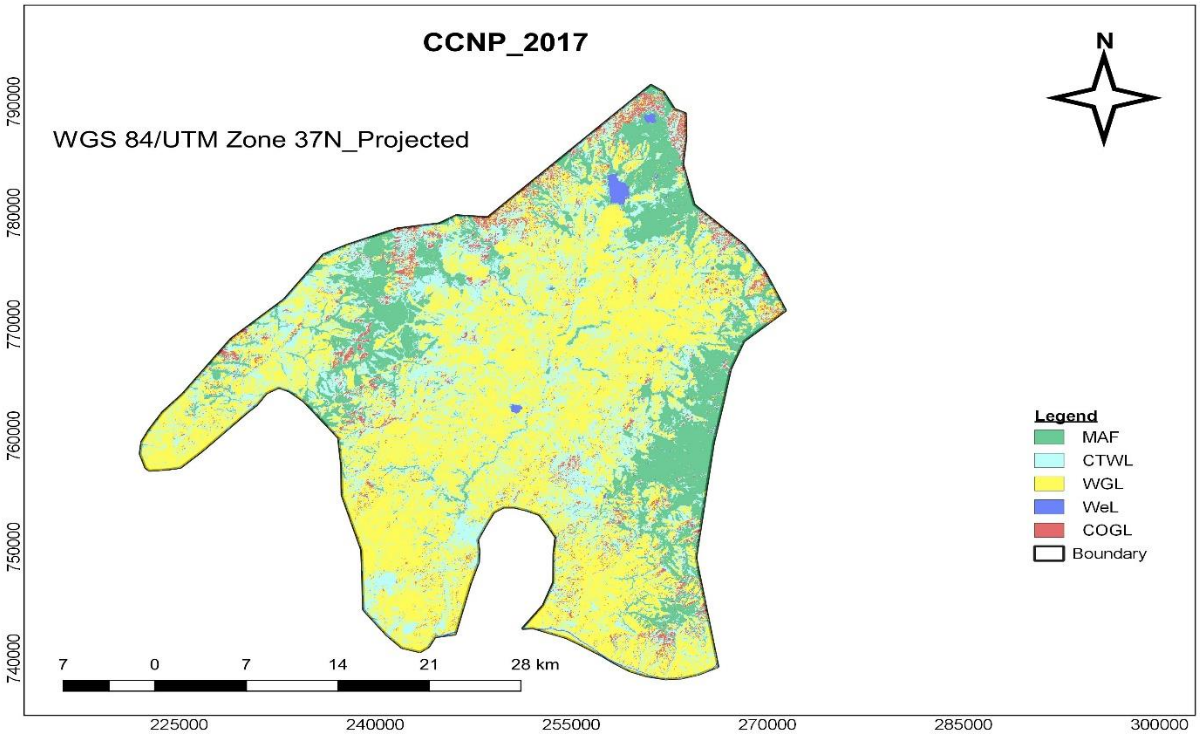

Figure : 12 LC Map of CCNP for the year 2017.

MAF = Moist afromontane forest, CTWL = Combretum terminalia woodland, WGL = Wooded grass land, WeL = Wetland, COGL = Cultivated and overgrazed land

4.1.3.2.1 Land Cover Change Matrices of CCNP

Table : 13 Land cover change matrices of CCNP (1990 – 2002)

	LCC_2002 (ha)						
	LC_Type	MAF	CTWL	WGL	WeL	COGL	Total
LCC_1990 (ha)	MAF	**18711.82**	7682.03	198.44	33.75	413.74	27039.78
	CTWL	1092.78	**29018.7**	22457.62	6.47	4682.88	57258.45
	WGL	6.85	7836.10	**23846.15**	2.15	1871.10	33562.35
	WeL	262.53	526.59	39.60	**670.86**	5.94	1505.52
	COGL	271.53	1116.90	4440.87	0.000000	**2659.41**	8488.71
	Total	20345.51	46180.32	50982.68	713.23	9633.07	127854.81

As observed on (Figure : 10 and Table : 13) the area of WGL and COGL were remarkably increased from 33, 562.35 ha to 50,982.68 ha and from 8,488.71 ha to 9,633.07 ha in between the years 1990 and 2002 respectively. On the other hand, the result indicated as the area were declining in the years between 1990 and 2002 from 27,039.78 ha to 20,345.51 ha, from 57,258.45 ha to 46,180.32 ha and from 1,505.52 ha to 713.23 ha for MAF, CTWL and WeL land cover types respectively.

Table : 14 Land cover change matrices matrices of CCNP (2002-2017)

		LCC _2017(ha)					
	LC_Type	MAF	CTWL	WGL	WeL	COGL	Total
LCC_2002 (ha)	MAF	**18401.31**	1373.54	351.77	30.96	187.93	20345.51
	CTWL	4397.27	**21 460.92**	19432.49	57.24	832.40	46180.32
	WGL	87.87	9726.91	**38149.04**	32.31	2986.55	50982.68
	WeL	21.33	12.51	68.68	**610.71**	0.000000	713.23
	COGL	276.33	3938.82	3754.93	0.000000	**1662.99**	9633.07
	Total	23184.11	36512.7	61756.91	731.22	5669.87	127854.81

On the other way, the MAF land was increased from 20,345.51 ha in 2002 to 23,184.11 ha in 2017 while, a small portion of the land was converted to CTWL (1373.54 ha), WGL (351.77 ha), WeL (30.96 ha) and COGL (187.93 ha). Similarly, the WGL has increased from 50,982.68 ha in 2002 to 61,756.91 ha in 2017 while a small part of it was converted to CTWL (9726.91 ha), COGL (2986.55 ha), MAF (87.87 ha) and WeL (32.31 ha). The WeL was also slightly increased from 713.23 ha in 2002 to 731.22 ha in 2017 when a small part of the land was changed to WGL (68.68 ha), MAF (21.33 ha) and CTWL (12.51 ha). On contrast, the area of CTWL was declined from 46,180.32 ha in 2002 to 36,512.7 ha in 2017 while 4,397.27 ha, 19,432.49 ha, 832.40 ha and 57.24 ha were converted to MAF, WGL, COGL and WeL land cover types respectively. Similarly, the COGL was decreased from 9633.07 ha in 2002 to 5669.87 ha in 2017 while, a small part of it was changed to WGL (3754.93 ha), CTWL (3938.82 ha) and MAF (276.33 ha) respectively.

4.1.3.2.2 Rate of Land Cover Change in CCNP

As indicated below (on Table : 15) the rate of land cover change of Chebera-Churchura National Park for the entire period were presented. The result of the present study showed as the area of MAF, CTWL and WeL were declined in between the year 1990 to 2002 with a rate of 557.86 ha, 923.18 ha and 66.02 ha per year respectively. Where as the WGL and COGL land covers were increased with a rate of 1451.69 ha /yr and 95.36 ha /yr in the year between 1990 and 2002 respectively. On the other hand, between the year 2002 and 2017 the area of MAF, WGL and WeL showed an increasing trend with a rate of 189.24, 718.28 and 1.2 ha per year respectively. On contrast, CTWL and COGL land cover types were decreasing with a rate of 644.51 ha and 264.21 ha per year in between 2002 and 2017 respectively.

Table : 15 Rate of changes in land cover Classes (1900 – 2017)

LC_Type	1990 to 2002		2002 to 2017	
	ha/yr	% per year	ha/yr	% per year
MAF	(-)557.86	(-)0.44	189.24	0.15
CTWL	(-)923.18	(-)0.72	(-)644.51	(-)0.50
WGL	1451.69	1.14	718.28	0.56
WeL	(-)66.02	(-)0.052	1.2	0.0009
COGL	95.36	0.075	(-)264.21	(-)0.21

4.1.3.2.3 Accuracy Assessment of Chebera-Churchura National Park

Like the previous one, the accuracy assessment for all the images of Chebera-Churchura was conducted. For all maps, the producer accuracy, user accuracy and Kappa statistics were computed. Overall, the maps met the minimum 85% accuracy (Appendix 5).

4.2 DISCUSSION

4.2.1 Vegetation Characterstics

The result of the present study revealed that vegetations found in different habitat types of both study area were varied in, species composition, distribution, aboundancy and carbon storage potential. This might be due to variations in land use management, physiographic, altitudinal, edaphic and climatic factors (Mulugeta Lemenih and Bongers, 2017), (Tesfaye Mehari, 2015) and (Amonye Asfaw, 2011). More over, the vegetations found in each habitat type depicted high variations in DBH class, Height class, Basal area, species composition and Tree stand density per hectare which made a significant difference on carbon storage capacity.

The findings of the present study is in line with the reports of the previous study. For example, the range of BA found in this study is comparable with the ranges (3.84 -10.36 m^2 ha-^{1}) reported by Singh and Singh (1991) and (6.58-23.21 m^2 ha-^{1}) reported by Jha and Singh (1990). Similarly, the stem densities over 10cm diameter on BS shows a gradual decline towards the higher diameter class. But in CC except showing an increasing trend from class 1 towards class 2 it shows similar declining trends towards the higher diameter class. In this study, the higher number of stems were recorded in diameter class 1 and 2 on both sites and the density of tree species decreases with increasing diameter class which is in line with the study reported by Birhanu Kebede *etal*., (2014). In general, this trend shows an inverted J-shaped pattern indicating the recovery of species; it could be a secondary growth after disturbance (Mulugeta Lemenih and Bongers, 2017) and (Abyot, D.*etal*., 2014).

4.2.2 Carbon Stocks in Different Carbon Pools

4.2.2.1 Above Ground Carbon Stock

Biomass accumulation in the forest ecosystem is mainly influenced by the kind of forest, type of pool, tree density and size class, species composition, forest age, and level of protection, all of which determine the magnitude of C storage in the forest. The estimation of mean AGC in CC and BS in this study shows variation with land cover types. The following discussions were made by comparing this study with other reports only in considering the Afromontane forest land cover. The mean AGC of the present study in CC and BS are comparable with those reported for the global AGC stock in tropical dry and wet forests that ranges between 13.5 to 122.85 t ha^{-1} and 95 to 527.85 t ha^{-1} respectively (Murphy and Lugo, 1986).

Table : 16 Comparison of mean carbon stock (t ha-^{1}) of the present result with previous studies.

Comparison of Carbon Stock (t ha-^{1})						
Study area	AGC	BGC	DWC	LC	SOC	Total
BSNPAF	94.55	24.58	3.25	0.01	216.5	338.89
CCNPAF	103	26.72	5.02	0.02	195	329.76
Chilimo Forest	90.25	17.32	-	0.39	109.4	218.01
Egdu Forest	278.08	55.62	-	3.47	277.56	614.73
Hanan Forest	48.37	-	-	-	45.71	94.34
MSSF	133	26.99	-	5.26	121.28	286.53
MZ	237.39	47.56	-	6.49	57.67	348.86
SCF	122.85	25.97	-	4.95	135.94	289.71
SMNP AMF	57.83	13.88	6.40	0.85	92.7	168.02
SMNP LLF	270.89	54.18	0.725	0.019	242.5	568.31
TGF	306.36	61.52	-	0.9	274.32	643.1

(BSNP = Borena-sayint national park, AF = Afromontane forest, CCNP = Chebera-churchura national park, MSSF = Menagesha suba state forest, MZ = Mount Zequalla forest, SCF = Selected church forest, SMNP = Semen mountain national park, LLF = lowland forest,TGF = Tara Gedam forest.)

As indicated on Table : 16 above, the finding of the present study was relatively higher than the AGC stock reported for Hanan forest and Chilimo forest (Belay Melese *et al*., 2014) and for SMNP afromontane forest (Habtamu Assaye and Zerihun Asrat, 2014). However, it showed big variations from the previous studies reported for Tara Gedam forest (Mohammed Gedefaw,2014), SMNP lowland forest (Tibebu Yelemfrhat, 2014), Egdu forest (Adugna Feyissa *et al.*, 2013), Mount Zequalla forest (Abel Girma *et al*., 2014), Menagasha Suba State Forest (Mesfin Sahile, 2011) and Selected Church Forests (Tulu Tolla *et a*l., 2013). The BGC has similar pattern with that of the aboveground values due to the fact that it is 0.26 times (26%) of the aboveground results. It had similarity with the above mentioned studies because of the fact that it was derived from above ground carbon (Mesfin Sahle, 2011). The variations in the present and previous studies might be due to the variatons in species composition, density, basal area and study site .

4.2.2.2 Dead Wood Carbon Stock

In many forest ecosystems dead woods are an important component of the carbon pool. As shown on table 16 : above, the mean carbon stock of dead wood carbon pool in the present study for CC and BS was significantly higher than the value (2.76 t ha^{-1}) and (0.726 t ha^{-1}) reported for Chato forest and SMNP lowland forest by (Birhanu *et al*., 2017) and (Tibebu Yelemfrhat, 2014) respectively. However, it was sligtly lower than the value reported for SMNP afromontane forest by (Habtamu Assaye and Zerihun Asrat, 2014). The variations might be due to the difference in extent of protection and the magnitude of removal of dead wood for fire. Furthermore, deadwood dynamics are closely related to forest management, such as harvesting operations. The findings of the present study indicated that the carbon stock of deadwood is generally smaller as compared to above and below ground carbon pools.

4.2.2.3 Litter Carbon Stock

According to Brown and Lugo (1982) litter fall in dry tropical forests range between 2.52- 3.69 t ha^{-1} $year^{-1}$. The mean carbon stock of litter biomass obtained in this study for CC and BS afromontane forest was significantly lower than the value indicated above but,it was in line with the findings reported by (Tibebu Yelemfrhat, 2014) for SMNP low land forest. While comparing the result with other studies, the mean carbon stock in litter biomass of the present study was significantly lower than those reported from Egdu Forest by (Adugna Feyissa *et al*., 2013), Selected Church Forests (Tulu Tola, 2011), Menagasha Suba State Forest (Mesfin Sahile, 2011), Mount Zequalla Forest (Abel Girma *et al*., 2014) and SMNP Afromontane forest (Habtamu Assaye and Zerihun Asrat, 2014). The variation might be due to factors like rate of decomposition (which is governed by climatic factor like temperature and moisture), the forest vegetation type (species, age and density), land cover types and climate (Fisher and Binkly, 2000).

4.2.2.4 Soil Carbon Stock

The amount of C stored in the soil was highly affected by species rich ness, age, size and density of forest, Topography, soil depth and the understory cover. However, it showed a decreasing trend with increasing soil depth for all land cover types of the present study. In the present study, the result of the mean soil carbon stock showed significant variations with soil depth across all land cover types.The mean soil carbon stock in the first layer (0-30 cm depth) was higher than that of the second layer (30-60cm) for all land cover types on both study sites. The mean soil carbon stock of AAGL (306.27 t $ha\text{-}^{1}$) in BS of the present study was significantly higher than that of other land cover types of similar study site. Relatively, small carbon stock (286.90 t $ha\text{-}^{1}$) was observed in AAWL followed by (216.49 t $ha\text{-}^{1}$) in DAF land cover types as a second and third. The variations might be due to high and rapid decomposition rate of the grass material and its incorporation to the soil as organic matter in AAGL. This finding was more or less similar with the findings reported by Habtamu Assaye and Zerihun Asrat,(2014). But for DAF and AAWL land cover types the reason of variation might be the removal of trees and dead woods for fire, timber and construction material through illegal tree felling (Mehari Alebachew, 2015).

In contrast to BS, the result of the study showed that the value for mean soil carbon stock (195. t ha-^{1}) in CC site was higher for afromontane forest than other land cover types. The second higher mean soil carbon stock (149.04 t ha-^{1}) was observed in Wet land land cover types followed by WGL and CTWL as third and fourth places with (148.05 t ha-^{1}) and (133.114 t ha-^{1}) respectively. The soil organic carbon stock (SOC) for different forest types of Kolli hills in India ranges from 63.37 to 273 t ha-^{1} and the average SOC was 96.05 t ha-^{1} (Ramachandran *et al*., 2007). While comparing this result with the present study, the mean soil carbon stock in the present study for CC and BS afromontane forest were by two fold higher than from the above indicated result respectively. But it was comparable with the above mentioned ranges. On the other hand, while comparing this result with other studies, the mean soil carbon stock in the the present study was lower than those reported from Egdu forest, Tara Gedam Forest and SMNP low land forest by (Adugna Feyissa *et a*l., 2013), (Mohammed Gedefaw, 2013) and (Tibebu Yelemfrhat, 2014) respectively (Table 14 : above). However, the mean value of soil carbon stock in montane forest of the present study was bigger than the findings of Tulu Tola (2011), Mesfin Sahile (2011), Habtamu Assaye and Zerihun Asrat (2014) and Abel Girma *et al*.,(2014) who reported for selected church forest, Menagasha Suba State Forest, SMNP afromontane forest and Mount Zequalla Forest respectively.

In general, the findings of the present study revealed significant variation for soil organic carbon stock with soil depth and land cover types as well as other previous studies. The variations might be arised from the presence of different tree species, soil nutrient availability, climate, topography and disturbance regime (Houghton, 2005).

4.2.2.5 Total Carbon Stock Density

Forests in general and forest soils in particular play a vital role in the global carbon balance. According to (Lal, 2004) more than 3.3- fold of the atmospheric and 4.5- fold of the biotic carbon pool were stored in the global carbon pool. Forest soils contributes 54 % of the carbon stored in old- growth forests (Luyssaert *et al*., 2008). In the present study the density of total carbon stock were constituted from the biomass and soil carbon pools. The result of the present study indicated that soil carbon pool and the tree component (AGB and BGB) stored the greatest amount of carbon among other carbon pools while, dead wood and litter cabon pools stored the least carbon stock respectively. Therefore, the estimation of carbon stock both in the tree component and in soil becomes imperative to assess the carbon sequestration potential (Ramachandran *et al*., 2007). In the present study, the estimated ratios between the mean SOC and total biomass carbon were 1.45 and 1.98 for MAF and CTWL land cover types in CC respectively. Similarly, the ratios between the mean SOC and total biomass carbon for DAF and AAWL land cover types in BS were 1.76 and 15.73 respectively. In the case of AAWL, the ratio between the two carbon types revealed significant variation among other land cover types. This might be due to the conversion of Erica wood land to grass land and/or agricultural land, land cover types and also due to the particularity of Erica arboria species on the area which lacks species composition and diversity. Ingeneral, the result of the present study indicated that the carbon content in the soil carbon pool was significantly higher than that of the AGB carbon pool, which suggests that the expansion of cultivated and grazing land on the border of national park made shirinking the size of forest and wood land areas which indicating more recent changes in land covers on both study areas. Land cover and plant species significantly influences SOC estimation.

4.2.3 Land Cover Change

Forest cover in Ethiopia was decreased by more than 90 % between 1900 and 2004 (4,073, 213 ha) (Nyssen *et al*., 2004). Anthropogenic factors such as expansion of large scale farming, settlements, urbanization and over grazing are mainly responsible for major land use and land cover changes (LULCC). The result of change detection analysis in the present study showed significant changes on land cover of both study sites for the years between 1990 and 2017. According to the classified land between 1990 and 2017 the change detected for Borena-Sayint and Chebera-Churchura National parks indicated that forest land, wood land and wet land land covers were transformed to grass land, cultivated land, bare land and degraded land. As it was observed in this study, the conversion of land cover has a negative impact on the bio-diversity and socio-economic settings. For example, on the boundaries of both national park, the expansion of degraded land, farm land, grazing land, and settelments were at the expense of forest land , wood land and wet land. Further more, both study areas were highly affected by the expansion of development activities like road and power lines with in the park boundaries. During the first phase of this study (1990 - 2003), there was an increased in the area for COGL and Grass land land cover types on both study sites. For instance, in BS the area for COGL was increased from 2.89 to 8.53 % and for AAGL 21.84 to 37.21 % (Table : 8). Similarly, the area for COGL and WGL in CC of the same period were expanded from 6.64 to 7.53 % and from 26.25 to 39.88 % respectively (Table :12).

At the begining of this study time, since it was a transition period, there were poor land administration and national settlement programme during that time. Hence, there were an expansion of agricultural land, grazing land and settelements on the high lands of both study site which made a decline on natural resourses. In addition to this, the increasing of human and livestock population on the area had brought a significant pressure on the forest. More over, during this time due to the lack of institution that administered the national parks, the protection given for the area by local community and government was not as such stronge enough. Hence, any one could cut and carry trees for timber, fuel wood and other purposes and also there was free grazing of live stock on the area.

However, during the second phase of this study (2003 - 2017), there was an expansion of DAF area from 20.87 to 26.54 %, AAWL from 33.39 to 40.51 % and a little increament for COGL area from 8.53 to 9.59 % while, there was a remarkable decline in AAGL area from 37.21 to 23.36 % in BS site (Table :8). On the other way, for CC site between 2002 and 2017 the area coverage for MAF was remarkably increased from 15.91 to 18.13 % and for WGL from 39.88 to 48.30 % while there was a remarkably decreased for CTWL area from 36.12 to 28.56 % and for COGL from 7.53 to 4.44 % (Table : 12). During the second phase of this study, national parks were established at both study sites by the regional government up on the requiest and participation of the local communities and this enabled the area to get better protection and conservation for the natural resources. CCNP was established as a national park in 2005. Similarly, BSNP was established in 2009 as a national park Ingeneral, the result of the present study revealed that during the second phase of this study, the area of forest and wood land vegetation showed an increasing trend on both sites than the first phase of this study.

5 CONCLUSSIONS AND RECOMMENDATIONS

5.1 CONCLUSSIONS

Tree planting and conserving of the existing forest offers relatively a low cost approach and enables to sequester more carbon. More over, the mean total carbon stock density in the present study was 854.41(3135.68 co_2 equivalents) t ha $^{-1}$ and 950.59 (3488.67 co_2 equivalent) t ha $^{-1}$ for CC and BS sites respectively (Table : 6). This implies that each site has a high potential for sinking carbon dioxide from the atmosphere. There fore, this made the country could contribute to the effort of global climate change mitigation. On the other hand, in the present study for both study sites, eight major land cover types were identified, and their magnitude interms of area in ha and % were assessed between the years 1990 and 2017.

In general, during the last 27 years, a total of 98.2 ha of dry afromontane forest, 66.1 ha of afro alpain grass land and 290.42 ha of cultivated and over grazed lands were gained while 454.72 ha of afro alpain wood land was lost at BSNP. Similarly, for CCNP a total 3855.67 ha of moist afromontane forest, 20,745.75 ha of combretum terminalia wood land, 774.3 ha of wet land and 2,818.84 ha of cultivated and over grazed land were lost while 28,194.56 ha of wooded grass land was gained for similar period.

5.2 RECOMMENDATIONS

Forests in general and forest soils in particular play a vital role in the global carbon balance. Currently, the potential role of forests in both protected area for sinking atmospheric carbon dioxide is well recogenized. Hence, different forest management options could be implemented to maximize the forest carbon storage potential. These include awareness creation at all levels on forest protection, Engadgement of the local community on development activities and conservation work, making boundary demarcation with well identified pillars for each park, establishing plantations as a buffer on the marginal and degraded area of each park. Such interventions may build a system for sustainable management and utilization of forests on both protected areas for enhancing carbon credit, creating revenue for the park adminstration and support the lively hood of the surrounding local communities.

In general, based on the findings of the present study the following points need to be considered seriously.

- Attentions should be given for sectors like EWCA and MEFCC poletically as well as financially.
- Increasing awareness creation on the issue of climate change and effect of deforestation and forest degradation at all levels through more power full means.
- Empowering and engadeging the surrounding local communities on forest management and development activities is essential.
- Establishing clear boundary with pillars for each park is basic to differentiate the park from the surrounding private and communal lands.
- Establish and implement appropriate polices for human and live stock growth.
- Establish regular monitoring and management methods for both protected area forests.

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APPENDICES

Appendix : 1 Description of BSNP Mean Biomass Carbon Analysis Result

A. Description of MBC in ton per hectar using SPSS soft ware version 23

						95% Confidence Interval for Mean			
Carbon Pools	Stratum	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
AGC	DAF	29	94.5538	72.85700	13.52920	66.8405	122.2671	6.00	248.67
	AAWL	23	14.0348	12.00875	2.50400	8.8418	19.2278	0.52	39.75
	AAGL	11	0.2209	0.42272	0.12745	-0.0631	0.5049	0.00	1.12
	Total	63	48.6871	65.53353	8.25645	32.1827	65.1915	0.00	248.67
BGC	DAF	29	24.5838	18.94215	3.51747	17.3786	31.7890	1.56	64.65
	AAWL	23	3.6496	3.12195	0.65097	2.2995	4.9996	0.14	10.33
	AAGL	11	0.0573	0.10891	0.03284	-0.0159	0.1304	0.00	0.29
	Total	63	12.6587	17.03821	2.14661	8.3677	16.9497	0.00	64.65
DWC	DAF	29	3.2486	5.17575	0.96111	1.2799	5.2174	0.00	16.97
	AAWL	23	0.5565	1.06930	0.22296	0.0941	1.0189	0.00	4.24
	AAGL	11	0.0000	0.00000	0.00000	0.0000	0.0000	0.00	0.00
	Total	63	1.6986	3.82404	0.48178	0.7355	2.6616	0.00	16.97
LC	DAF	29	0.0079	0.01449	0.00269	0.0024	0.0134	0.00	0.04
	AAWL	23	0.0000	0.00000	0.00000	0.0000	0.0000	0.00	0.00
	AAGL	11	0.0000	0.00000	0.00000	0.0000	0.0000	0.00	0.00
	Total	63	0.0037	0.01052	0.00133	0.0010	0.0063	0.00	0.04

B. Table of one way ANOVA result for biomass carbon over different land cover types.

		One way ANOVA				
		Sum of Squares	df	Mean Square	F	Sig.
AGC	Between Groups	114466	2	57232.78	22.62	0.000
	Within Groups	151802	60	2530.040		
	Total	266268	62			
BGC	Between Groups	7737.57	2	3868.783	22.62	0.000
	Within Groups	10261.1	60	171.018		
	Total	17998.6	62			
DWC	Between Groups	131.412	2	65.706	5.085	0.009
	Within Groups	775.231	60	12.921		
	Total	906.643	62			
LC	Between Groups	0.001	2	0.000	5.026	0.010
	Within Groups	0.006	60	0.000		
	Total	0.007	62			

Appendix : 2 Description of BSNP Soil Carbon Analysis Result

A. Comparision of soil carbon stock across different land cover type

Estimates					
Dependent Variable	Stratum	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
BD	DAF	0.894	0.031	0.832	0.956
	AAWL	0.679	0.039	0.599	0.759
	AAGL	0.743	0.048	0.645	0.84
OC	DAF	4.294	0.377	3.528	5.059
	AAWL	7.344	0.487	6.356	8.332
	AAGL	7.046	0.597	5.836	8.256
SOC	DAF	108.246	9.479	89.023	127.47
	AAWL	143.449	12.237	118.632	168.267
	AAGL	153.135	14.987	122.74	183.53

B. Table that describe tests between subjects effects

Tests of Between - Subjects Effects						
Source	Dependent Variable	Type II Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	BD	.834a	3	0.278	14.920	0.000
	OC	180.423b	3	60.141	21.125	0.000
	SOC	29585.630c	3	9861.877	5.488	0.003
Intercept	BD	25.552	1	25.552	1371.000	0.000
	OC	1326.793	1	1326.793	466.044	0.000
	SOC	653160.249	1	653160.249	363.493	0.000
LC	BD	0.378	2	0.189	10.151	0.000
	OC	86.361	2	43.18	15.167	0.000
	SOC	15720.433	2	7860.217	4.374	0.020
Soil Depth	BD	0.456	1	0.456	24.459	0.000
	OC	94.062	1	94.062	33.040	0.000
	SOC	13865.197	1	13865.197	7.716	0.009
Error	BD	0.671	36	0.019		
	OC	102.489	36	2.847		
	SOC	64688.341	36	1796.898		
Total	BD	27.057	40			
	OC	1609.705	40			
	SOC	747434.22	40			
Corrected Total	BD	1.505	39			
	OC	282.912	39			
	SOC	94273.971	39			

a. R Squared = .554 (Adjusted R Squared = .517)
b. R Squared = .638 (Adjusted R Squared = .608)
c. R Squared = .314 (Adjusted R Squared = .257)

C. ANOVA table that describes the effect of land cover on dependent variables

Dependent Variable		Sum of Squares	df	Mean Square	F	Sig.
BD	Contrast	0.378	2	0.189	10.151	0.000
	Error	0.671	36	0.019		
OC	Contrast	86.361	2	43.18	15.167	0.000
	Error	102.489	36	2.847		
SOC	Contrast	15720.433	2	7860.22	4.374	0.020
	Error	64688.341	36	1796.9		

D. ANOVA table that describes the effect of Soil Depth on dependent variables

Dependent Variable		Sum of Squares	df	Mean Square	F	Sig.
BD	Contrast	0.456	1	0.456	24.459	0.000
	Error	0.671	36	0.019		
OC	Contrast	94.062	1	94.062	33.04	0.000
	Error	102.489	36	2.847		
SOC	Contrast	13865.197	1	13865.2	7.716	0.009
	Error	64688.341	36	1796.9		

Appendix : 3 Description of CCNP Bio mass Carbon Analysis Result

A. Table of one way ANOVA result for biomass carbon over different land cover types.

		Sum of Squares	df	Mean Square	F	Sig.
AGC	Between Groups	149774.790	3	49924.930	36.488	0.000
	Within Groups	172401.867	126	1368.269		
	Total	322176.658	129			
BGC	Between Groups	10122.859	3	3374.286	36.488	0.000
	Within Groups	11651.970	126	92.476		
	Total	21774.829	129			
DWC	Between Groups	389.405	3	129.802	1.939	0.127
	Within Groups	8435.402	126	66.948		
	Total	8824.806	129			
LC	Between Groups	0.006	3	0.002	8.745	0.000
	Within Groups	0.031	126	0.000		
	Total	0.037	129			

B. Description of MBC in ton per hectar using SPSS soft ware version 23

Carbon pools	Stratum	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
AGC	MAF	33	102.7800	64.04028	11.14798	80.0690	125.4844	14.19	339.29
	CTWL	28	51.7900	20.25927	3.82864	43.9343	59.6457	25.10	93.33
	WGL	59	26.4056	22.77439	2.96497	20.4706	32.3406	0.95	112.09
	WL	10	0.0000	0.00000	0.00000	0.0000	0.0000	0.00	0.00
	Total	130	49.2283	49.97493	4.38309	40.5563	57.9004	0.00	339.29
BGC	MAF	33	26.7221	16.65091	2.89855	20.8180	32.6263	3.69	88.22
	CTWL	28	13.4661	5.26726	0.99542	11.4236	15.5085	6.53	24.27
	WGL	59	6.8685	5.91724	0.77036	5.3264	8.4105	0.45	29.14
	WL	10	0.0000	0.00000	0.00000	0.0000	0.0000	0.00	0.00
	Total	130	12.8009	12.99219	1.13949	10.5464	15.0554	0.00	88.22
DWC	MAF	33	5.0155	15.34929	2.67197	-0.4272	10.4581	0.00	87.67
	CTWL	28	1.9971	2.86990	0.54236	0.8843	3.1100	0.00	12.48
	WGL	59	1.0478	3.40841	0.44374	0.1596	1.9360	0.00	25.79
	WL	10	0.0000	0.00000	0.00000	0.0000	0.0000	0.00	0.00
	Total	130	2.1788	8.27099	0.72541	0.7436	3.6141	0.00	87.67
LC	MAF	33	0.0215	0.01805	0.00314	0.0151	0.0279	0.00	0.04
	CTWL	28	0.0129	0.01922	0.00363	0.0054	0.0203	0.00	0.05
	WGL	59	0.0061	0.01326	0.00173	0.0026	0.0096	0.00	0.04
	WL	10	0.0000	0.00000	0.00000	0.0000	0.0000	0.00	0.00
	Total	130	0.0110	0.01693	0.00148	0.0081	0.0139	0.00	0.05

Appendix 4 : Description of CCNP Soil Carbon Analysis Result

A. ANOVA table that describes the effect of land cover on dependent variables

Univariate Tests

Dependent Variable		Sum of Squares	df	Mean Square	F	Sig.
BD	Contrast	0.236	3	0.079	3.381	0.025
	Error	1.282	55	0.023		
OC	Contrast	10.247	3	3.416	1.921	0.137
	Error	97.782	55	1.778		
SOC	Contrast	8694.97	3	2898.323	1.699	0.178
	Error	93799.183	55	1705.44		

B. Comparision of soil carbon stock across different land cover types

Estimates					
				95% Confidence Interval	
Dependent Variable	Stratum	Mean	Std. Error	Lower Bound	Upper Bound
BD	MAF	1.125	0.038	1.049	1.201
	CTWL	1.233	0.036	1.161	1.305
	WGL	1.091	0.041	1.009	1.172
	WL	1.081	0.044	0.993	1.169
OC	MAF	2.949	0.333	2.281	3.617
	CTWL	1.864	0.314	1.234	2.494
	WGL	2.246	0.356	1.532	2.961
	WL	2.441	0.385	1.669	3.212
SOC	MAF	97.319	10.324	76.629	118.01
	CTWL	66.557	9.734	47.05	86.064
	WGL	74.025	11.037	51.906	96.144
	WL	74.519	11.921	50.628	98.41

C. ANOVA table that describes the effect of land cover on dependent variables

Univariate Tests						
Dependent Variable		Sum of Squares	df	Mean Square	F	Sig.
BD	Contrast	0.515	1	0.515	22.108	0.000
	Error	1.282	55	0.023		
OC	Contrast	49.359	1	49.359	27.763	0.000
	Error	97.782	55	1.778		
SOC	Contrast	36086.085	1	36086.09	21.159	0.000
	Error	93799.183	55	1705.44		

E. Table that describe tests between subjects effects

Tests of Between - Subjects Effects						
Source	Dependent Variable	Type II Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	BD	.752a	4	0.188	8.063	0.000
	OC	59.606b	4	14.901	8.382	0.000
	SOC	44781.055c	4	11195.26	6.564	0.000
Intercept	BD	78.067	1	78.067	3.35E+03	0.000
	OC	333.61	1	333.61	187.648	0.000
	SOC	365931.3	1	365931.3	214.567	0.000
LC	BD	0.236	3	0.079	3.381	0.025
	OC	10.247	3	3.416	1.921	0.137
	SOC	8694.97	3	2898.323	1.699	0.178
Soil depth	BD	0.515	1	0.515	22.108	0.000
	OC	49.359	1	49.359	27.763	0.000
	SOC	36086.085	1	36086.09	21.159	0.000
Error	BD	1.282	55	0.023		
	OC	97.782	55	1.778		
	SOC	93799.183	55	1705.44		
Total	BD	80.101	60			
	OC	490.997	60			
	SOC	504511.54	60			
Corrected Total	BD	2.033	59			
	OC	157.388	59			
	SOC	138580.24	59			

a. R Squared = .370 (Adjusted R Squared = .324)
b. R Squared = .379 (Adjusted R Squared = .334)
c. R Squared = .323 (Adjusted R Squared = .274)

Appendix 5 : Accuracy Assessment of CCNP

A) Classification Accuracy Assessment of 1990

MAF	Class 1. PA [%] = 98.2367 UA [%] = 99.265 KC = 0.981	
CTWL	Class 2. PA [%] = 87.913 UA [%] = 81.850 KC = 0.803	
WeL	Class 3. PA [%] = 94.262 UA [%] = 98.766 KC = 0.984	
WGL	Class 4. PA [%] = 99.959 UA [%] = 88.661 KC = 0.880	
COGL	Class 5. PA [%] = 70.00 UA [%] = 48.686 KC = 0.482	
	Overall accuracy [%] = 96.291	Kappa hat classification = 0.934

(MAF = Moist afromontane forest, CTWL = Combretum terminalia woodland, WeL = Wet land WGL = Wooded grass land, COGL = Cultivated and overgrazed land, PA = Producer Accuracy, UA = User Accuracy, KC = Kappa Coeficient)

B) Classification Accuracy Assessment of 2002

MAF	Class 1.	PA [%] = 99.169	UA [%] = 99.922	KC = 0.998
CTWL	Class 2.	PA [%] = 98.724	UA [%] = 94.628	KC = 0.940
WeL	Class 3.	PA [%] = 98.283	UA [%] = 99.505	KC = 0.993
WGL	Class 4.	PA [%] = 100.0	UA [%] = 88.648	KC = 0.883
COGL	Class 5.	PA [%] = 79.583	UA [%] = 81.624	KC = 0.814
		Overall accuracy [%] = 98.667		Kappa hat classification = 0.978

C) Classification Accuracy Assessment of 2017

MAF	Class 1.	PA [%] = 98.605	UA [%] = 99.895	KC = 0.997
CTWL	Class 2.	PA [%] = 94.372	UA [%] = 86.093	KC = 0.849
WeL	Class 3.	PA [%] = 93.124	UA [%] = 95.336	KC = 0.941
WGL	Class 4.	PA [%] = 100.0	UA [%] = 96.156	KC = 0.960
COGL	Class 5.	PA [%] = 58.790	UA [%] = 40.557	KC = 0.400
		Overall accuracy [%] = 96.805		Kappa hat classification = 0.939

Appendix 6 : Accuracy Assessment of BSNP

A) Classification accuracy assessment of 1990

DAF	Class 1.	PA [%] = 86.799	UA [%] = 99.879	KC = 0.997
AAWL	Class 2.	PA [%] = 95.0966	UA [%] = 71.190	KC = 0.634
AAGL	Class 3.	PA [%] = 93.692	UA [%] = 92.491	KC = 0.909
	Class 4.	PA [%] = 100.0	UA [%] = 63.0435	KC= 0.627
		Overall accuracy [%] = 89.873		Kappa hat classification = 0.863

B) Classification accuracy assessment of 2003

DAF	Class 1.	PA [%] = 92.546	UA [%] = 88.327	KC = 84.926
AAWL	Class 2.	PA [%] = 94.150	UA [%] = 98.734	KC =87.985
AAGL	Class 3.	PA [%] = 88.344	UA [%] = 91.331	KC = 0.834
COGL	Class 4.	PA [%] = 86.0	UA [%] = 81.566	KC = 0.79
		Overall accuracy [%] = 89.051		Kappa hat classification = 0. 860

C) Classification accuracy assessment of 2017

DAF	Class 1.	PA [%] = 93.172	UA [%] = 91.528	KC = 0.838
AAWL	Class 2.	PA [%] = 87.727	UA [%] = 83.972	KC = 0.816
AAGL	Class 3.	PA [%] = 82.525	UA [%] = 77.166	KC= 0.738
COGL	Class 4.	PA [%] = 75.434	UA [%] = 76.540	KC = 0.720
		Overall accuracy [%] = 87.210		Kappa hat classification = 0.852

BIOGRAPHICAL SKETCH

Negash Hailegiorgis Sirneisa was born in Ambo, Ethiopia in 1979. He completed his Elementary and Secondary Education at Ambo in June 1998. He attended a diploma programme in Forestry at Hawassa University, Wondo Genet College of Forestry and Natural Resources from October , 1999 - June, 2000. After graduation he was worked as a data collecter, Assistant Cartographer and Field Supervisor at Ambo Branch, Central Statistics Agency (November, 2001 to October, 2007) and again as an Expert of Forestry at Kersa Malima District of Agriculture and Rural Development (June, 2007 to February, 2014). From (September, 2011 to Jully 2013), he again attended a B.Sc. degree in Geographic Information Science from the same University. After graduation, he was employed as an Expert of Remote Sensing at Ministry of Environment, Forest and Climate Change (February, 2014 to September, 2016). In 2016, he joined the School of Graduate Studies of Hawassa University, Wondo Genet College of Forestry and Natural Resources to persue his M.Sc. study in Forest Resource Assessement and Monitoring.