ADDIS ABABA UNIVERSITY
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DEPARTMENT OF BIOLOGY

CARBON STOCK AND ITS VARIATIONS ALONG ENVIRONMENTAL FACTORS IN GENDO MOIST MONTANE FOREST, EAST WOLLEGA ZONE, WESTERN ETHIOPIA

WORKU NIGUSSIE

A Thesis Submitted to

Department of Biology

Presented in Partial Fulfillment of the Requirements for the Degree of Master

of Science in Biology

Addis Ababa University
Addis Ababa, Ethiopia
August 2016

ADDIS ABABA UNIVERSITY
GRADUATE PROGRAMS
DEPARTMENT OF BIOLOGY

This is to certify that the thesis prepared by Worku Nigussie, entitled "*Carbon stock and its variations along environmental factors in Gendo Moist Montane Forest, East Wollega Zone, Western Ethiopia: Implication for climate change mitigation*" and submitted in partial fulfillment of the requirements for the Degree of Master of Science in Biology complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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	Name	signature	Date
Advisor:	Teshome Soromessa (PhD)	_____	_____
	Name	signature	Date

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ABSTRACT

Carbon Stock and its Variations along Environmental Factors in Gendo (Gura Tirigni) Moist Montane Forest, East Wollega Zone, Western Ethiopia: Implication for Climate Change Mitigation.

Worku Nigussie,
Addis Ababa University, 2016

Global climate change is an environmental problem in today's modern world because of the change in global weather pattern. The study was conducted to estimate the carbon stock and its variations along environmental factors in Gendo (Gura Tirigni) forest as potential sink for climate change mitigation. Forest plays important role in the global carbon cycle as carbon sinks of the terrestrial ecosystem. Estimations of forest carbon stocks are based on the estimation of forest biomass. Tree species data collection was done by complete listing method. Soil and litter data collection had also been carried out using representative sampling. The result of the present study showed that 4687 trees and shrubby trees had a DBH ≥5 cm. From this study the mean total carbon stock of Gendo forest was 564.96±27.05 ton ha^{-1}. The mean aboveground carbon, belowground carbon, litter carbon and soil organic carbon (0-10cm soil depth) were: 128.60±7.53 ton ha^{-1}, 26.52±1.62 ton ha^{-1}, 3.12±0.25 ton ha^{-1}, and 94.96±4.61 ton ha^{-1} respectively. Carbon stock variations in different pools along environmental factors (altitude, slope and aspect) were recorded. LC along altitudinal gradient and SOC along altitude, aspect and slope gradients show significant variations.

Keywords: Biomass**,** Carbon pools, Carbon stocks, Environmental factors, Gendo forest

Acknowledgement

First of all I would like to express my sincere thanks to my advisor Dr. Teshome Soromessa for his many suggestions and constant support during this research and this brother hood approach impressed me so much and made me to remember him throughout my life. In a sense, I feel very fortune to have had this golden opportunity to work with such an experienced, talented and creative person. Next I express my sincere thanks to Department of Biology of Addis Ababa university and to all my instructors for facilitating conditions for my education and financial support, particular thanks go to staff members of Addis Ababa University Environmental Science Center for providing me laboratory facilities and cooperation to conduct the research successfully and also my appreciation goes to Ministry of Education for giving me this chance.

I also express my gratitude and appreciation to my wife Abiyote Mosisa and my little children Elsabet Worku and Biruk Worku who helped me during field data collection.

TABLE OF CONTENTS PAGE

LIST OF TABLES PAGE

LIST OF FIGURES **PAGE**

LIST OF ACRONYMS

AD	After Death
AGB	Aboveground Biomass
AGC	Aboveground Carbon
$AGCO_2$	Aboveground Carbon dioxide
ANOVA	Analysis of Variance
BD	Bulk Density
BGB	Below-ground biomass
BGC	Belowground Carbon
$BGCO_2$	Belowground Carbon dioxide
CDM	Clean Development Mechanism
CNS	Carbon Nitrogen Sulfur
DBH	Diameter at Breast Height
DEFRA	Department for Environment, Food and Rural Affairs
E	East
ELCNSTA	Environmental Literacy Council and National Science Teachers Association
FAO	World Food and Agricultural Organization
FCPF	World Bank's Forest Carbon Partnership Facility
FDRE	Federal Democratic Republic of Ethiopia
FPAs	Forest priority Areas
GHGs	Green House Gasses
GPS	Global Positioning System
Gt	Giga tone
IPCC	Intergovernmental Panel for Climate Change
IUCN	International Union for Conservation of Nature

LB	Litter Biomass
LC	Litter Carbon
LCO_2	Litter Carbon dioxide
LOI	Loss on Ignition
Mt	Mega Ton
N	North
NE	North East
NW	North West
OM	Organic Matter
PPM	Parts Per Million
REDD	Reduced Emission from Deforestation and Degradation
R-PP	Readiness Preparation Proposal
S	South
S CO_2	Soil Carbon dioxide
SE	South East
SNNPR	Southern Nations, Nationalities and Peoples Region
SOC	Soil organic Carbon
SOM	Soil Organic Matter
SW	South West
UNFCCC	United Nations Framework Convention on Climate Change

1. INTRODUCTION

The global carbon cycle has received the most attention in recent years as it has become evident that increased levels of CO_2 in the atmosphere are causing changes in our climate at an alarming rate (IPCC, 2001). Worldwide concern for natural and biological resources is higher than ever before. Issues such as loss of biodiversity, ozone layer depletion, desertification etc. have taken the center stage in the global discourse. Anthropogenic factors are identified as the main drivers (Ehlert, 2008). Humankind increasingly influences carbon cycle through the burning of ever-greater quantities of oil, gasoline and coal and the cutting down of forests.

There are six recognized major greenhouse gases: CO_2 (carbon dioxide), CH_4 (methane), HFCs (hydrofluorocarbons), PFCs (perfluorocarbons), N_2O (nitrous oxide) and SF_6(sulphur hexafluoride). Carbon accounting often refers to the accounting of all major GHGs using a carbon dioxide equivalent (CO_2e) that standardises these gases based on their global warming potential. About two-thirds of the net increase in atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4) and nitrous oxides (N_2O and NO) is due to the burning of fossil fuels, in industry, including the production of cement, urban consumption and transportation.

Carbon exists in the earth's atmosphere primarily as the gas-carbon dioxide. It constitutes a very small percentage of the atmosphere about 0.04%. However, it plays essential role in photosynthesis, plants take up carbon dioxide from atmosphere, converting it into carbohydrate and releasing oxygen into the atmosphere. When these plants or trees die or are burnt, the carbon stored in them are released back into the atmosphere. This natural cycling of carbon is

maintained and controlled by a dynamic balance between biological and inorganic processes since the geological history of earth.

Nevertheless, the atmospheric concentration of carbon dioxide in the last five decades explains a disturbingly increasing trend. The rate at which carbon dioxide being added to the atmosphere is also observed to be much faster than at any time in the past 80,000 years (www.research.noaa.gov) (accessed on 28th April 2012). The carbon dioxide concentration in the atmosphere is continuously being measured and recorded since 1957 (Keeling, 1989). The carbon dioxide concentration in the atmosphere has increased from about 280 ppm, during the pre-industrial period, to approximately 390 ppm in the present-day (www.research.noaa.gov (accessed on 28th April 2012). The rise in the carbon dioxide level in the atmosphere is mainly caused by anthropogenic activities. In the 19^{th} century, with the advent of industrial revolution, humans have been burning a huge amount of fossil fuels, releasing the carbon stored in it back into the atmosphere as carbon dioxide. Since the industrial rebellion, the carbon dioxide level in the atmosphere has increased tremendously causing remarkable changes in the natural global carbon cycle. Besides the combustion of fossil fuels, other human activities such as deforestation also have a considerable impact on the ability of terrestrial biosphere to emit or remove carbon dioxide from the atmosphere. Deforestation and degradation of forests lead to emission of carbon dioxide through burning of forest biomass and decomposition of plant parts and soil carbon. These human activities have accelerated and contributed to a long-term rise in atmospheric carbon dioxide level. With all the carbon dioxide pumped into the atmosphere from the various human activities, the planet would have been overheated rapidly if not for the nature's mechanism of sequestering the carbon from the atmosphere and storing it in

its reservoirs like the oceans and the forests and soils. The nature's way of sequestering carbon from the atmosphere is a process of achieving balance of carbon dioxide levels in the atmosphere and maintaining the global carbon cycle, and this cycle has been happening billions of years. However, humans have greatly disturbed this balance with activities like combustion of fossil fuels and change in land-use patterns such as deforestation.

1.1 Significance of the Study

Forests can make a very significant contribution to a low-cost global mitigation portfolio that provides synergies with adaptation and sustainable development. Opportunities to increase activities include simplifying procedures, developing certainty over future commitments, reducing transaction costs, and building confidence and capacity among potential buyers, investors and project participants (IPCC, 2007; cited in Marshet Tefera and Teshome Soromessa, 2015).

Forest is most important means of offsetting carbon emission for sequestrating carbon in bio-mass and giving positive effect on livelihood of the rural farmer because of its cost effectiveness and associated environmental and social benefits. The carbon sequestration benefits of forest can be perceived to be more important at the global than at national, regional or local levels (Sharma, 2000). Estimation of total plant biomass and soil carbon sequestered in any forest system is very important as it gives ecological benefits to the local people. Therefore, this study puts base line information about the carbon sequestration potential of Gendo (Gura Tirigni) forest so as to manage it and for further study.

1.2 Carbon Finance Prospects for Ethiopia

Ethiopia is located at 2°54' N - 15°18' N latitude and 32°42' E - 48°18' E longitude. It is a land-locked country with a land area of 1.12 million km^2 occupying a significant portion of the Horn of Africa. The country has diverse climate, geology and topography resulting in a heterogeneity of soil types (Hurni *et al*, 2007; Mesfin Abebe, 1998).

Climate change funding mechanisms available for financing forestry sector are Clean Development Mechanism (CDM) and Reducing Emissions from Deforestation and Forest Degradation (REDD). Ethiopia has so far registered only one CDM project (Humbo, SNNPR, UNFCCC registration Dec. 2009, area of 2,728 ha). Concerning REDD, Ethiopia has prepared Readiness Preparation Proposal (R-PP) to the World Bank‟s Forest Carbon Partnership Facility (FCPF). Actual areas under CDM are emerging on project basis. For example there are now three projects, in the Abote, Ada Berga, and Sodo areas, that are mentioned as potential CDM projects. With respect to REDD, the large amount of carbon stored in the different forest categories may continue to release CO_2 to the atmosphere through deforestation and forest degradation. If Ethiopia decides to protect these forest resources through carbon finances, it is possible to mitigate the release of 2.76 billion tons of carbon into the atmosphere (Yitebitu Moges *et al.,* 2010). The experience in other countries shows that management intervention on natural forests increases wood production, carbon sequestration, besides its benefits in terms of biodiversity conservation and watershed protection. For example, the average accumulation rate of carbon dioxide in managed forests is around 5.5 tons ha^{-1} yr^{-1} in woodlands, and 21 in tropical rainforests, subtropical forests and lowland forests, while unmanaged tropical rainforests grow at

a rate of about 0.5 tons ha^{-1} yr^{-1} according to Yitebitu Moges *et al.* (2010), about 40-fold increase in annual yields. Additionally, unmanaged forest is subject to further degradation.

Carbon sequestration from atmosphere can be advantageous from both environmental and socio-economic perspectives. There are evidences from several studies in Ethiopia and other countries. The environmental perspective includes the removal of CO_2 from the atmosphere (Yitebitu Moges *et al*., 2010), the improvement of soil quality (Zewdu Eshetu, 2000), and the increase in biodiversity; while socioeconomic benefits include increased yields (Sombroek *et al.*, 1993), monetary incomes from potential carbon trading schemes (McDowell, 2002), normalizing droughts through its potential for creating atmospheric condensation making cloud seeding, as well as reducing flood hazards and increasing ground water recharge by increasing water infiltration through soil columns. However, Ethiopia is lacking periodic inventory data of forests and carbon stocks, and this may be a challenge in developing sustainable forest management planning that attracts climate finances. Carbon stock evaluation in moist montane forest like Gendo (Gura Tirigni) helps for managing the forests sustainably from the economic and environmental points of view for the welfare of human society beside their aesthetic, spiritual, and recreational value. Various scholars also agreed on the urgency and importance of studying and documenting the vegetation resources of Ethiopia, among others, Teshome Soromessa *et al.* (2004); Ensermu Kelbessa and Teshome Soromessa (2008); Teshome Soromessa *et al.* (2011); Fekadu Gurmessa *et al*. (2011 and 2012); Adugna Feyissa *et. al.* (2013); Teshome Soromessa (2013); Teshome Soromessa and Ensermu Kelbessa (2013a and 2013b); Teshome Soromessa and Ensermu Kelbessa (2014); Mohammed Gedefaw *et. al.* (2014) are some of them. However, no study has been conducted in Gendo forest that is intended at evaluating carbon sequestration

potential of this forest. Gendo forest vegetation is one of the moist montane forests found in East Wollega Zone, Ethiopia, containing diverse animals and plant species (Teshome Gemechu *et al*., 2015).

1.3 Statement of the Problem

Developing countries like Ethiopia, challenges of climate change are enormous due to the fact that the economy of the country mainly depends on agriculture which is climate sensitive sector. As a result, Ethiopia is on a frontline to be affected by climate change and variability regardless of its contribution (Akililu Amsalu and Dereje Gebremichael, 2010; Alebachew Adem and Woldeamlak Bewket, 2011). Even Africa contributes only 4% to global GHGs emission (Henry, 2010).

Environmental factors are known to regulate carbon storage in forest ecosystems (Valencia *et al.,* 2009). Topographic characteristics such as altitude, slope and aspect are known to drive patterns of tree species distribution and influence forest carbon stock (Valencia *et al.,* 2009; McEwan *et al*., 2011). de Castilho *et al.* (2006) indicated that topography plays a significant role in determining live tree biomass, and elevation has been found to play a role in forest productivity. Carbon storage in forests is also known to be related to biotic factors such as species diversity. Individual tree species have unique functional traits, such as specific leaf area and wood density that convey a particular capacity for carbon capture and sequestration. Thus, species rich forests may have an increased capacity for carbon storage (Brown *et al.*, 1999; McEwan *et al*., 2011). Unlike in the developed countries, Ethiopia does not have carbon inventories and databank to monitor and enhance carbon sequestration potential of different forests. Only small efforts have

been made so far to assess the biomass and soil carbon sequestration potential at small scale (Mesfin Sahile, 2011).

Gendo Forest is entirely encompassed within moist montane rain forests with respect to its altitudinal range, vegetation compositions and climatic conditions. Gendo Forest have ecological, economic, social and cultural values that local communities obtained from it (including timber trees, hydrological cycle, shadow or shading of villages in its immediate vicinity during hot weather condition). Even though not too much, when compared with other moist mountain forests, Gendo forest also hosts 18 endemic species 8 of which are threatened and near threatened according to IUCN red data book. This implies the fact that Gendo Forest contributed in preservation of endemic, threatened and indigenous plant gene pool (Teshome Gemechu *et al*., 2015).

1.4 Objectives of the Study

1.4.1 General objective

The overall objective of this study is to estimate the carbon stock potentials of Gendo (Gura Tirigni) forest as a potential sink for climate change mitigation.

1.4.2 Specific objectivities

- To estimate the amount of carbon stored in different carbon pools; aboveground biomass, belowground biomass, soil organic matter and litter biomass of different tree species within Gendo forest.
- To determine statistically and technically valid estimate, based on existing data, of the amount of carbon that captured or retained in the Gendo (Gura Tirigni) forest.
- To determine the impact of environmental factors on carbon sequestration.
- To provide baseline information for the future management of the forest

2. REVIEW OF RELATED LITERATURE

2.1 An Overview of the Global Climate Change

Climate change is a global challenge. The GHGs in the atmosphere are responsible to create warming the earth‟s surface by absorbing the outgoing infrared radiation. The result is to trap part of thermal energy re-irradiated by Earth‟s surface in the lower atmosphere which heats up. The higher the concentration of GHGs in the atmosphere, the greater the proportion of longer wave radiation that is trapped and so the greater the warming. Human-induced GHGs emissions enhance this effect to create warming greater than that which would occur naturally (The Scottish Government, 2008). The concentration of these gases in the atmosphere has been increasing since the beginning of the industrial era. Carbon dioxide concentrations in the atmosphere have increased by just over one third from a range of 275 to 285 parts per million (ppm) in the pre-industrial age (AD1000-1750) to 375ppm in 2005 and the rate at which this concentration is increasing is accelerating (DEFRA, 2007; The Scottish Government, 2008). Similarly, the IPCC (2007a) realized that most of the increase in global temperatures since the mid-20^{th} century is very likely due to the human-induced accumulation of GHGs in the atmosphere (DEFRA, 2007). The average global temperatures have risen by 0.74^{o}C over the past century and the rate of warming is increasing with 0.4^{o}C since the 1970s (DEFRA, 2007; IPCC, 2007b).

According to Green Facts (2007) report, the global climate change already has a measurable impact on many natural and human systems. For instance, it is increasingly being observed that snow and ice are melting and frozen ground is thawing, hydrological and biological systems are changing and in some cases being disrupted, migrations are starting earlier, and species

geographic ranges are shifting towards the poles. Over the past years, there are different significant impacts of climate change expected to occur on society which are associated with its extremes, such as droughts, floods, heat waves and severe storms (DEFRA, 2007; IPCC, 2007a; The Scottish Government, 2008). As warming continue increasing, ecosystems ability will likely be affected and respond to climate change either migrating to new locations that are similar to their current climate, or they will change, adapting to the changing climate, with some species becoming less abundant or locally extinct and others thriving under the new conditions (ELCNSTA, 2007).

In addition, rising atmospheric CO_2 is also increasing the absorption of CO_2 by seawater, causing the ocean to become more acidic, with potentially disruptive effects on marine plankton and coral reefs. Mitigation measures which are technically and economically feasible strategies that aim to reduce emissions of GHGs would reduce warming over this century and beyond which can further help to avoid, reduce or delay many impacts of climate change (Green Fact, 2007).

Ethiopia is vulnerable to climate change because of its geographic multiplicity and complexity, and great reliance on climate sensitive economic sectors particularly agriculture and pastoralism (Aklilu Amsalu and Dereje Gebremichael, 2010). IPCC's mid-range emission scenario shows that, compared to the 1961-1990 average mean annual temperature across Ethiopia will increase by 0.9 - 1.1^{o}C by the year 2030 and from 1.7- 2.1^{o}C by the year 2050 (Alebachew Adem and Woldeamlak Bewket, 2011). IPCC's regional review of the impact of climate change identified three vulnerable sectors in Ethiopia like food security, water resource and health (IPCC, 2001).

Forests play a critical role in the natural global carbon cycle. It sequesters and stores more carbon than any terrestrial ecosystem i.e. they store more than 80% of all terrestrial above ground carbon and more than 70% of all soil organic carbon (Jandl *et al*., 2006; Sundquist *et al.,* 2008). As a result, forest ecosystems are regarded as the largest terrestrial carbon pool. According to the intergovernmental panel on climate change (IPCC, 2007a) report, forests have an average biophysical mitigation potential of 5,380 Mt CO_2 yr^{-1} until 2050. In Ethiopia different factors like deforestation, overharvesting and permanent conversion to other forms of land use is leading to shrinkage of forest resources. As a result, forest cover has been declining rapidly and only remnant forests are confined to some areas especially in the west and south-western parts of the country, which are less populated (Tesfaye Bekele, 2002). Deforestation is one of the main causes of the prevailing land degradation in Ethiopia. Tree cutting is a common practice, which has been taking place for centuries. Some parts of northern Ethiopia that currently are bare and experience severe land degradation once had a good vegetation cover (FDRE, 1998). Even though the original forest cover of Ethiopia is not well documented, and estimates are not consistent, about 420,000 square kilometers (35% of Ethiopia,,s land) was covered by forests in the twentieth century. These forest cover have declined to 16% in 1952, 3.6% by 1980, 2.6% by 1987, and an estimated 2.4% in 1992 (FDRE, 1998). However many recent researches indicate the forest cover of Ethiopia is in recovering trend about 12.5%.

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Deforestation has taken place and will be taking place in the proportions that were many and varied than the past, thus the remaining forests have also been continuously threatened (Kidane Mengistu, 2002). Among these, over harvesting, over grazing, habitat loss, fragmentation, introduction of exotic species, inappropriate investment practices, deliberate fire, misguided state policy, shifting agriculture are all anthropogenic causes of deforestation (Nurhussien Taha, 1994; Daba Wirtu, 2001; Dash, 2003; Mesfin Bayu, 2004; Matheos Ersado and Yoseph Assefa, 2004; Teshome Soromessa and Ensermu Kelbessa, 2013a and 2013b; Teshome Soromessa and Ensermu Kelbessa, 2014; Teshome Soromessa, 2015). Thus many people living in natural environment especially in Africa, wild plants are indispensible to their daily existence (Lykke, 2000). In the processes of interaction with natural ecosystem for his own agriculture, man has modified the natural ecosystem. The reduction of forests vegetation to a few scattered patches, the decline of animals and difficulty of germinations were followed by massive soil erosion and nutrient depletion, resulting in widespread of deficiency diseases of crop plants, animals and reduction of agricultural productivity (Legesse Negash, 1995; Demel Teketay, 2004).

Forests sequester and store more carbon than any other terrestrial ecosystem and are an important natural „brake" on climate change. When forests are cleared or degraded, their stored carbon is released into the atmosphere as carbon dioxide (CO_2). Tropical deforestation is estimated to have

released of the order of 1–2 billion tons of carbon per year during the 1990s, roughly 15–25% of annual global greenhouse gas emissions (Malhi and Grace, 2000; Fearnside and Laurance 2003 and 2004; Houghton, 2005). The largest source of greenhouse gas emissions in most tropical countries is from deforestation and forest degradation. In Africa, for example, deforestation accounts for nearly 70% of total emissions (FAO, 2005). Moreover, clearing tropical forests also destroys globally important carbon sinks that are currently sequestering CO_2 from the atmosphere and are critical to future climate stabilization.

Why carbon cycle drew much attention is because carbon dioxide being the chief among the greenhouse gases, it has potentials to influence the global climate pattern (Brown, 1993), and it also has a relatively long residence time in the atmosphere. About 60% of the observed global climate change is attributable to this increasing carbon dioxide concentration in to the atmosphere (Grace, 2004).

2.2 The Position of Forests in the Global Carbon Cycle

Human beings have become a component in the earth"s system, driving and accelerating global warming through the rapid release of greenhouse gases (GHGs) into the atmosphere. Human beings alter the composition of the atmosphere through increasing the concentration of greenhouse gases (GHGs) in the atmosphere by fossil fuel burning which represents about two-third of the global emissions and by deforestation and land use changes representing about one-third. These are anthropogenic causes of climate change. There is no doubt that our climate is changing. This will pose huge challenges to nations, organizations, enterprises, cities, communities and individuals. Developing countries will suffer most from adverse consequences

of climate change, and the highly vulnerable regions and people are already being affected. Forests play an important role in the global carbon balance. As both carbon sources and sinks, they have the potential to form an important component in efforts to combat global climate change. FRA (2010) estimated that the world‟s forests store 289 Gt of carbon in their biomass alone (www. fao.org/forestry/fra/fra2010/en/). As sources of GHGs, deforestation accounts for approximately 20% of anthropogenic emissions (FAO 2006; Stern, 2006). Although deforestation is reported to represent about 20% of the global GHGs emissions, regionally the figure varies. About 70% GHGs emissions is caused by deforestation in Africa (Gibbs et al., 2007). For the world as a whole, carbon stocks in forest biomass decreased by an estimated 0.5 Gt annually during the period 2005–2010, mainly because of a reduction in the global forest area. On the other hand, the recent IPCC report estimated that the global forestry sector represents over 50% of global greenhouse mitigation potential (IPCC, 2007). Consequently, forestry became the focus of global climate change policy and is given a key position in international climate treaties. While sustainable management, planting and rehabilitation of forests can conserve or increase forest carbon stocks, deforestation, degradation and poor forest management reduce them.

2.3 Factors Influencing Carbon Stocks in Forest Ecosystems

Topography is one of the most important environmental gradients that affect biomass, stem size,and stand density and spatial heterogeneity of stems. Topographic factors such as altitude, slope and aspect have also a significant effect on the carbon stock of forests. On the other hand, Sheikhb *et al.,* (2009) indicated that forest carbon stock can increase or decrease depending on a number of factors such as climate, vegetation type, nutrient availability, disturbance, and land use and management practice.

Altitude has a significant effect on species richness, which declines even with a 100m increase in altitude and also affects species composition (Sheikh *et al.*, 2009). On the other hand, the increase in precipitation and decrease in temperature with an increase in altitude creates change in climate along the altitudinal gradient influencing the composition and productivity of vegetation and consequently affect the quantity and turnover of SOM (de Castilho *et al.*, 2006). Similarly, Sheikh *et al.* (2009) stipulated that altitude affect the SOM by controlling soil water balance, soil erosion and geologic deposition process and this further affects the quantity of the whole carbon stock of the forest. For instance, the result of the study carried by de Castilho *et al.,*(2006) showed that the total biomass increased with altitude. Therefore, emphasizing the altitudinal gradient in the forest is helpful to test the effects of environmental variables on forest carbon stocks. Hence, the relationship between forest carbon and altitude and their correlation needs to be investigated (Sheikh *et al.,* 2009).

In addition, in mountainous or hilly terrain, physiographic characteristics of a site, such as slope gradient and aspect, are also known to influence the distribution of carbon across the landscape (Ganthany, 2004). According to Bayat (2007), slope and aspect has significant relationship with biomass in forest areas due to the interaction between solar radiation and soil properties (e.g. soil moisture and soil nutrient). For instance, as Bayat (2007) study showed, the south-facing slopes which receive the most insulation (compared to the north-facing, which receive the least amount of insulation) have typically hot and dry soil surfaces. On the other hand, Johnson *et al.* (2000) investigated the ability of elevation, slope and aspect to determine organic matter, pH and cat-ion exchange capacity and they found that the correlations explained 4-25% of the variation in these

soil properties. Considering the influence of aspect and slope in order to detect the influence of these physiographic features on carbon storage is important (Ganthany, 2004), and can be used to manage forests to maximize their carbon storage capacity

3. MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Geographical location

The study was carried out in western Ethiopia, Oromia National Regional State, East Wellega Zone, Gida Ayana District in Gendo (Gura Tirigni) moist montane forest located at 433km west of Addis Ababa, 103km north of Nekemte town and 7km south of Ayana town. It is situated at 9^0 49.5' N ─ 9^0 59.6' N and 36^0 40' E ─36^0 43' E, on Nekemte-Bahir Dar main road having a total area of 57 hectares (including about two hectares community plantation; about one hectare at east edge and one hectare at south-east and south edges). The altitude of Gendo forest range between 2183 and 2268 m a.s.l. (GPS reading during field survey, 2016)

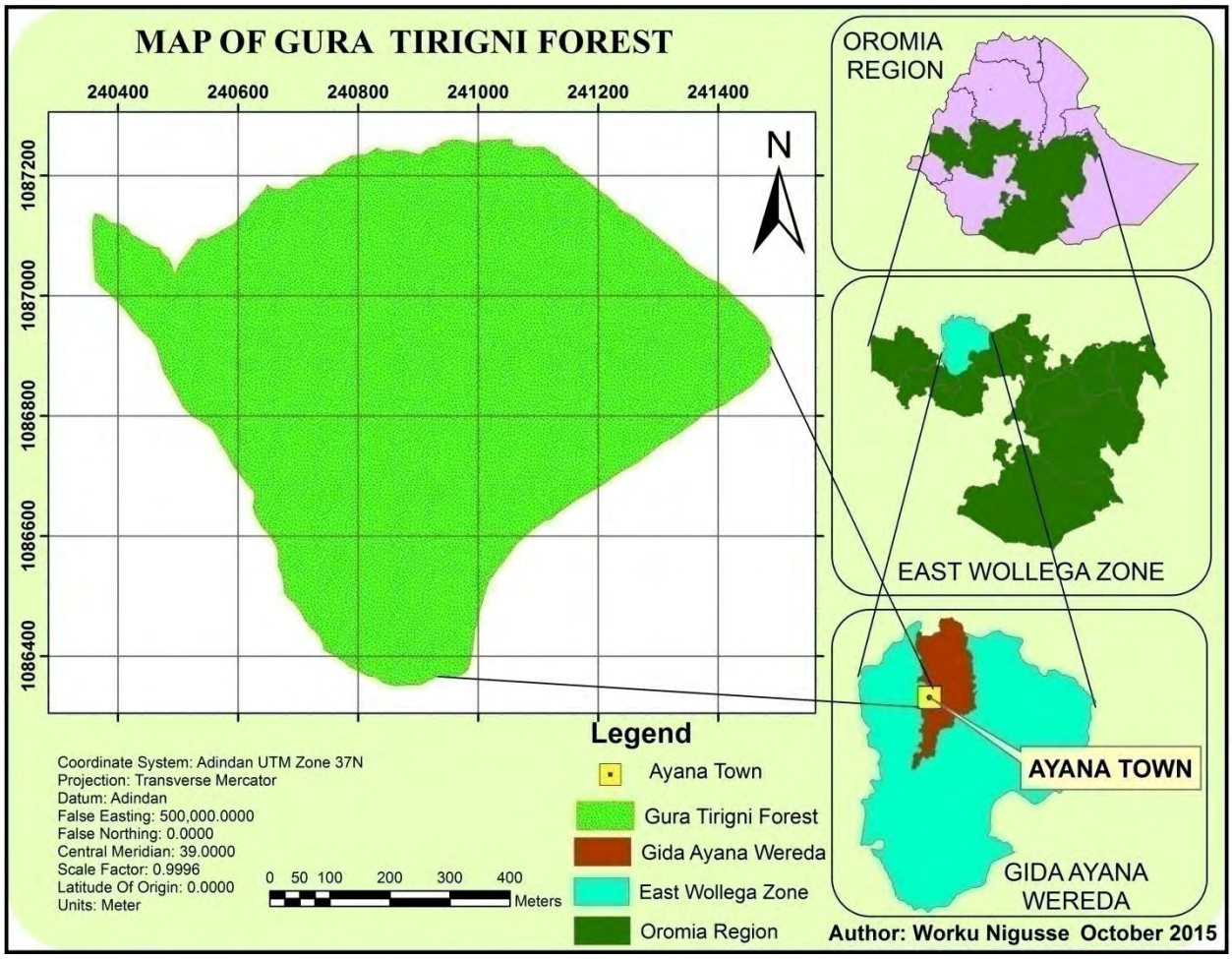

Figure 1: Map of Gendo (Gura Tirigni) forest

3.1.2 Climate of the Study Area

There are two types of agro climatic zones in the Wereda: *Kola* about 51% and *Weyina Dega* 49% of the total land area (GAARDO, 2016). The nearest weather station for the study site is Gida Ayana Meteorological Station. The temperature and rainfall data of Gida Ayana Meteorological Station were collected from Ethiopia National Meteorological Agency, Addis Ababa (2016). The mean annual temperature of the study area is about 19.4^{o}C with a maximum of 24.5^{0}C recorded from January to May and minimum of 14.3^{o}C which is recorded in December and January (Figure 2). The average annual rainfall of the study area is 1572mm ranging from

(1397mm minimum to 1748 mm maximum) with the rains mainly falling from the end of April to October. Nevertheless, there are rains in any months of the year forming small amount of clouds letting additional moisture for the forest. Figure 3 shows that there is high amount of rain fall from May to September.

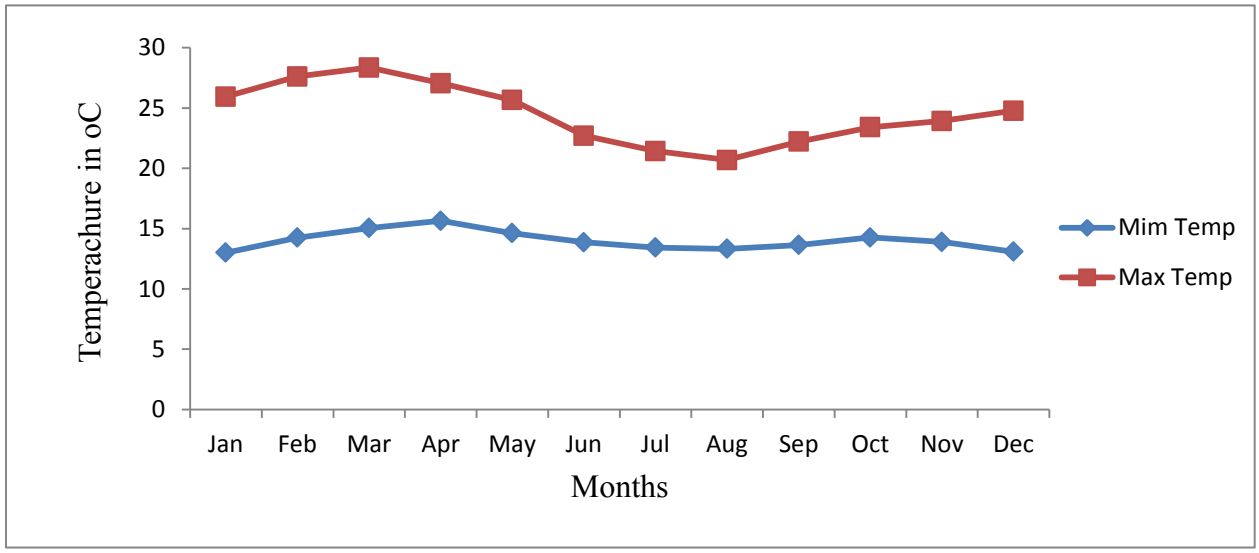

Figure 2: Mean monthly temperature (^{0}C) of the study area (2006-2015).

Source: (Ethiopia Meteorological Agency, 2016)

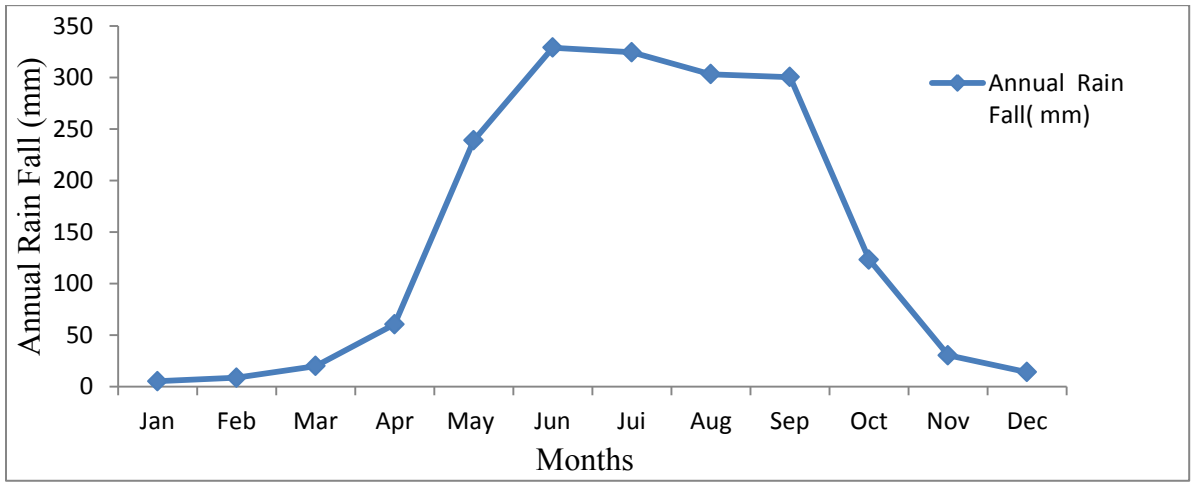

Figure 3: Annual rainfall (mm) of the study area (2006-2015)

Source: (Ethiopia Meteorological Agency, 2016)

3.1.3 Geology and Soils of the Study Area

Even though no specific study on the geology and soil character of the study area was conducted, the topography, geology and soil of the study area fits with that of *Weyina dega* agro climatic zones described by MoA (1986) and Mesfin Abebe (1998). According to basic data of Gida Ayana Agriculture and Rural Development Office, about 12,300 ha of land is plain (flat), 101,250 ha is hill slope, 6,619 ha is gentle gorge, 7,470 ha is swamps and 2,350 ha is other land forms (GAARDO, 2016). The study forest is characterized by gentle slope from south to north sides of hill foot with flat upper surface (Personal observation). The soil of the study area is pale brown to dark reddish and red in color, clay and clay-loam in texture (Murphy, 1959).

3.1.4 Vegetation Cover of the Study Area

Detailed data of the floristic composition and regeneration of the Gendo Forest is available from the study carried out by (Teshome Gemechu et al., 2015). Gendo Forest is entirely encompassed within moist montane rain forests with respect to its altitudinal range, vegetation compositions and climatic conditions. The most dominant species of the study forest are: *Embelia schimperi, Carissa spinarum, Croton macrostachyus, Vepirs dainellii, Urera hypselodendron, Teclea nobilis, Grewia ferruginea, Ficus sur, Clausena anisata, Albizia schimperiana.* Whereas*, Allophylus abyssinicus, Rhamnus prinoides, Rhus glutinosa* and *Pouteria adolfi-friederici* are the least dominant species.

3.1.5 Fauna

Gendo (Gura Tirigni) forest is habitat for Anubis baboons, Vervet monkeys, Bushbucks, Wild pigs, Common foxes, Spotted hyenas, Porcupines and various kinds of birds such as Finches, Doves, Crows, Ravens and reptiles like Snakes (Local people and personal observation).

3.2 DATA TYPE

Both primary and secondary data were used during collecting relevant data to achieve the objectives of the study. The primary data were obtained from the field to determine the carbon stock potential of Gendo (Gura Tirigni) forest by measuring trees' height and DBH; collecting litter and soil samples for laboratory analysis to estimate carbon stock of the study forest. Secondary data relevant to this study were collected from different resources including published and unpublished materials, books, journals, articles, report papers and electronic websites.

3.3 METHODOLOGY

The methodology and procedures that were used to estimate carbon stocks were simple step-by-step procedures using standard carbon inventory principles and techniques. Procedures were based on data collection and analysis of carbon accumulating in the aboveground biomass, belowground biomass, and leaf litter and soil carbon of forests using verifiable modern methods. As indicated in (Pearson *et al.*, 2005), the detailed procedures were explained in the following sub headings.

3.3.1 Delineation of the Study Site

Delineation of the forest boundaries was the first step in forest carbon stock measurement. The boundaries of the study forest area was delineated by taking geographic coordinates with GPS. The GPS points that were taken from the study site to indicate each sample plots were recorded.

3.3.2 Sampling Techniques

Systematic random sampling method was used to take samples. Sample plots were laid along line transects based on altitudinal variation of the study area. A randomly sampling plot (10m x 20m) in each site were established. To reveal the tree composition and biomass, all live trees

with a diameter ≥ 5cm were recorded as indicated by (Pearson *et al.,* 2005 and 2007). The diameter were measured at breast height (1.3m height from the ground) to estimate biomass and the size class distribution of trees as well as species diversity in a sampling plot. DBH was measured by using caliper and meter. Trees with multiple stems connected near the ground was counted as single individuals and bole circumference was measured separately. Tree height was measured by using clinometers. The methodology and procedures applied to estimate carbon stocks were simple step-by-step procedures using standard carbon inventory principles and techniques as (Pearson *et al.,* 2005 and 2007). Procedures were based on data collection and analysis of carbon accumulating in the aboveground biomass, belowground biomass, litter biomass, and soil organic carbon of forests using verifiable modern methods.

3.3.3 Field Measurements

Sample plots (10m x 20m) were laid through systematic random sampling method with nine transect lines in the various qualitatively classified biomass levels to account for the largest variability in the biomass range. Ground inventory data of tree parameters i.e., DBH and height of the trees were collected.

3.3.4 Vegetation Data Collection and Identification

Data collection of the study forest was conducted between January 20, 2016 ─ May 15, 2016 and June 03 ─ 14, 2016. Seventy one plots, each 10m x 20m, ($200m^2$) were used for trees and shrubs DBH and height measurement. Nine transect lines 200m far apart from each other were used systematically following uphill to ensure a uniform assessment throughout all the plots and each plots were laid on the transect line belt 100m far apart. Depending on the length of transect line belts, 495m (the shortest) to 1860m (the longest), the number of plots laid on each transect belt vary from 3 (the least) to 14 (the highest). Number of transect lines with their length, total

number of plots, altitude, slope and aspect of each plots were shown on Appendix 2. Vernacular names, number of individuals, height, and diameter at breast height of each trees and shrubs with DBH ≥ 5cm in the study forest were recorded.

The estimations of aboveground and belowground carbon depend on the aboveground biomass of living tree species. To estimate the aboveground biomass all trees and shrubs within selected sample plots with DBH ≥ 5cm were identified and their DBH measured. Aboveground biomass was calculated from DBH using the model that was developed by (Brown *et al.,* 1989). Trees and shrubs with multiple stems at 1.3m height were treated as a single individual and DBH of the largest stem was taken. Plant identification was done by using Flora of Ethiopia and Eritrea.

3.3.5 Field Carbon Stock Measurement

The major activities of carbon stock measurement during the field data collection were aboveground tree biomass, belowground biomass, litter biomass, and soil organic matter measurements. Detailed methods are explained under the following sub headings.

3.3.5.1 Aboveground Biomass (AGB)

The aboveground biomass consists of all living vegetation above the soil, inclusive of stems, stumps, branches, bark, seeds and foliage. The DBH (at 1.3m) and height of individual trees with DBH ≥ 5cm was measured in each permanent rectangular plot (10m x 20m) that is 200m^2 using linear tape and clinometers respectively, starting from the edge and working inwards, and marking each tree to prevent accidentally counting it twice. Each tree was recorded individually; together with its species name (vernacular name was used during field work).

Equipment that were used for tree DBH and height measurements are GPS, compass, measuring tape, plastic rope length of 60m setting up observation of plots, wooden stick 1.3m long to measure stem height for DBH measurement, clinometer for tree height measurement, marker pen and work sheets.

3.3.5.2 Belowground Biomass (BGB)

Belowground carbon pool consists of all the biomass contained within living roots of trees, and of the biomass in tree stems below 1% height (stump height). Fine roots of less than 2mm diameter (the suggested minimum) are often excluded because these often cannot be distinguished empirically from soil organic matter (IPCC, 2006). The measurement of BGB is relatively expensive and time consuming as compared to AGB which is relatively simple. This is due to the wide variability in the way that roots are distributed in the soil. As a result, estimation of BGB is more efficient and effective using a conservative ratio for shoot: root predicts root biomass based on AGB carbon. For example, the lowest shoot to root ratio ever reported for species X is 5:1(MacDicken, 1997; Watson, 2008). Although, there are different regression models (with less data) that are available for estimation of BGB as a function of AGB recommended by Cairns *et al*. (1997) for different regions (Pearson *et al.*, 2007). In this regard, studies carried out by Cairns *et al.* (1997) found that the root to shoot ratios were constant between latitude (temperate and boreal), soil texture (fine, medium and coarse), and tree-type (angiosperm and gymnosperm) even though, roots are believed to depend on climate and soil characteristics as indicated by Brown and Lugo (1982). They have reviewed 160 studies covering temperate and boreal forests and found a mean root to shoot ratio of 0.26, ranging between 0.18 and 0.30. However, according to MacDicken (1997), for cases in which more accurate estimates of BGB are economically feasible using locally established methods is

important. As indicated by MacDicken (1997), this carbon pool is 20% of above ground biomass.

3.3.5.3 Litter Biomass (LB)

The leaf litter is defined as all dead organic surface material on top of the mineral soil. A sub plot in the large plot with a size of 1m × 1m was established to sample litters. In each large plot there were five sub plots which were laid four at the corners and one in the center to minimize heterogeneity. The litter samples were taken in sub plot of (1m × 1m) along diagonal from one corner to the other and then the leaf litters within the $1m^2$ sub plots were collected. For laboratory analysis, hundred grams of composite samples were brought to the laboratory placing in a sample plastic bag and oven dried at 105^{o}C for 24 hours and then the total dry weight was determined in the laboratory after oven drying of the sample. Oven-dried samples were taken in pre-weighed crucibles. The samples were ignited at 550^{o}C for two hour in muffle furnace. After cooling in desiccator, the crucibles with ash were weighed and percentage of organic carbon was calculated. Carbon fraction was measured in the laboratory (Bhishma *et al.*, 2010). Dead wood was not considered in this study due to the unavailability of it in the study sites.

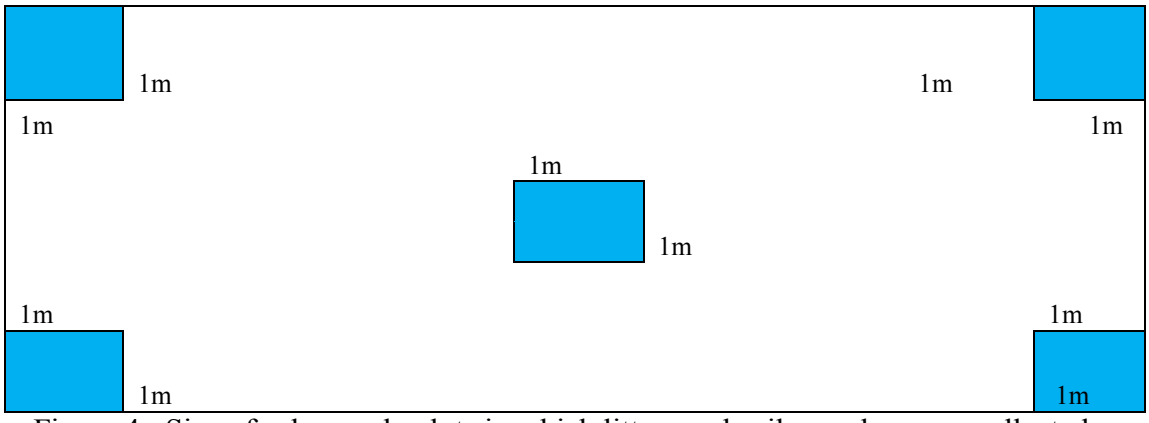

Figure 4: Size of sub sample plots in which litters and soil samples were collected

3.3.5.4 Soil Organic Carbon (SOC)

Soil samples for soil carbon determination were collected at the same sampling sub-plots recommended for litter sampling. The Samples were dug using core sampler with a diameter of 5 cm and the depth of the soil in which that took the sample was 10 cm. Mixing of soils was done properly by taking equal amount of soil from each sub plots to make a composite in order to reduce heterogeneity. Hundred grams of composite samples were brought to Addis Ababa University Center for Environmental Science for laboratory analysis putting in a sample paper bags. In the laboratory, soils were prepared and oven dried at 105^{o}C for 24 hours to remove the soil moisture. The oven dried soil sample has been ignited using a muffle furnace at 550^{o}C for 12 hours to determine the organic matter content (%OM) of a soil sample. Finally, the bulk density and soil organic carbon were determined after getting percentage of organic carbon.

Equipment that were used during litter and soil sample collections are: GPS for setting up altitude, compass for setting up directions, clinometer for measuring slope, balance for measuring weight, plastic ropes 60m long for setting up a plot and 4m long for setting up a sub plot, hammer and stake for fixing a plot and sub plots, pickaxe for digging up the ground, knife for cutting, meter tape for measure length and width of plots, plastic bags for sample collection, marker for leveling samples and work sheet for taking notes.

3.3.6 Estimation of Parameters for Recorded Data

3.3.6.1 Estimation of Carbon in Different Carbon Pools

3.3.6.1.1 Estimation of Aboveground Biomass (AGB)

Aboveground biomass namely stem, stump, branches, bark, seed and foliage includes not only live trees but also live understory (IPCC, 2003). An allometric equation has a statistical relationship between key characteristics dimension of trees that are fairly easy to measure, such as DBH or height, and other properties that are more difficult to assess, such as aboveground biomass.

Table 1**:** Estimation of aboveground biomass as a function of DBH using regression equations collected from different literature

Equation	Author	Applicability	Life zone	DBH Range
Y = exp{-1.996 + 2.32 x ln(DBH)}	FAO (1997)	General	Dry transition to moist (rainfall > 900 mm)	5 to 40 Cmm
Y = 10 ^ (-0.535 + log10(π x r2))	FAO (2004)	General	Dry (rainfall < 900 mm)	< 30 cm
Y = exp{-2.134 + 2.530 x ln(DBH)}	FAO (2004)	General	Moist (rainfall 1500 to 4000mm)	< 80 cm
Y = 34.4703 - 8.0671 DBH + 0.6589 DBH2	Winrock (from Brown *et al., (*1989)	General	Moist (rainfall < 1500 mm)	≥ 5 cm
Y = exp{-3.1141 + 0.9719 x ln[(DBH2)H]}	Winrock (from Brown *et al.,* 1989)	General	Moist (rainfall 1500 to 4000 mm)	> 5 cm
Y = exp{2.4090+ 0.9522 x ln[(DBH2)HS]}	Winrock (from Brown *et al.,* 1989)	General	Moist (rainfall 1500 to 4000 mm)	> 5 cm
Y = (0.0899 ((DBH2)0.9522) x (H0.9522) x (S0.9522))	Luckman(1997)	General	Not specified	Not Specified
Y =-12.05 + 0.876(BA) (2005)	Muraliks	General	Rainfall 1378 + 116.86 mm	Not Specified
*Y = 0.139 * DBH2.32*	Brown(1997)	General	Dry < 1500 mm	5 to 40cm
*ln (DW1) = -2.5202 + 2.14ln (D) + 0.4644 * ln (H)*	Nelson *et al*. (1999)	General	Around 2000 mm	< 25 cm

From the different available allometric equations to estimate aboveground biomass, the model that was developed by (Brown *et al.,* 1989) is recommendable for this study site since the general criteria described by the author fit with the study area. The equation to be used to calculate the aboveground biomass is given below:

$$Y = 34.4703 - 8.0671\ DBH\ + 0.6589(DBH)^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (equ.1)$$

where, Y is above ground biomass and DBH is diameter at breast height.

Estimation of aboveground carbon content

$$AGC = AGB\ x\ 0.5 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (equ.2)$$

where, AGC is above ground carbon content and AGB is above ground biomass

To estimate the amount of CO_2 sequestered in the aboveground biomass, the aboveground carbon was multiplied by 3.67. Because the ratio of CO_2 to C is (44/12) = 3.67

3.3.6.1.2 Estimation of Belowground Biomass (BGB)

According to (MacDicken, 1997), standard method for estimation of belowground biomass can be obtained as 20% of aboveground tree biomass i.e., root-to-shoot ratio value of 1:5 is used. Similarly, (Pearson *et al.,* 2005) described this method as it is more efficient and effective to apply a regression model to determine belowground biomass from the knowledge of biomass in aboveground. Thus, the equation developed by (MacDicken, 1997) to estimate belowground biomass was used. The equation is given below:

$$BGB = AGB * 0.2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (equ.3)$$

where: BGB is below ground biomass, AGB is above ground biomass and 0.2 is conversion factor (or 20% of AGB).

To estimate the carbon content and amount of CO_2 in BGB, the same procedure was applied like that of AGB.

$$BGC = BGB * 0.5 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (equ. 4)$$

where, BGC is carbon content of belowground biomass and BGB is belowground biomass

To get belowground biomass CO_2 in the similar trend with the aboveground CO_2, the belowground carbon was multiplied by 3.67.

3.3.6.1.3 Estimation of Carbon Stocks in the Leaf Litter Biomass

According to (Pearson *et al.*, 2005), estimation of the amount of biomass in the leaf litter can be calculated by:

$$LB = \frac{(Wfield)}{A} * \frac{(Wsub-sample\ dry\ )}{(Wsub-sample\ fresh\ )} * \frac{1}{10000}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathrm{equ.} 5)$$

where, LB is Litter Biomass (biomass of litter ton ha^{-1}), W_{field} is weight of wet field sample of litter sampled within an area of size 1 m^2 (g), A is size of the area in which litter were collected (ha), $W_{sub\text{-}sample\ (dry)}$ is weight of the oven-dry sub-sample of litter taken to the laboratory to determine moisture content (g) and $W_{sub\text{-}sample\ (fresh)}$ is weight of the fresh sub-sample of litter taken to the laboratory to determine moisture content (g).

The percentage of organic carbon storage from the dry ash in the litter carbon pool was calculated as follows (Allen *et al*., 1986):

$$\%Ash = \frac{Wc - Wa}{Wb - Wa} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (equ.\ 6)$$

where, % Ash is percentage of ash, Wc is the weight of ash and crucibles (g), Wa is the weight of the crucible (g) and Wb is the weight of oven dried grind samples and crucibles (g).

From the percentage ash (%Ash), percentage of organic carbon (%C) was calculated by using equation 7 below.

$$\%C = \ 100 - \%Ash\ \ * 0.58 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (equ.\ 7)$$

where, %C is percentage of organic carbon (%) and 0.58 is conversion factor.

3.3.6.1.3 Carbon Stocks in Dead Litter Biomass

Litter carbon stock was calculated by using equation 8 below.

$$LC = LB * \%C \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (equ. 8)$$

where, CL is total carbon stocks in the dead litter in ton ha^{-1} and %C is carbon fraction determined in the laboratory (Pearson *et al.,* 2005).

The litter carbon has to be multiplied by 3.67 to get the amount of CO_2 sequestered in litter biomass.

3.3.6.1.4 Estimation of Soil Organic Carbon

The carbon stock density of soil organic carbon can be calculated as recommended by (Pearson *et al.*, 2005) from the volume and bulk density of the soil using equation 9 below.

$$V = h * \pi r^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (equ. 9)$$

where, V is volume of the soil in the core sampler augur in cm^3, h is the height of core sampler augur in cm and r is the radius of core sampler augur in cm (Pearson *et al.,* 2005).

However, for this study beaker is used for measuring the volume of the soil due to unavailability of core sampler augur. More over bulk density of soil samples were calculated by using equation 10 below.

$$BD = \frac{Wav(dry)}{V} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (equ.\ 10)$$

where, BD is bulk density of the soil sample per, $W_{av,\ dry}$ is average air dry weight of soil sample per the quadrant and ***V*** is volume of the soil sample in the core sampler auger in cm^3 (Pearson *et al.,* 2005).

Then, the carbon stock in soil was calculated as follows:

$$SOC = BD * d * \%C \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (equ. 11)$$

where, SOC is soil organic carbon stock per unit area (ton ha^{-1}), BD is soil bulk density (g cm^{-3}), *d* is the total depth at which the sample was taken (10 cm) and *%C* is carbon concentration (%).

Loss on Ignition (LOI) analysis is used to determine the organic matter content (%OM) of a soil sample. This is a relatively simple procedure as compared to traditional acid digestion methods and CNS analysis used to determine %OM (Schulte and Hopkins 1996; Konen et al., 2002). It does not involve the use of any chemicals, only the use of a muffle furnace. For the LOI method, soil is oxidized at a high temperature (500–575^{o}C), and the mass loss is proportional to the organic-matter content of the soil. LOI calculates %OM by comparing the weight of a sample before and after the soil has been ignited. Before ignition the sample contains OM, but after ignition all that remains is the mineral portion of the soil. The difference in weight before and after ignition represents the amount of the OM that was present in the sample.

The LOI method measures the organic matter content of soils, but the conversion of the organic-matter content to a carbon basis may be difficult because the carbon content of organic matter is not consistent and varies with vegetation type, degree of decomposition, age, and other factors (Batti and Bauer, 2002). Thus, direct correlation between LOI and total carbon may be necessary for each soil type, geographic region, or land management practice (Konen *et al.,* 2002). Percentage of OM of soil calculated by using the following formula:

$$\%OM = \frac{[Pre-ignition\ weight\ \ g\ ] - [\ Post-ignition\ weight\ \ g\ ]}{[Post-ignition\ weight\ \ g\ ]} * 100 \ldots (equ. 12)$$

Equipment that were used during litter and soil %OM analysis in laboratory are: electronic balance, porcelain crucibles, aluminum foil, scissors, tongs, spoon, litter sample, soil samples, oven (adjusted on 105^{o}C), muffle furnace (adjusted on 550^{o}C), desiccator, pen and pencil and booklet/ paper.

A desiccator is a glass container used to equilibrate objects within a controlled atmosphere. Temperature inside a desiccator is normally room temperature. Humidity of this atmosphere is usually the factor that is being considered. Objects, such as crucibles, can pick up moisture from the air. This causes an increase in water content in an object and can produce errors when weighing. By using a desiccator objects are allowed to equilibrate in an environment of low or controlled moisture. This allows me to avoid errors associated with weighing water along with an object.

3.3.6.1.5 Total Carbon Stock Density

The carbon stock density is calculated by summing the carbon stock densities of the individual carbon pools of the stratum using the (Pearson *et al.*, 2005) formula. In addition, it is recommended that any individual carbon pool of the given formula can be ignored if it does not contribute significantly to the total carbon stock (Bhishma *et al*., 2010).

Carbon stock density of a study forest was calculated using equation 13 below.

$$Cdencity = CAGB + CBGB + CLit + SOC \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (equ. 13)$$

where, $C_{density}$ is carbon stock density for all pools (ton ha^{-1}), C_{AGB} is carbon in aboveground biomass (ton ha^{-1}), C_{BGB} is carbon in belowground biomass (ton ha^{-1}), C_{Lit} is carbon in dead litter (ton ha^{-1}) and SOC is coil organic carbon (ton ha^{-1}).

The total carbon stock is then converted to tons of CO_2 equivalent by multiplying it by 44/12, or 3.67 (Pearson *et al.*, 2007).

3.3.7 Data Analysis

After data collection was completed, data analysis of various carbon pools measured in the forest was accomplished. The data obtained from diameter at breast height, height of each plants, fresh and dry weight of litter and soil were analyzed using excel and Statistical Package for Social Science (SPSS) software version 20. The height and diameter data were arranged into five classes: ≤10, >10-20, >20-30, >30-40 and >40 for applying appropriate model of biomass estimation equation. The relationship between each parameter was tested by multiple regression and descriptive statistics. The relation between forest carbon stock with altitude, slope and aspect were tested independently.

4. RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Floristic Composition of the Studied Forest

A total of fifty four different species of plants were identified in Gendo (Gura Tirigni) forest, East Wollega Zone, West Ethiopia. A total of 4687 numbers of trees and shrubby trees of the fifty four different plant species were recorded from the field to determine the carbon stock potentials of the studied forest. Among the recorded plant species, the most frequent species were: *Embelia schimperi, Carissa spinarum, Croton macrostachyus, Vepirs dainellii, Urera hypselodendron, Teclea nobilis* and *Grewia ferruginea* having a total number of individuals 378, 331, 329, 267, 213, 196 and 195 respectively. However, *Allophylus abyssinicus, Rhamnus prinoides, Rhus glutinosa* and *Pouteria adolfi-friederici* are the least frequent species with 4, 8, 12 and 13 numbers of individuals respectively (Table 2).

Table 2: Species list collected from Gendo (Gura Tirigni) forest with their call number, scientific name, vernacular name, family, number of trees (shrubs), average DBH, average height and % frequency of species

Scientific name	Vernacular name (Afaan Oromoo)	Family	Species Code	No of Trees	Average DBH (cm)	Average Height (m)	No of plots that species occurs	% frequency of species
Acacia abyssinica Hochst ex.Benth.	Laaftoo	Fabaceae	C15	82	27.33	10.65	11	2.4
Acacia etbaica Schweinf.	Doddota	Fabaceae	C46	111	12.04	5.69	8	1.8
Albizia schimperiana Oliv	Mukarbaa	Fabaceae	C11	55	40.91	26.41	18	3.9
Allophylus abyssinicus (Hochest.) Radlkofer	Sarara/Malqaqqoo	Sapindaceae	C50	4	15.69	7.75	2	0.4
Apodytes dimidiata E.Mey. ex Am	Dongii	Icacinaceae	C34	147	28.78	7.40	15	3.3

Scientific name	Vernacular name (Afaan Oromoo)	Family	Species Code	No of Trees	Average DBH (cm)	Average Height (m)	No of plots that species occurs	% frequency of species
Argomuellera macrophylla Pax	Timboo Jaldeessaa	Euporbiaceae	C27	32	5.27	2.19	2	0.4
Aspiliamoss ambicensis (Oliv) Wild	Daalattii	Asteraceae	C54	154	6.41	3.92	2	0.4
Bersama abyssinica Fresen	Lolchiisaa	Melianthaceae	C55	91	5.75	3.07	4	0.9
Brucea antidysenterica J.f.Mill	Qomaanyoo	Simarobaceae	C6	16	5.37	2.30	2	0.4
Buddleja polystachya Fresen.	Hanfaaree	Loganiaceae	C17	66	16.57	6.44	7	1.5
Carissa spinarum L.	Agamsaa	Apocynaceae	C24	331	6.08	4.02	10	2.2
Cassipourea malosana (Baker) Alston	Hudduufardaa	Rhizophoraceae	C30	32	27.97	13.88	30	2.2
Caulpurnia aurea (Ait.) Benth.	Ceekaa	Fabaceae	C32	166	7.55	5.22	9	2.0
Celtis africana Burm.f.	Qayyii (Cayyii)	Ulmaceae	C43	60	21.02	12.22	15	3.3
Clausena anisata (Willd.) Benth.	Hulumaayii	Rutaceae	C38	56	8.88	1.63	5	1.1
Cordia africana Lam.	Waddeessa	Boraginaceae	C19	86	28.82	8.76	15	3.3
Croton macrostachyus Del	Makkaannisa	Euporbiaceae	C1	329	27.61	10.95	37	8.1
Dombeya schimperiana A.Rich.	Daannisa Diimaa	Sterculaceae	C52	21	17.77	9.86	2	0.4
Dombeya torrida (J.F. Gmel) P. Bamps	Daannisa Adii	Sterculaceae	C49	18	19.43	9.84	4	0.9
Dracaena steudneri Engl	Warqee Jaldeessaa	Dracaenaceae	C47	21	19.49	7.52	5	1.1
Ekebergia capensis Sparm	Somboo	Meliaceae	C31	61	23.74	11.63	8	1.8
Embelia schimperi Vartke	Hanquu	Myrsinaceae	C3	378	6.84	4.54	11	2.4
Erythrina brucei Schweinf	Waleensuu	Fabaceae	C23	85	35.00	17.77	20	4.4
Ficus sur Forrsk.	Harbuu	Moraceae	C5	127	24.94	15.65	16	3.5
Flacourtia indica (Burem.F) Merril	Akuukkuu	Flacoutiaceae	C28	15	39.54	6.39	9	2.0
Gnidia glauca (Fresen)Gilg	Diddiksaa/ Qaqaroo	Thymelaceae	C37	20	5.18	2.89	2	0.4

Scientific name	Vernacular name (Afaan Oromoo)	Family	Species Code	No of Trees	Average DBH (cm)	Average Height (m)	No of plots that species occurs	% frequency of species
Grevillea robusta A Cunn ex.Br.		Proteaceae	C7	95	15.87	9.40	3	0.7
Grewia ferruginea Hochst ex A. Rich.	Dhoqonuu	Tiliaceae	C16	195	6.21	4.71	10	2.2
Hypericum quartinianum A.Rich.	Ulee Foonii	Guttiferaceae	C41	111	8.48	5.57	3	0.7
Juniperus procera Hochst ex Endl.	Gaattiraa	Cuppressaceae	C13	27	30.84	14.02	14	3.1
Justicia schimperiana (Hochst ex Nees) T.Anders.	Dhummuugaa	Acanthaceae	C22	104	5.20	2.03	5	1.1
Lepidotrichilia volkensii (Gurke) Leroy	Dhama'ee	Meliaceae	C25	86	7.58	3.73	5	1.1
Macaranga capensis (Bail.) Sim.	Ho'aa	Euporbiaceae	C14	40	18.98	9.17	13	2.9
Maesa lanceolata Forssk.	Abbayyii	Myrsinaceae	C4	76	13.44	5.66	10	2.2
Maytenus gracilipes (Welw ex Oliv.)	Qacamaa/ Kombolcha	Celastraceae	C10	58	7.66	3.64	5	1.1
Maytenus addat (Loes) Sebsebe	Kombolcha	Celastraceae	C48	67	13.29	5.20	5	1.1
Millettia ferruginea (Hochst.) Baker	Sootalloo	Fabaceae	C45	57	24.68	12.53	10	2.2
Nuxia congesta R.Br.ex Fresen.	Naffuroo	Loganiaceae	C40	23	30.59	6.29	5	1.1
Oncoba spinosa Forssk.	Harsammeessaa	Flacoutiaceae	C44	47	7.82	3.81	3	0.7
Pittosporum viridiflorum Sims	Soolee/Qasammee	Pittosporaceae	C21	23	15.16	8.59	5	1.1
Podocarpus falcatus (Thumb.) R.Br.ex Mirb	Birbirsa	Podocarpaceae	C12	54	32.94	23.35	10	2.2
Pouteria adolfi-friederici (Engl.) Baehni	Qararoo	Sapotaceae	C26	13	27.65	9.35	1	0.2
Rhamnus prinoides L'Herit.	Geeshoo	Rhamnaceae	C8	8	6.39	2.90	2	0.4
Rhus glutinosa A.Rich.	Xaxessaa	Anacardaceae	C53	12	16.39	7.73	2	0.4
Rytigynia neglecta (Hiern) Robyns	Mixoo Seeraa	Rubiaceae	C36	48	8.48	3.22	2	0.4

Scientific name	Vernacular name (Afaan Oromoo)	Family	Species Code	No of Trees	Average DBH (cm)	Average Height (m)	No of plots that species occurs	% frequency of species
*Schefflera volkensii (*Engel) Harms	Gatamaa	Araliaceae	C42	36	34.50	13.00	13	2.9
Solanecio gigas (Vatke) C.Jeffrey	Jirma-Jaldeessaa	Asteraceae	C39	65	19.43	3.42	3	0.7
Syzygium guineense (Wild.) DC.	Baddeessaa	Myrtaceae	C35	67	25.95	10.86	12	2.6
Teclea nobilis Del	Hadheessa baala qal'aa	Rutaceae	C2	196	17.35	9.12	19	4.2
Urera hypselodendron (A.Rich.) Wedd	Lanqessaa	Urticaceae	C29	213	6.61	6.88	12	2.6
Vepirs dainellii (Pichi-Serm.) Kokwaro	Hadheessa baala bal'aa	Rutaceae	C20	267	19.99	8.73	18	3.9
Vernonia adoensis Sch. Bip.ex Walp.	Ulee harree	Asteraceae	C33	35	9.53	4.29	2	0.7
Vernonia amygdalina Del.	Ebicha	Asteraceae	C18	93	15.59	6.58	8	1.8
Vernonia rueppellii Sch. Bip, ex.Walp.	Reejjii	Asteraceae	C9	154	11.73	5.69	7	1.5

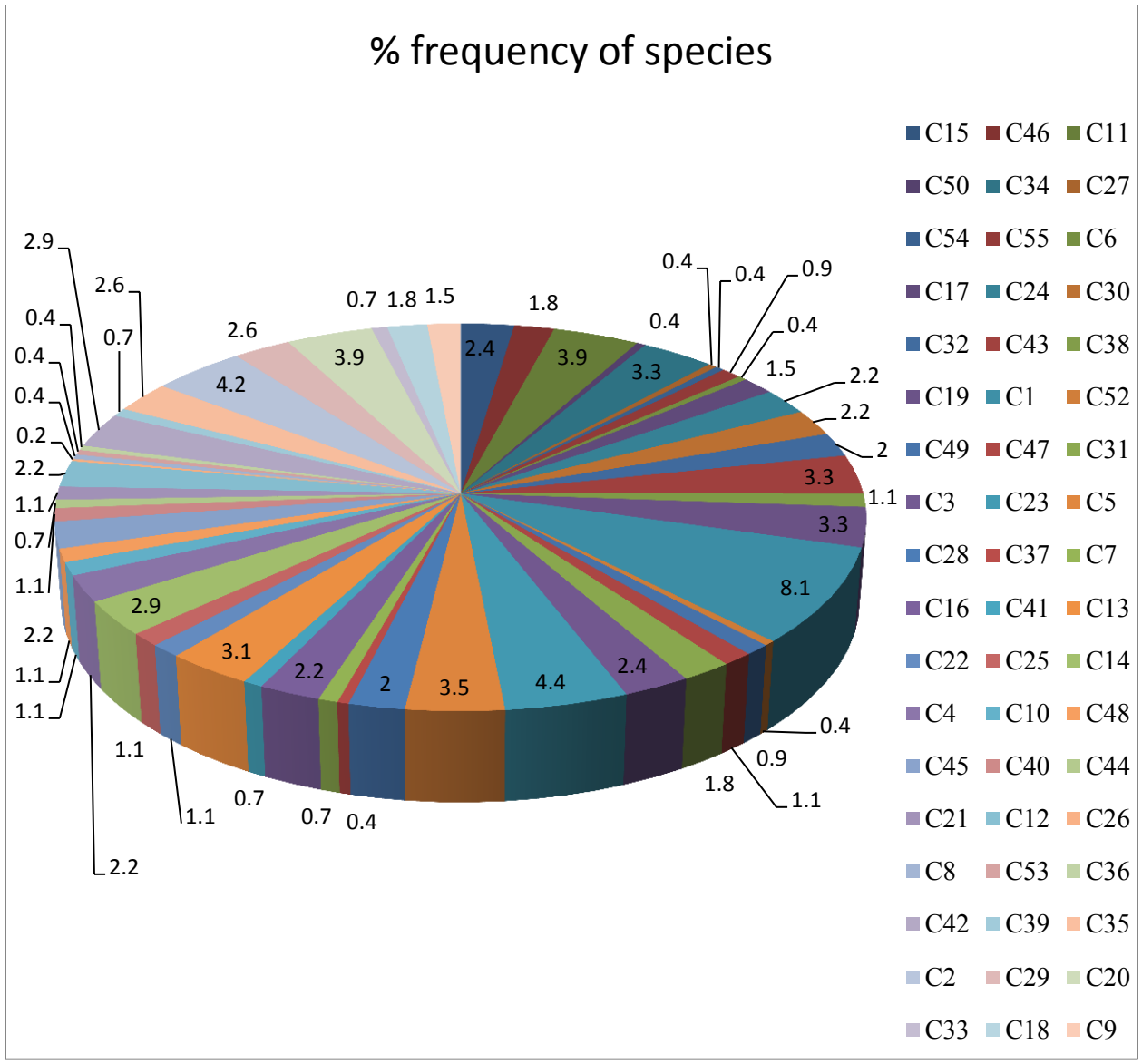

Figure 5**:** Percentage frequency of tree species collected from the field

Based on the results (Table 2) *Pouteria adolfi-friederici* (0.2%), *Rhamnus prinoides* (0.4%), *Rhus glutinosa* (0.4%), *Rytigynia neglecta* (0.4%), *Gnidia glauca* (0.4%), *Dombeya schimperiana* (0.4%) and *Allophylus abyssinicus* (0.4%) had the least percentage frequencies and *Croton macrostachyus* had the highest percentage frequency (8.1%).

4.1.2 Diameter at Breast Height and Height Distribution of Trees in the Studied Forest

4.1.2.1 Diameter at Breast Height (DBH)

From the raw data collected from the field, the DBH of trees were classified into five classes: ≤10cm, >10cm-20cm, >20cm-30cm, >30cm-40cm and >40cm (Appendix 1). The majority of trees were distributed in the second DBH class (>10cm-20cm) followed by the third DBH class (>20cm-30cm) and the first DBH class (0-10cm). On the other hand the least tree distribution were recorded in the fifth DBH class (>40cm) and fourth DBH classes (>30cm-40cm) respectively. This showed that the study forest is occupied by young age and regenerating plants.

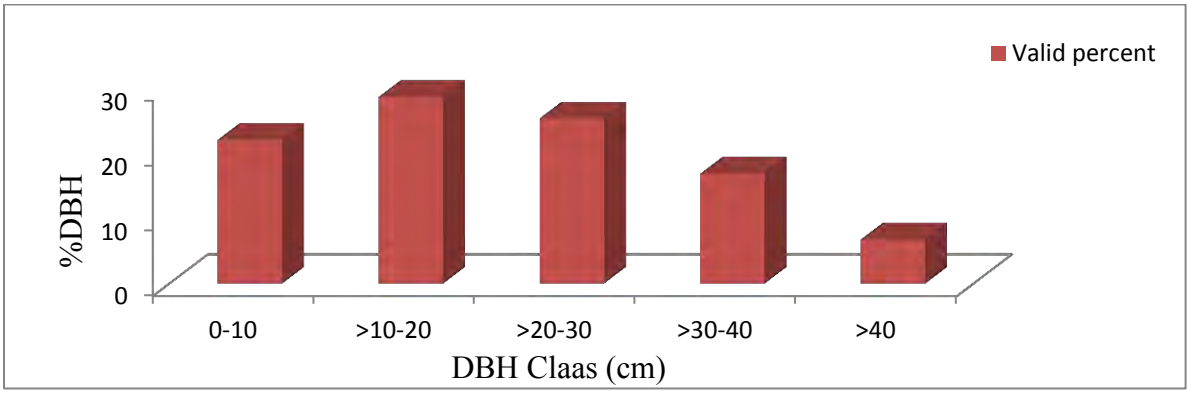

Figure 6**:** DBH distribution of plants in Gendo forest

4.1.2.2 Height Distribution of Plants

Like that of DBH distribution of plants, the height distribution of plants also classified into five classes (0-10m), (>10m-20m), (>20m-30m), (>30m-40m) and (>40m). The majorities of plants were found in the first height class followed by the second and third height classes. The shortest plants were recorded in the last two classes; fourth and five height classes. Like the result of the DBH class, the result of height distribution also indicate the study forest is regenerating forest.

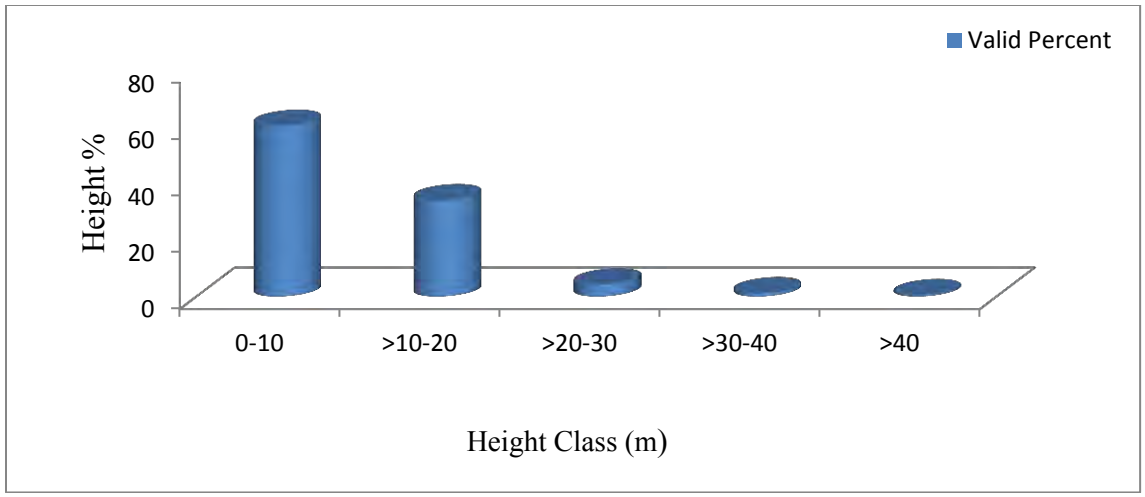

Figure 7: Height distribution of plants in the study Gendo forest

4.1.3 Estimation of Biomass and Carbon Stocks in Different Pools

4.1.3.1 Aboveground Biomass (AGB)

The result of the study showed that the maximum value of aboveground biomass is 859.86 ton ha^{-1} and the minimum value 62.32 ton ha^{-1} (Figure 8). The mean value of aboveground biomass recorded was 259.18±14.97 ton ha^{-1} (Appendix 6).

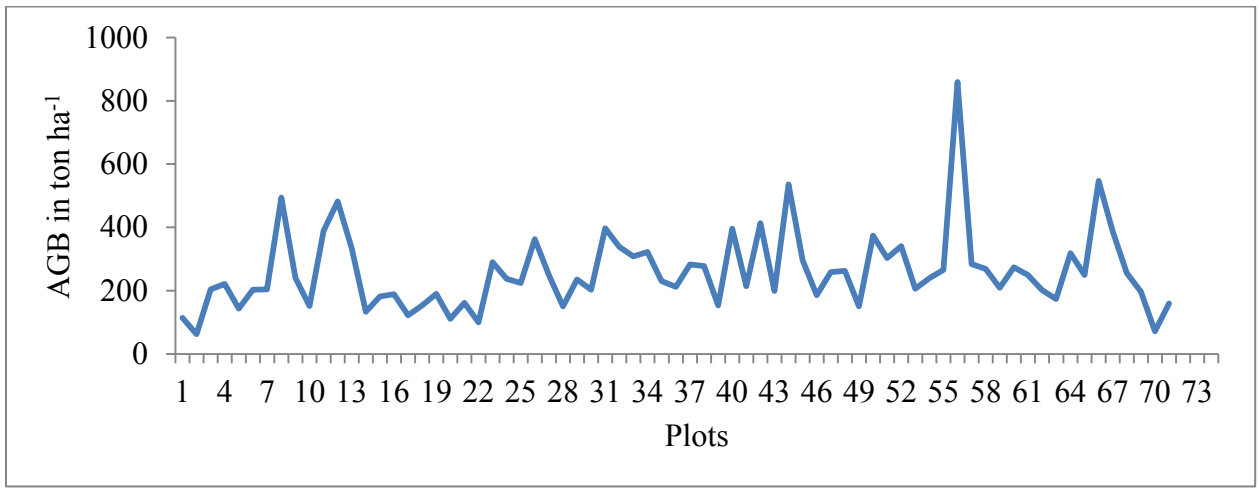

Figure 8: AGB vs. plots in ton ha^{-1}

4.1.3.2 Estimation of Carbon Stocks in AGB

The result of this study showed that 429.93 ton ha^{-1} the maximum and 31.16 ton ha^{-1} the minimum carbon stocks was observed in the aboveground biomass with mean value of 128.60±7.53 ton ha^{-1}. The minimum and maximum CO_2 sequestered in AGB were 114.36 ton ha^{-1} and 1577.84 ton ha^{-1} respectively with mean value of 471.96±27.63 ton ha^{-1}(Appendix 7). The value of carbon stocks in each sample plots are illustrated in (Figure 9).

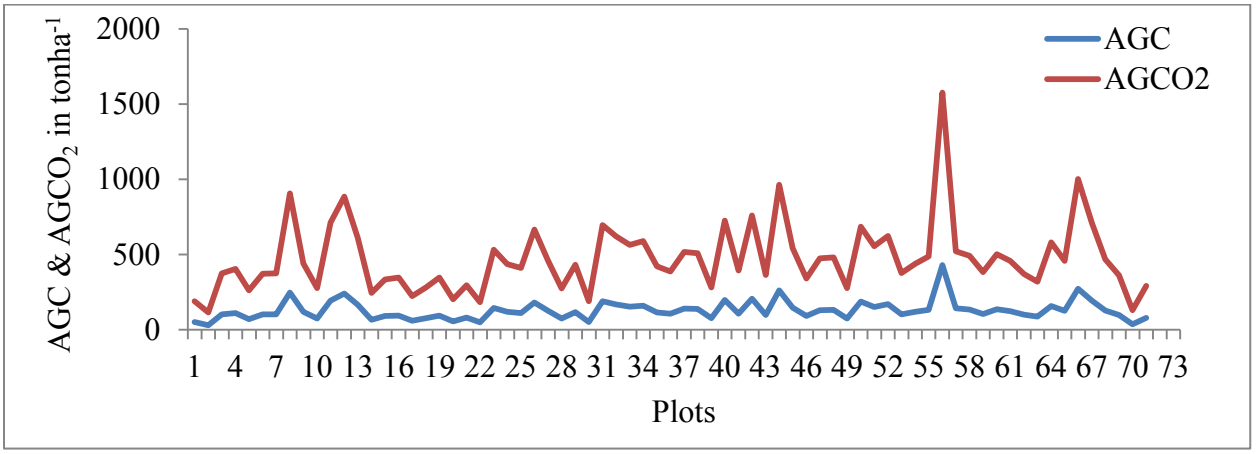

Figure 9: AGC and AG (CO_2) vs. plots in ton ha^{-1}

4.1.3.3 Belowground Biomass BGB

Belowground biomass was calculated from AGB which was a multiplication factor of 0.2. The result of this study showed that 12.46 ton ha^{-1} and 168.37 ton ha^{-1} were the minimum and the maximum values of BGB respectively. The mean BGB was found to be 51.90± 2.98ton ha^{-1}(Appendix 6). This is graphically illustrated (Figure 10).

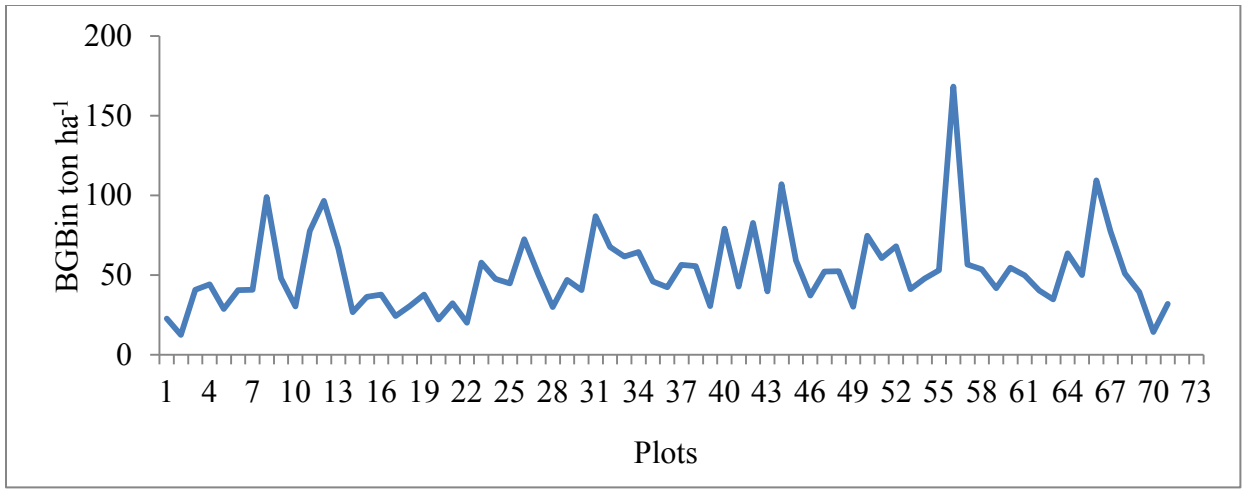

Figure 10: Belowground Biomass vs. Plots

4.1.3.4 Estimation of Carbon Stocks in BGB

The root biomass carbon stock was calculated by assuming that, it is 50% of its belowground biomass. Therefore, the result of this study showed that 6.23 ton ha^{-1} and 84.19 ton ha^{-1} were the minimum and the maximum belowground carbon stocks (BGC) respectively. The mean value of belowground carbon in this study was 26.52±1.62 ton ha^{-1} (Appendix 6). Like that of above ground carbon dioxide, the carbon dioxide sequestered in the belowground biomass was also increased with an increasing of belowground biomass and carbon stocks. This carbon pool sequestered a minimum of 22.88 ton ha^{-1} and a maximum of 308.96 ton ha^{-1} with a mean sequestered value of 97.33±5.93 ton ha^{-1} (Appendix 7). This is graphically shown(Figure 11).

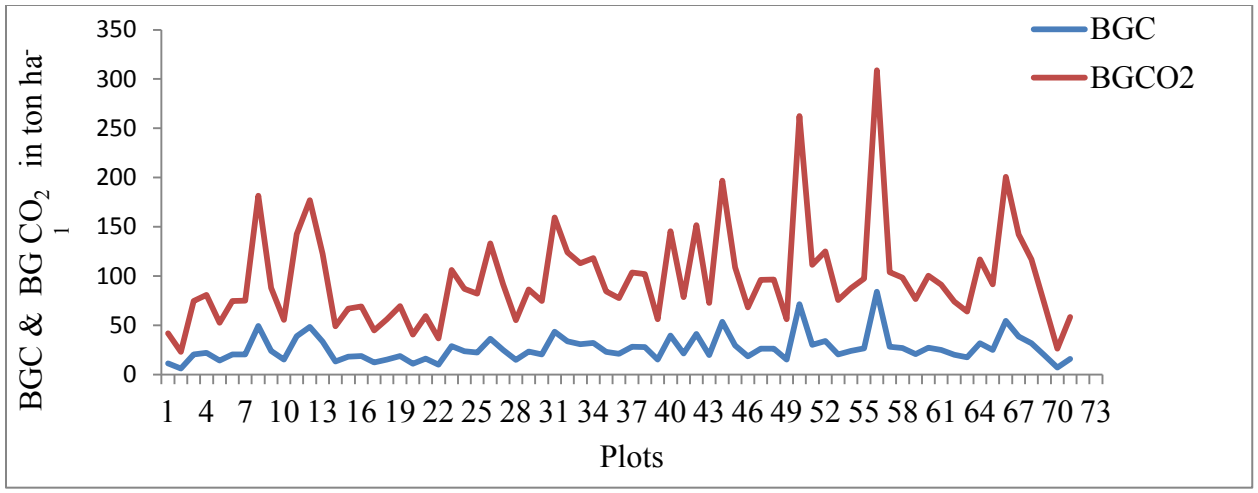

Figure 11: Belowground Carbon and CO_2 Sequestered in Belowground vs. plots

4.1.3.5 Estimation of Carbon Stocks in Litter Biomass

Based on the result obtained, the mean minimum value of carbon stock in litter recorded was 0.09 ton ha^{-1} and the maximum value 8.81 ton ha^{-1} with a mean value 3.12±0.25 ton ha^{-1}. The mean CO_2 s sequestered in litter was 11.63±0.42 ton ha^{-1} with maximum value 18.64 ton ha^{-1} and minimum value 2.28 ton ha^{-1} (Appendix 6). Detailed illustration was shown in Figure 12.

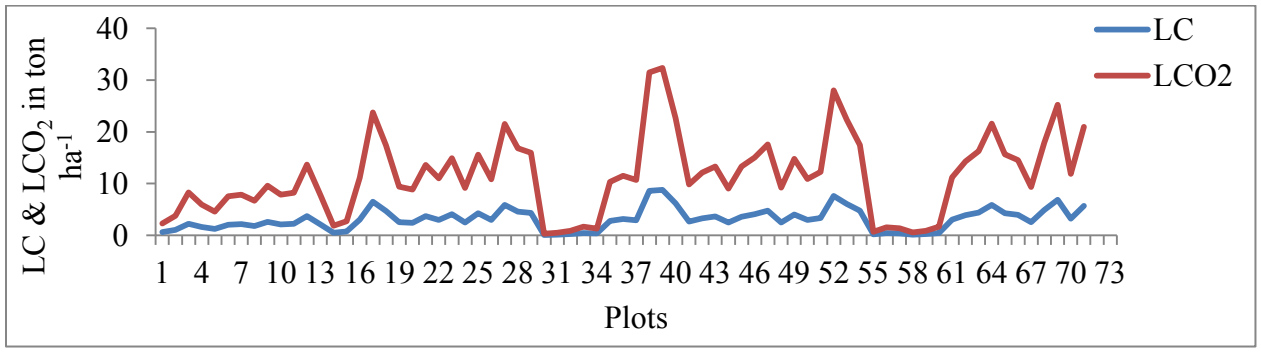

Figure 12: Litter Carbon Stock and CO_2 Sequestered in Litter Biomass vs. plots

4.1.3.6 Estimation of Carbon Stocks in (SOC)

4.1.3.6.1 Bulk Density

The bulk density was computed on the soil profile. The bulk density of the study soil was 0.29 g cm^{-3} minimum value and 1.65 g cm^{-3} maximum value with a mean value of 0.77±0.29 g cm^{-3} as shown in Appendix 5.

4.1.3.6.2 Soil Organic Carbon

The laboratory results for the organic carbon of the sample soils are shown in (Appendix 5). The result showed that, the highest percentage of organic carbon was 21.15%: whereas, 4.56% is the lowest value and the mean percentage value of organic carbon in this pool is 12.50%±0.45. On the other hand, the carbon content of the soil carbon pool was 168.95 ton ha^{-1} maximum and 15.76 ton ha^{-1} minimum values with a mean value 94.96±4.61 ton ha^{-1} (Appendix 6).

4.1.4 Soil Carbon Sequestration

The mean value of the sum of soil carbon sequestration in all plots along the soil profile is shown in Appendix 5. The mean carbon sequestration in the soil with depth ranged from 0 cm to 10 cm was found to be 348.52 ton ha^{-1} with 57.84 ton ha^{-1} minimum and 620.05±0.29 ton ha^{-1} maximum values of CO_2 that is sequestered in the studied forest (Appendix 5).

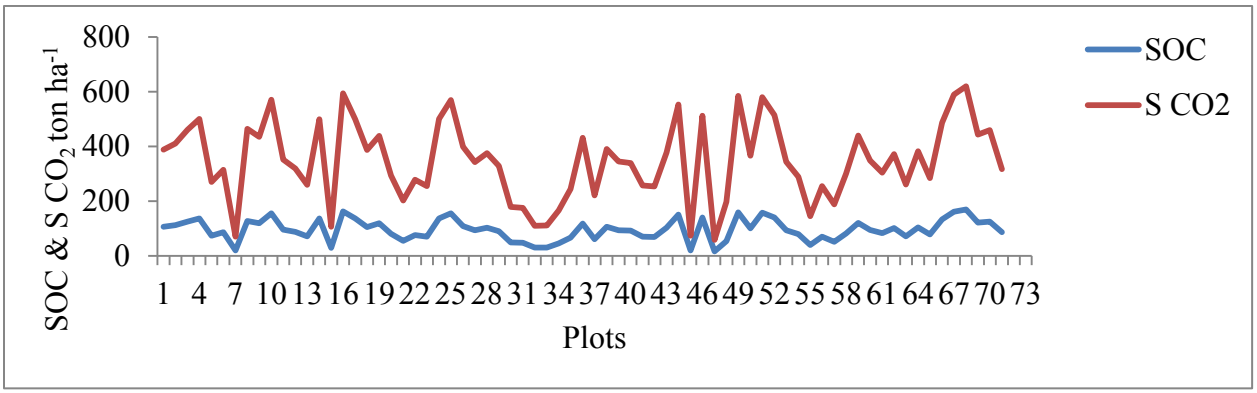

Figure 13: Soil Organic Carbon and CO_2 Sequestered in Soil vs. plots

4.1.5 Carbon Stocks in Different Pools

The summarized illustration of the different carbon pools is shown in Figure 14 below.

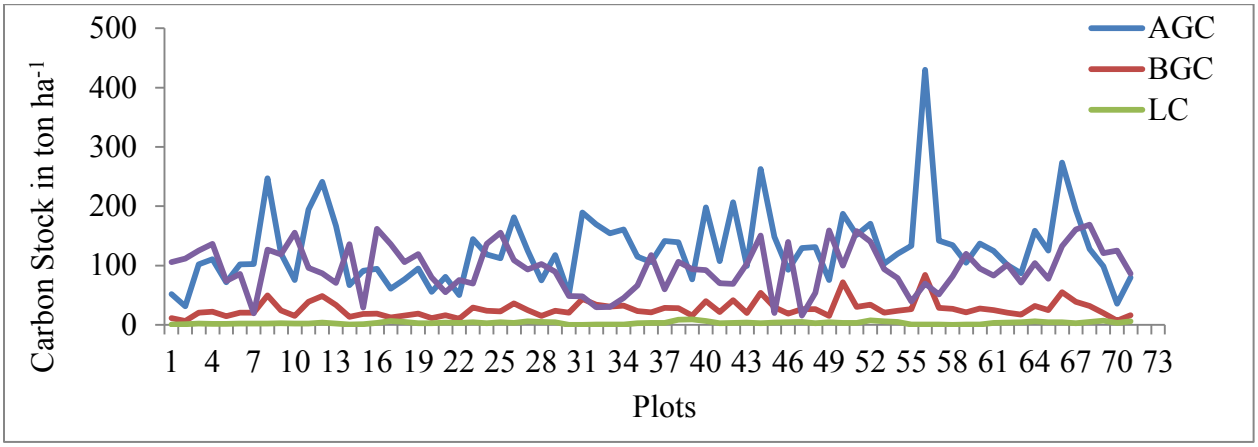

Figure 13: Carbon Stock in Different Carbon Pools vs. Plots

4.1.6 Estimation of Total Carbon Stocks in the Study Site

The total carbon stock of the study area (aboveground carbon, belowground carbon, litter carbon and soil organic carbon) for all seventy one sample plots of the study area was found ranging between 224.89 ton ha^{-1} to 1612.28 ton ha^{-1} with a mean carbon stock values of 564.96 ±27.05ton ha^{-1} in all carbon pool of the study site (Appendix 6). Graphically, it is represented as follows in Figure 15:

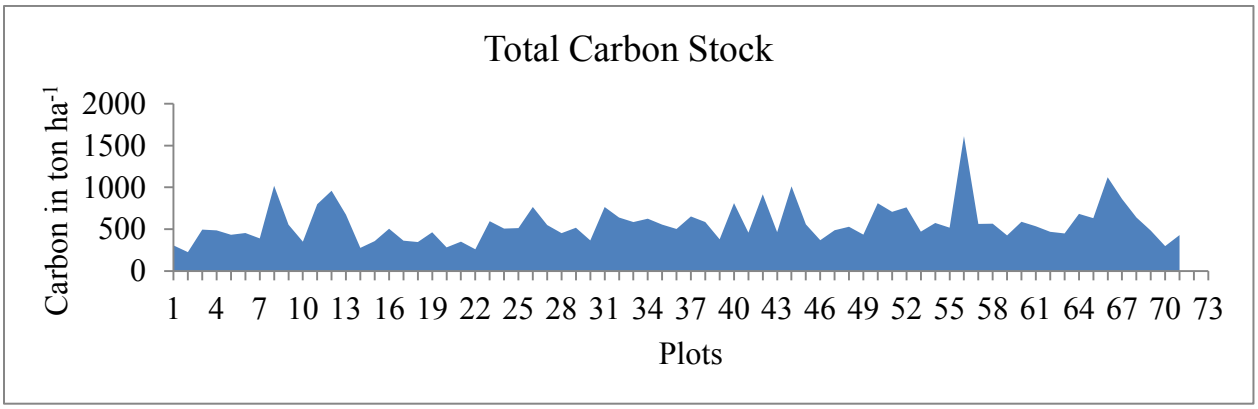

Figure 14: Total Carbon Stocks vs. Plots

Table 3**:** Summary of mean carbon stock of AGC, BGC, LB, LC and SOC of the study site

	AGC	BGC	LC	SOC	Total Carbon Stock
Mean	128.60±7.53	26.52±1.62	3.12±0.25	94.96±4.61	564.98±27.05

4.1.7 Factors Affecting the Carbon Stocks of the Study Site

There are different factors that affect the amount and concentration of organic carbon in forests. Among the many factors, altitude, slope and aspect have a pronounced effect on organic carbon concentration. Each of them is discussed as follow:

4.1.7.1 Altitudinal Variation and Carbon Stocks

According to the result shown on (Table 4) the upper altitude range (2241-2268m a.s.l) is high in aboveground carbon stock while the lower (2183-2212m a.s.l) and the middle (2213-2240m a.s.l) parts of altitude have low to moderate carbon stock in aboveground biomass. 118.70±0.58, 126.94±0.41 and 137.44±0.41 ton ha^{-1} carbon stocks were recorded at the lower, middle and upper altitude respectively in aboveground biomass. Similar trend was shown in belowground biomass in which 24.17±0.58 ton ha^{-1}, 26.46±0.58 ton ha^{-1} and 28.14±0.48 ton ha^{-1} carbon stocks were recorded in the lower, middle and upper altitude respectively with highest value found at the upper part of altitudinal range followed by the middle and lower altitudinal ranges. The ANOVA analysis at 95% level of confidence did not indicate significance with (F=0.36, P=0.79) in AGC and (F=0.31, P=0.82) in BGC stocks. However, in the case of litter carbon stock and SOC, the trend changed. There was a significance difference at α=0.05 (F=5.63, P=0.02) in litter carbon stock and (F=9.72, P=0.00) SOC stocks (Appendix 8). The litter carbon stock was higher

(5.58±0.53ton ha^{-1}) in the lower parts of altitude and low in the upper altitude (1.62±0.34) and moderate in the middle altitude(3.05±0.19). The results were shown in the Table 4.

The carbon stock in the soil pool was higher in middle altitude (111.87±5.44 ton ha^{-1}) and lower in the upper altitude (65.32±8.29 ton ha^{-1}) with the lower altitude carbon stocks slightly similar with the middle altitudinal class (103.23±6.42 ton ha^{-1}). In the similar trends the result showed that at 95% level of significance SOC with (F=9.72, P=0.00) indicated there is significant variation in soil carbon along different altitudes which could be due to difference in the forest cover and types of plant species. 103.23±6.42 ton ha^{-1}, 111.87±5.44 ton ha^{-1} and 65.32±8.29 ton ha^{-1} of carbon stocks were recorded in the lower, middle and upper altitude respectively in the soil pool shown in Table 4.

Table 4: Variation of Carbon Stocks along Altitudinal Range

Altitude range	AGC	BGC	LC	SOC	Total Carbon Stock
2183-2212	118.70±0.58	24.17±0.58	5.58±0.53	103.23±6.42	551.16±0.58
2213-2240	126.94±0.41	26.46±0.58	3.05±0.19	111.87±5.44	579.82±0.41
2241-2268	137.44±0.41	28.14±0.48	1.62±.34	65.32±8.29	552.66±0.48
Mean	128.60±0.29	26.52±0.29	3.12±0.25	94.96±4.61	564.96±0.29

4.1.7.2 Carbon Stocks of Different Pools and Slope Gradient

Slope gradient was another factor that affects concentration of carbon stock in different pools in the studied forest. Aboveground carbon and belowground carbon stocks were found to be low in hilly areas of the forest. The carbon stock of the middle slope gradient was higher in both aboveground carbon and belowground carbon stocks and lower in the lower and higher slope. In the two carbon pools (AGC and BGC) the highest carbon stock is the middle slope range (>20-40%) followed by the lower (0-20%) and the higher in similar trend. However, in LC and SOC

the highest carbon stock is in the lower slope range followed by the middle and the higher slope ranges (Table 5). The ANOVA statistical analysis at 95% level of significance indicate that SOC show variation along slope gradient with (F=42.08, P=0.00). On the other hand, the analysis did not indicate significant variation in AGC, BGC and LC with (F=0.69, P=0.50 AGC, F=0.59, P=0.56 BGC and F=0.61, P=0.55 LC) shown in Table 7.

Table 5: Carbon stocks in different pools with respect to slope gradient

Slope Group(%)	AGC (ton ha^{-1})	BGC (ton ha^{-1})	LC (ton ha^{-1})	SOC (ton ha^{-1})	Total Carbon Stock (ton ha^{-1})
0-20	131.87±10.88	26.68±2.19	3.61±0.43	129.189±4.36	585.02±40.97
>20-40	132.50±12.63	27.69±2.86	3.00±0.35	73.913±5.43	568.65±44.06
>40	106.62±15.46	22.314±2.85	2.08±0.45	63.068±5.29	495.02±56.31
Mean	128.60±7.53	26.52±1.62	3.12±0.25	94.96±4.61	564.97±27.05

4.1.7.3 Carbon Stock and Aspect

Aspect was another parameter that affects the carbon stocks of different pools through which the direction of the plots were found to determine in which direction the highest and lowest carbon stock is found in the study forest. Based on the result that obtained, the mean AGC stock was lowest in SE (98.89±8.66 ton ha^{-1}) and highest in W (158.22±33 ton ha^{-1}), with mean 128.60±33.00 ton ha^{-1}). Similar trend was observed for carbon stocks in belowground carbon pool with the lowest value is recorded in SE (19.78±1.73 ton ha^{-1}) and highest value in W (31.503±6.46 ton ha^{-1}) in W direction and the least value (19.77±1.73 ton ha^{-1}) in SE aspect. On the other hand, the highest carbon stock in litter biomass was recorded in the N aspect (4.00±0.86 ton ha^{-1}) and the lowest value of litter carbon stock was recorded in the E aspect (1.97±0.38 ton ha^{-1}). The recorded result of soil organic carbon stocks indicate the minimum

value in the NW aspect (81.80±12.69 ton ha^{-1}) and maximum value in SE aspect (142.81±5.76 ton ha^{-1}). In general, the highest carbon stock was recorded in the W aspect (664.89±117.82 ton ha^{-1}) and the minimum carbon stock recorded was in the SE aspect (467.84± 29.93 ton ha^{-1}) (Table 6). Finally, the carbon stock value of each aspect from lowest to the highest was shown as follows:

SE(467.84±29.93) < E(476.39±84.94) < N(510.50±50.69) < NE(511.63±99.22) < SW(543.50±46.87) < S(637.55±27.38) < NW(647.37±64.84) < W(664.89±117.82).

Table 6**:** Mean carbon stocks different pools and aspects

Aspect	No of Plots	AGC	BGC	LC	SOC	Total Carbon Stock
E	9	111.32±22.17	22.26±4.44	1.97±0.38	84.86±14.28	476.39±84.94
N	10	111.18±15.42	23.79±3.17	4.00±0.86	86.25±7.48	510.50±50.69
NE	7	113.82±28.06	22.92±5.56	2.29±0.44	83.24±6.14	511.63±99.22
NW	9	150.62±17.73	30.25±3.64	3.80±0.60	81.80±12.69	647.37±64.84
S	10	148.86±7.65	29.77±1.53	3.24±0.90	86.24±14.55	637.55±27.38
SE	7	98.89±8.66	19.78±1.73	3.24±0.62	142.81±5.76	467.84±29.93
SW	8	117.92±12.34	28.67±6.41	2.99±0.62	112.21±12.42	543.50±46.87
W	11	158.22±33	31.50±6.46	3.15±0.67	94.31±13.52	664.89±117.82
Mean	71	**128.60±7.53**	**26.52±1.62**	**3.12±0.25**	**94.96±4.61**	**564.96±27.05**

Table 7: One-way ANOVA results of the three factors indicated above were shown below to show a significance difference in the carbon stocks values of different pools

Environmental factors	**Carbon pools**	**F-value**	**P-value**
Altitude	AGC	0.36	0.78
	BGC	0.31	0.82
	LC	5.63	**0.02**
	SOC	9.72	**0.00**
Slope	AGC	0.69	0.50
	BGC	0.59	0.56
	LC	0.61	0.55
	SOC	42.08	**0.00**
Aspect	AGC	1.17	0.33
	BGC	0.91	0.51
	LC	1.19	0.32
	SOC	2.56	**0.02**

- Bold values are significant at α=0.05 (95%)

4.2 DISCUSSION

4.2.1 Frequency of Tree Species

Croton macrostachyus had the highest percentage frequency (8.1%) and *Pouteria adolfi-friederici* (0.2%), *Rhamnus prinoides* (0.4%), *Rhus glutinosa* (0.4%), *Rytigynia neglecta* (0.4%), *Gnidia glauca* (0.4%), *Dombeya schimperiana* (0.4%), and *Allophylus abyssinicus* (0.4%) had the lowest percentage frequencies in the study forest. According to Lambrecht (1989), frequency is the indication of homogeneity and heterogeneity of vegetation. High value in higher frequency and low value in lower frequency classes reveal constant or similar composition. On the other hand, high percentage of number of species in the lower frequency classes and low percentage of number of species in the higher frequency classes indicates a high degree of floristic heterogeneity. The species that appear in lower frequency classes have irregular occurrence whereas those appearing in higher classes have regular horizontal classes (Lambrecht, 1989). The present study revealed that there is high percentage number of species in higher frequency classes and low percentage number of species in lower frequency classes. This indicates that the forest under the study has high degree of floristic homogeneity and low heterogeneity.

4.2.2 DBH and Height Arrangement of Trees and their Contribution in the Studied Forest

Trees species with the highest average DBH in the study forest were like *Albizia schimperiana* (40.91cm), *Flacourtia indica* (39.54cm), *Erythrina brucei* (35cm), *Schefflera volkensii* (34.5cm),*Podocarpus falcatus* (32.94cm), *Nuxia congesta* (30.59cm), *Juniperus procera* (30.84cm), *Cordia africana* (28.82cm), *Cassipourea malosana* (27.97cm), *Pouteria adolfi-friederici* (27.67cm), *Croton macrostachyus* (27.61cm) and *Syzygium guineense* (25.95cm). Tree with the lowest average DBH in were: *Gnidia glauca* (5.18), *Justicia schimperiana* (5.20), *Argomuellera macrophylla* (5.27cm), *Brucea antidysenterica* (5.35cm), *Bersama abyssinica*

(5.75cm), *Carissa spinarum* (6.08cm), *Grewia ferruginea* (6.21cm), *Rhamnus prinoides* (6.39cm), *Aspiliamoss ambicensis* (6.41cm), *Urera hypselodendron* (6.61cm) and *Embelia schimperi* (6.84cm).

Tree species with highest average height in the study forest were: *Albizia schimperiana* (26.41m), *Podocarpus falcatus* (23.35m), *Erythrina brucei* (17.77m) and *Ficus sur* (15.65m). On the other hand, Shrubby species with lowest average height were: *Clausena anista* (1.63m), *Justicia schimperiana* (2.03m), *Btucea antidysenterica* (2.30m), *Argomuellera macrophylla* (2.19m) and *Gnidia glauca* (2.89m).

According to Abiyou Tilahun (2010), information on forest structure is very important to conserve healthy regeneration of the species underutilization. Analysis based on relative density distribution by DBH and height classes carried out for tree species of the forest site showed different patterns. Different patterns of species population structure can indicate variation in population dynamics.

Based on the result organized from the five DBH classes: 0-10cm, >10cm-20cm, >20cm-30cm, >30cm-40cm and >40cm (Appendix 1) that showed the majority of trees were distributed in the second DBH class (>10-20cm) followed by the third DBH class (>20cm-30cm) and the first DBH class (0-10cm). The lowest DBH distribution were recorded in the fifth DBH class (>40cm) and followed by the fourth DBH class (>30cm-40cm). This showed that the study forest was occupied by young and regenerating plants. Lower DBH distribution in the fourth and fifth DBH classes indicate older trees with high DBH might be used by the nearby community for

different consumption like timber production. Like that of DBH, the height distribution of plants also classified into five classes (0-10m), (>10m-20m), (>20m-30m), (>30m-40m) and (>40m). The majority of plants were distributed in the first height class (0-10m) followed by the second height class (>10m-20m) and third height classes (>20m-30m). The shortest plants were recorded in the last two classes; fourth height class (>30m-40m) and fifth height class (>40m). In general in the study forest as height trees increase distribution of trees decrease. The implication of the results of height distribution of the study forest correlate with the implication of the result of DBH distribution.

4.2.3 Storage of Biomass in Different Pools

Forest has a large potential for temporary and long term carbon storage. In the forest ecosystems, greater carbon is stored in a large, long-lived species and in species with dense wood. Similarly, the results of the present study showed the disproportionate contribution of species to the above ground carbon stock. Tree species with high DBH such as *Erythrina brucei, Podocarpus falcatus, Juniperus procera, Schefflera volkensii, Flacourtia indica, Nuxia congesta, Acacia abyssinica* and *Cordia africana* contributed for the large amounts of biomass and carbon stocks. On the other hand tree/shrub species with low DBH such as *Gnidia glauca, Dombeya schimperiana, Aspilia mossambicensis, Argomuellera macrophylla, Brucea antidysenterica, Rhamnus prinoides* and *Oncoba spinosa* had less contributions. This unequal contribution of species to carbon stock of the forest site could probably be due to the density, age and size difference among species. While comparing with other studies, the mean carbon stock in above and below ground biomass of Gendo Forest was similar with those reported from Menagasha Suba State Forest (Mesfin Sahile, 2011) and Selected Church Forests (Tulu Tola, 2011) (Table 8). The value is also comparable to those reported for the global aboveground carbon stock in

tropical dry and wet forests ranged between 13.5-122.85 ton ha^{-1} and 95-527.85 ton ha^{-1}, respectively (Murphy and Lugo, 1986). Tree species in the forest area were dense and has protection due to its reserved status. The higher carbon stock in above ground biomass in the study site could be related to the higher tree density in forest area and presence of protection from human interference. Preventing deforestation from conifer dominated stands would have the largest per unit area impact on reducing carbon emissions from deforestation. Like aboveground pool the mean carbon stock in belowground pool is comparable with Menagasha Suba State Forest (Mesfin Sahile, 2011) and Selected Church Forests (Tulu Tola, 2011) (Table 8). However, in litter pool of the present study was less compared to values recorded for Selected Church Forests (Tulu Tola, 2011), Menagasha Suba State Forest (Mesfin Sahile, 2011) and Biheretsige and Central Closed Public Park (Marshet Tefera and Teshome Soromessa, 2015), but greater than values reported from Biheretsige and Central Closed Public Park (Marshet Tefera and Teshome Soromessa, 2015) and Arba Minch Water Forest (Belay Melese, 2014) and comparable with Egdu Forest (Adugna Feyisa, 2012) (Table 8). The amount of litter fall and its carbon stock of the forest can be influenced by the forest vegetation (species, age and density) and climate (Fisher and Binkly, 2000). Similarly, the tree stands in the forest area were relatively still young and this could result in low amount of litter fall. In addition, since the study area is located in tropical areas, the rate of decomposition is relatively fast (Fisher and Binkly, 2000). Thus, the lowest carbon stock in litter pool could probably be due to the high decomposition rate and less amount of litter fall. The mean value of SOC is lower than most of the studied places shown in Table 8. This could be because of the reason that the soil sample of the present study was collected from 10cm soil depth.

Table 8: Comparison of carbon stock (in ton ha^{-1}) of the present result with other studies

Study Place	AGC	BGC	LC	SOC
Selected Church Forest (Tulu Tola, 2011)	122.85	25.97	4.95	135.94
Menagesha Suba State Forest (Mesfin Sahile,2011	133	26.99	5.26	121.28
Egdu Forest (Adugna Feyisa,2012)	278.08	55.62	3.47	277.56
Tara Gedam Forest (Mohammed Gedefaw, 2013)	306.36	61.52	0.90	274.32
Arba Minch Water Forest (Belay Melese Wolde 2014)	414.7	83.48	1.28	83.80
Biheretsige and Central Closed Public Park (Marshet Tefera and Teshome Soromessa,2015)	25.4	5.1	5.17	113.55
Gendo Forest (the present study)	**128.60**	**26.52**	**3.12**	**94.96**

4.2.4 Influence of Environmental Variables on Carbon Stock

Although it has been reported in many studies in other parts of the world that the result of above and belowground tree biomass and its carbon stock decline with an increase in altitude (Luo *et al*., 2005, Leuschner *et al.*, 2007; Moser *et al.*, 2007; Zhu *et al.*, 2011). However, in the present study, due to the presence of trees that had high DBH in the middle and upper altitude, it was observed that the mean aboveground and belowground biomass carbon had showed relatively an increasing trend with increasing altitude. The altitudinal difference in the present study is very close together and insignificant. There was a significant variation in litter and soil organic carbon along altitudinal gradient, but there was no significant variation in aboveground and belowground carbon stocks along altitudinal gradient. Similar to the present result there were similar results also reported in tropical Atlantic moist forest in Brazil by Alves *et al.* (2010), in central Amazonian forest (de Castilho *et al.,* 2006), in moist temperate valley slopes of the Garhwal Himalaya of India (Gairola *et al.,* 2011) and in Mt Changbai of china (Zhu et *al.*, 2011). The presence of species characterized by large individuals occurring on higher altitude could have an effect on AGB and carbon stock, because few large individuals can account for large

proportion of the plots aboveground and belowground carbon (Brown and Lugo,1992). This could probably be the case in the present study area, where bigger trees with maximum DBH were more frequent in higher altitude.

The carbon stock of the study forest was highest at the middle altitudinal range followed by the lower and upper altitude range respectively. This is due to the absence of dense and biggest trees at both ends of the forest site and present in the middle part of the forest due to favorable conditions for tree growth.

The total carbon stock of the study forest was decreased as the degree of slope gradient increased. This was due to the inclined arrangement of the study site and the density of the trees followed this pattern. Aboveground carbon and belowground carbon density was higher in the middle slope range followed by the lower slope range and lower in the upper slope range. SOC and LC density was higher in the lower slope range and show decreasing trend from the lower to the higher slope range which could be because of erosion that moved litter down the hill.

In addition, the highest total carbon stock was found in the western aspect and the least in the southeastern part of the forest. The study forest side to west aspect capture light energy which is important for photosynthesis for longer time and store more carbon than the other aspects. Aboveground and belowground carbon density was higher in west aspect which is similar with the total carbon density. Soil organic carbon density was higher in southwest aspect and litter carbon density was higher in north aspect. SW and N aspects were away from the direction of solar radiation and the temperature is relatively cool, so decomposition is slower in those aspects.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study conducted in Gendo (Gura Tirigni) forest showed that the forest contains many diversified plant species. The forest is habitat for many animals. A total of fifty four different species of plants were collected, of which *Embelia schimperi, Carissa spinarum, Croton macrostachyus, Vepirs dainellii, Urera hypselodendron, Teclea nobilis* and *Grewia ferruginea* were the most frequent species. On the other hand, *Allophylus abyssinicus, Rhamnus prinoides, Rhus glutinosa* and *Pouteria adolfi-friederici* were the least dominant species. Based on the structural composition of DBH and height class distribution of Gendo (Gura Tirigni) forest, generally similar trends observed in both classes. The densities of tree species decreases as the DBH and height classes increases in the forest. This implies that, the predominance of small sized tree species in the lower classes than in the upper classes. The analysis of these two parameters in the study forest indicated that higher percentage number of tree species in the lower than in the higher frequency classes. Average carbon stocks of the different carbon pools of this study was comparatively similar with most researches done in Ethiopia in carbon sequestration potentials of forests. Like many others forests in Ethiopia the study forest carbon stocks indicates its potentials in the mitigation of climate change. The one way ANOVA result at 95% confidence interval show significant variation in litter carbon long altitudinal gradient and soil organic carbon along altitude, slope and aspect gradients. Both aboveground carbon and belowground carbon stocks increase up the hill from the lower altitude to the higher altitude with relatively very close values, which indicates the presence of plants with higher DBH in the upper altitude. On the contrary, the litter and soil carbon stocks were higher in the lower altitudinal class, this might be because of erosion and wind effect which move litter and soil down the hill.

On the other hand, the litter carbon stock was higher in the middle slope classes and low in the higher slope classes and the carbon stocks in the soil pool was higher in lower slope classes and lower in the higher slope classes with moderate carbon stocks in the middle slope classes. The mean AGC and BGC stocks were lowest in southeastern (98.89±8.66 & 19.78±1.73 ton ha^{-1}) and highest in western (158.22±33 & 31.50±6.46 ton ha^{-1}) part of the forest respectively. On the other hand, the highest carbon stocks in litter biomass were recorded in the northern (4.00±0.86 ton ha^{-1}) and the lowest litter carbon stock was recorded in eastern (1.97±0.38 ton ha^{-1}) aspect of the forest. The carbon stocks in soil were also recorded the minimum value in northwestern (81.80±12.69 ton ha^{-1}) and the maximum value in the southwestern (112.21±12.42 ton ha^{-1}) part of the forest. In general, the carbon stocks in the different pools were arranged in this order:

W (664.89±117.82 ton ha^{-1}) > NW (647.37±64.84 ton ha^{-1}) > S (637.55±27.38 ton ha^{-1}) > SW (543.50±46.87 ton ha^{-1}) >NE (511.63±99.22 ton ha^{-1}) > N (510.50±50.69 ton ha^{-1}) > E (476.39±84.94 ton ha^{-1}) > SE (467.84±29.93 ton ha^{-1}) from highest to lowest.

5.2 RECOMMENDATIONS

The following recommendations were drawn from the findings of the present study:

- The study conducted in this forest is limited to carbon sequestration potentials of the forest, thus further studies on the land use land cover change, sustainable managements of forests and rehabilitation and conservation of degraded lands are recommended.
- Forest carbon related awareness creation for local people and promotion of the local knowledge can be regarded as a possible way for sustainable forest management. This will enhance the capacity of the existing forest for climate change mitigation and other provision from the forest.
- This study could provide as useful information for further documentation on carbon stock capacity of the different carbon pools of moist montane forest and the influence of environmental factors on forest carbon stock.

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7. APPENDICES

7.1 APPENDIX 1**:** Species list collected from Gendo (Gurra Tirigni) forest with their call number, scientific name, vernacular name, family, number of trees (shrubs), average DBH, and average height

Scientific name	Vernacular name (Afaan Oromoo)	Family	Species Code	No of Trees	Average DBH (cm)	Average Height (m)	No of plots that species occurs	% frequency of species
Acacia abyssinica Hochst ex.Benth.	Laaftoo	Fabaceae	C15	82	27.33	10.65	11	2.4
Acacia etbaica Schweinf.	Doddota	Fabaceae	C46	111	12.04	5.69	8	1.8
Albizia schimperiana Oliv	Mukarbaa	Fabaceae	C11	55	40.91	26.41	18	3.9
Allophylus abyssinicus (Hochest.) Radlkofer	Sarara/Malqaqqoo	Sapindaceae	C50	4	15.69	7.75	2	0.4
Apodytes dimidiata E.Mey. ex Am	Dongii	Icacinaceae	C34	147	28.78	7.40	15	3.3
Argomuellera macrophylla Pax	Timboo Jaldeessaa	Euporbiaceae	C27	32	5.27	2.19	2	0.4
Aspilia mossambicensis (Oliv) Wild	Daalattii	Asteraceae	C54	154	6.41	3.92	2	0.4
Bersama abyssinica Fresen	Lolchiisaa	Melianthaceae	C55	91	5.7	3.07	4	0.9
Brucea antidysenterica J.f.Mill	Qomaanyoo	Simarobaceae	C6	16	5.37	2.30	2	0.4
Buddleja polystachya Fresen.	Hanfaaree	Loganiaceae	C17	66	16.57	6.44	7	1.5
Carissa spinarum L.	Agamsaa	Apocynaceae	C24	331	6.08	4.02	10	2.2
Cassipourea malosana (Baker) Alston	Hudduufardaa	Rhizophoraceae	C30	32	27.97	13.88	30	2.2
Caulpurnia aurea (Ait.) Benth.	Ceekaa	Fabaceae	C32	166	7.55	5.22	9	2.0
Celtis africana Burm.f.	Qayyii (Cayyii)	Ulmaceae	C43	60	21.02	12.22	15	3.3
Clausena anisata (Willd.) Benth.	Hulumaayii	Rutaceae	C38	56	8.88	1.63	5	1.1
Cordia africana Lam.	Waddeessa	Boraginaceae	C19	86	28.82	8.76	15	3.3
Croton macrostachyus Del	Makkaanniisa	Euporbiaceae	C1	329	27.61	10.95	37	8.1
Dombeya schimperiana A.Rich.	Daannisa Diimaa	Sterculaceae	C52	21	17.77	9.86	2	0.4
Dombeya torrida (J.F.	Daannisa Adii	Sterculaceae	C49	18	19.43	9.84	4	0.9

Scientific name	Vernacular name (Afaan Oromoo)	Family	Species Code	No of Trees	Average DBH (cm)	Average Height (m)	No of plots that species occurs	% frequency of species
Gmel) P. Bamps								
Dracaena steudneri Engl	Warqee Jaldeessaa	Dracaenace	C47	21	19.49	7.52	5	1.1
Ekebergia capensis Sparm	Somboo	Meliaceae	C31	61	23.74	11.63	8	1.8
Embelia schimperi Vartke	Hanquu	Myrsinaceae	C3	378	6.84	4.54	11	2.4
Erythrina brucei Schweinf	Waleensuu	Fabaceae	C23	85	35.00	17.77	20	4.4
Ficus sur Forrsk.	Harbuu	Moraceae	C5	127	24.94	15.65	16	3.5
Flacourtia indica (Burem.F) Merril	Akuukkuu	Flacoutiacea e	C28	15	39.54	6.39	9	2.0
Gnidia glauca (Fresen)Gilg	Diddiksaa/ Qaqaroo	Thymelacea e	C37	20	5.18	2.89	2	0.4
Grevillea robusta A Cunn ex.Br.		Proteaceae	C7	95	15.87	9.40	3	0.7
Grewia ferruginea Hochst ex A. Rich.	Dhoqonuu	Tiliacea	C16	195	6.21	4.71	10	2.2
Hypericum quartinianum A..Rich.	Ulee Foonii	Guttiferacea e	C41	111	8.48	5.57	3	0.7
Juniperus procera Hochst ex Endl.	Gaattiraa	Cuppressace a	C13	27	30.84	14.02	14	3.1
Justicia schimperiana (Hochst ex Nees) T.Anders.	Dhummuugaa	Acanthaceae	C22	104	5.20	2.03	5	1.1
Lepidotrichilia volkensii (Gurke) Leroy	Dhama'ee	Meliaceae	C25	86	7.58	3.73	5	1.1
Macaranga capensis (Bail.) Sim.	Ho'aa	Euporbiacea e	C14	40	18.98	9.17	13	2.9
Maesa lanceolata Forssk.	Abbayyii	Myrsinaceae	C4	76	13.44	5.66	10	2.2
Maytenus gracilipes (Welw ex Oliv.)	Qacamaa/ Kombolcha	Celastraceae	C10	58	7.66	3.64	5	1.1
Maytenus addat (Loes) Sebsebe	Kombolcha	Celastraceae	C48	67	13.29	5.20	5	1.1
Millettia ferruginea (Hochst.) Baker	Sootalloo	Fabaceae	C45	57	24.68	12.53	10	2.2
Nuxia congesta R.Br.ex Fresen.	Naffuroo	Loganiaceae	C40	23	30.59	6.29	5	1.1
Oncoba spinosa Forssk.	Harsammeessa a	Flacoutiacea e	C44	47	7.82	3.81	3	0.7
Pittosporum viridiflorum Sims	Soolee/Qasam mee	Pittosporace ae	C21	23	15.16	8.59	5	1.1

Scientific name	Vernacular name (Afaan Oromoo)	Family	Species Code	No of Trees	Average DBH (cm)	Average Height (m)	No of plots that species occurs	% frequency of species
Podocarpus falcatus (Thumb.) R.Br.ex Mirb	Birbirsa	Podocarpaceae	C12	54	32.94	23.35	10	2.2
Pouteria adolfi-friederici (Engl.) Baehni	Qararoo	Sapotaceae	C26	13	27.65	9.35	1	0.2
Rhamnus prinoides L'Herit.	Geeshoo	Rhamnaceae	C8	8	6.39	2.90	2	0.4
Rhus glutinosa A.Rich.	Xaxessaa	Anacardaceae	C53	12	16.39	7.73	2	0.4
Rytigynia neglecta (Hiern) Robyns	Mixoo Seeraa	Rubiaceae	C36	48	8.48	3.22	2	0.4
*Schefflera volkensii (*Engel) Harms	Gatamaa	Araliaceae	C42	36	34.50	13.00	13	2.9
Solanecio gigas (Vatke) C.Jeffrey	Jirma-Jaldeessaa	Asteraceae	C39	65	19.43	3.42	3	0.7
Syzygium guineense (Wild.) DC.	Baddeessaa	Myrtaceae	C35	67	25.95	10.86	12	2.6
Teclea nobilis Del	Hadheessa baala qal'aa	Rutaceae	C2	196	17.35	9.12	19	4.2
Urera hypselodendron (A.Rich.) Wedd	Lanqessaa	Urticaceae	C29	213	6.61	6.88	12	2.6
Vepirs dainellii (Pichi-Serm.) Kokwaro	Hadheessa baala bal'aa	Rutaceae	C20	267	19.99	8.73	18	3.9
Vernonia adoensis Sch. Bip.ex Walp.	Ulee harree	Asteraceae	C33	35	9.53	4.29	2	0.7
Vernonia amygdalina Del.	Ebicha	Asteraceae	C18	93	15.60	6.58	8	1.8
Vernonia rueppellii Sch. Bip, ex.Walp.	Reejjii	Asteraceae	C9	154	11.73	5.69	7	1.5

Where the following applies to all appendices:

C1= *Croton macrostachyus* Del

C2= *Teclea nobilis* Del

C3= *Embelia schimperi* Vartke

C4= *Maesa lanceolata* Forssk.

C5= *Ficus sur* Forrsk.

C6= *Brucea antidysenterica* J.f.Mill

C7= *Grevillea robusta* A Cunn ex.Br.

C29= *Urera hypselodendron* (A.Rich.) Wedd

C30= *Cassipourea malosana* (Baker) Alston

C31= *Ekebergia capensis* Sparm

C32= *Caulpurnia aurea* (Ait.) Benth.

C33= *Vernonia adoensis* Sch. Bip.ex Walp.

C34= *Apodytes dimidiata* E.Mey. ex Am

C35 =*Syzygium guineense* (Wild.) DC.

C8= *Rhamnus prinoides* L'Herit.

C9= *Vernonia rueppellii* Sch. Bip, ex.Walp.

C10= *Maytenus gracilipes* (Welw ex Oliv.)

C11= *Albizia schimperiana* Oliv

C12=*Podocarpus falcatus* (Thumb.) R.Br.ex Mirb

C13= *Juniperus procera* Hochst ex Endl.

C14= *Macaranga capensis* (Bail.) Sim.

C15= *Acacia abyssinica* Hochst ex.Benth

C16= *Grewia ferruginea* Hochst ex A. Rich.

C17= *Buddleja polystachya* Fresen.

C18= *Vernonia amygdalina* Del.

C19= *Cordia africana* Lam.

C20= *Vepirs dainellii* (Pichi-Serm.) Kokwaro

C21= *Pittosporum viridiflorum* Sims

C22=*Justicia schimperiana* T.Anders.

C23= *Erythrina brucei* Schweinf

C24= *Carissa spinarum* L.

C25= *Lepidotrichilia volkensii* (Gurke) Leroy

C26= *Pouteria adolfi-friederici* (Engl.) Baehni

C27= *Argomuellera macrophylla* Pax

C28= *Flacourtia indica* (Burem.F) Merril

C36= *Rytigynia neglecta* (Hiern) Robyns

C37= *Gnidia glauca* (Fresen)Gilg

C38= *Clausena anisata* (Willd.) Benth.

C39= *Solanecio gigas* (Vatke) C.Jeffrey

C40= *Nuxia congesta* R.Br.ex Fresen.

C41= *Hypericum quartinianum* A..Rich.

C42= *Schefflera volkensii (*Engel) Harms

C43= *Celtis africana* Burm.f.

C44= *Oncoba spinosa* Forssk.

C45= *Millettia ferruginea* (Hochst.) Baker

C46= *Acacia etbaica* Schweinf

C47= *Dracaena steudneri* Engl

C48= *Maytenus addat* (Loes) Sebsebe

C49= *Dombeya torrida* (J.F. Gmel) P. Bamps

C50=*Allophylus abyssinicus* Radlkofer

C52= *Dombeya schimperiana* A.Rich.

C53= *Rhus glutinosa* A.Rich.

C54= *Aspilia mossambicensis* (Oliv) Wild

C55= *Bersama abyssinica* Fresen

7.2 APPENDIX 2**:** Number of transect lines and their length, number of plots, altitude, slope and aspect of plots

Transect	Length (m)	Plots			Altitude (m) a.s.l	Slope %	Aspect
		Range	Plot Total	Number			
				1	2213	20	NE
				2	2230	25	E
				3	2236	15	E
1	655	1 to 4	4	4	2229	10	SE
				5	2205	42	NE
				6	2227	45	NE
				7	2244	30	E
				8	2238	20	E
				9	2226	15	SE
2	812	5 to 10	6	10	2219	10	SE
				11	2194	15	NE
				12	2213	30	NE
				13	2230	25	E
				14	2248	20	E
				15	2241	25	E
				16	2234	15	SE
3	985	11 to 17	7	17	2217	10	SE
				18	2187	20	N
				19	2229	35	N
				20	2247	41	NE
				21	2251	44	NE
				22	2255	36	E
				23	2246	25	E
				24	2239	20	SE
				25	2228	15	SE
4	1090	18 to 26	9	26	2216	15	S
				27	2183	10	N
				28	2196	25	N
				29	2225	30	N
				30	2248	44	N
				31	2256	35	N
				32	2268	27	S
				33	2263	41	S
				34	2249	29	S
				35	2237	45	S
				36	2220	30	S
				37	2216	25	S
5	1535	27 to 38	12	38	2205	5	S
				39	2185	22	N
				40	2209	27	N

Transect	Length (m)	Plots			Altitude (m) a.s.l	Slope %	Aspect
		Range	Plot Total	Number			
				41	2226	35	N
				42	2230	45	NW
				43	2237	25	NW
				44	2244	20	NW
				45	2259	25	NW
				46	2263	20	W
				47	2254	25	W
				48	2247	25	W
				49	2231	20	SW
				50	2227	35	SW
				51	2212	12	S
6	1860	39 to 52	14	52	2201	5	S
				53	2191	20	NW
				54	2232	25	NW
				55	2240	45	NW
				56	2256	30	W
				57	2265	42	W
				58	2258	25	W
				59	2251	15	SW
				60	2242	20	SW
				61	2239	25	SW
				62	2227	25	SW
7	1250	53 to 63	11	63	2207	43	SW
				64	2197	20	NW
				65	2223	40	NW
				66	2236	20	W
				67	2221	15	W
8	760	64 to 68	5	68	2205	5	SW
				69	2197	20	W
				70	2226	35	W
9	495	69 to 71	3	71	2202	25	W

7.3 APPENDIX 3: Mean aboveground biomass, belowground biomass and carbon stocks of trees and shrubs collected from Gendo (Gurra Tirigni) forest by species type written in code.

Transect No	Plot No	Species code	No of Tr /Sh	Average DBH(cm)	Average height(m)	AGB (ton/ha)	BGB (ton/ha)	AGC (ton/ha)	AG CO_2 (ton/ha)	BGC (ton/ha)	BG CO_2 (ton/ha)
1	1	C1	12	18.25	6.65	106.70	21.34	53.35	195.79	10.67	39.16
1	1	C2	8	10.54	5.58	22.64	4.53	11.32	41.54	2.26	8.29
1	1	C3	61	14.16	7.21	52.35	10.47	26.18	96.08	5.24	19.23
1	1	C4	9	16.53	6.78	81.16	16.23	40.58	148.93	8.12	29.78
1	1	C5	4	27.32	10.36	305.87	61.17	125.94	561.27	30.59	112.25
1	2	C7	35	21.32	8.07	161.98	32.39	80.99	297.23	16.20	59.46
1	2	C1	9	16.74	3.56	84.07	16.81	42.04	154.27	8.41	30.85
1	2	C8	4	7.15	2.66	10.48	2.09	5.24	19.23	1.05	3.84
1	2	C9	27	13.42	4.45	44.88	8.97	22.44	82.35	4.49	16.47
1	2	C6	9	5.32	2.24	10.20	2.04	5.1	18.72	1.02	3.74
1	3	C11	2	26.44	22.50	281.79	56.36	140.89	512.08	28.18	103.42
1	3	C7	46	12.25	10.54	34.52	6.90	17.26	63.34	3.45	12.67
1	3	C4	15	11.65	5.69	29.92	5.98	14.96	54.90	2.99	10.78
1	3	C12	2	30.33	26.76	423.61	84.72	211.81	777.32	42.36	155.46
1	3	C13	1	33.61	18.21	507.65	101.53	253.83	931.54	50.76	186.31
1	3	C6	7	5.42	2.36	10.10	2.02	5.05	18.53	1.01	3.71
1	3	C14	3	20.13	6.70	139.08	27.82	69.54	255.21	13.91	51.04
1	4	C15	2	40.85	13.56	804.45	160.89	402.23	1476.16	80.45	295.23
1	4	C7	14	14.03	9.58	50.93	10.19	25.46	93.45	5.09	18.69
1	4	C16	27	6.26	4.31	9.79	1.96	4.89	17.96	0.98	3.59
1	4	C17	9	22.61	6.28	188.91	37.78	94.45	346.65	18.89	69.33
1	4	C1	6	29.57	15.45	372.06	74.41	186.03	682.73	37.21	136.55
1	4	C10	11	9.04	3.25	15.39	3.08	7.69	28.22	1.54	5.65
1	4	C14	1	18.07	7.46	103.84	20.77	51.92	190.55	10.38	38.09
2	5	C2	12	19.66	8.51	130.55	26.11	65.27	239.54	13.06	47.93
2	5	C11	3	28.05	23.27	326.61	65.32	163.31	599.38	32.66	119.86
2	5	C3	38	6.14	3.25	9.78	1.96	4.89	17.95	0.98	3.59
2	5	C9	21	11.84	5.22	31.32	6.26	15.66	57.47	3.13	11.49
2	5	C18	7	13.05	6.85	41.41	8.28	20.71	75.99	4.14	15.19
2	5	C5	6	27.81	14.22	319.71	63.94	159.85	586.67	31.97	117.33
2	6	C2	16	13.03	7.24	41.22	8.24	20.61	75.64	4.12	15.13
2	6	C19	4	30.01	6.90	385.78	77.16	192.89	707.91	38.58	141.59
2	6	C1	9	34.16	10.67	527.77	105.55	263.88	968.44	52.77	193.67
2	6	C4	8	7.02	5.40	10.31	2.06	5.1618	18.94	1.03	7.78
2	6	C9	23	14.06	6.50	51.30	10.26	25.65	94.14	5.13	18.83
2	7	C20	17	19.79	6.71	132.88	26.58	66.44	243.83	13.29	48.77
2	7	C2	5	16.09	6.90	75.25	15.05	37.63	138.10	7.52	27.59
2	7	C19	3	37.11	8.64	642.51	128.50	321.25	1178.99	64.25	235.80
2	7	C3	54	5.42	4.20	10.10	2.02	5.05	18.53	1.01	3.71
2	7	C5	8	27.64	15.04	314.87	62.97	157.44	577.79	31.49	115.56
2	7	C21	2	14.04	7.94	51.09	10.22	25.54	93.73	5.11	18.75

Transect No	Plot No	Species code	No of Tr /Sh	Average DBH(cm)	Average height(m)	AGB (ton/ha)	BGB (ton/ha)	AGC (ton/ha)	AG CO_2 (ton/ha)	BGC (ton/ha)	BG CO_2 (ton/ha)
2	8	C16	30	6.42	6.00	9.84	1.97	4.92	18.06	0.98	3.61
2	8	C1	13	22.43	11.75	185.18	37.04	92.59	339.81	18.52	67.97
2	8	C12	3	57.06	31.23	1719.44	343.89	859.72	3155.17	171.94	631.04
2	8	C22	18	5.15	2.12	10.40	2.08	5.20	19.08	1.04	3.82
2	8	C23	1	44.06	16.05	958.15	191.63	479.08	1758.21	95.82	351.66
2	8	C17	6	16.77	6.35	84.49	16.90	42.08	154.43	8.45	31.01
2	9	C2	17	18.16	9.22	105.27	21.05	52.64	193.17	10.53	38.63
2	9	C19	6	27.23	8.41	303.36	60.67	151.68	556.67	30.34	111.33
2	9	C4	12	10.19	5.03	20.68	4.14	10.34	37.95	2.07	7.59
2	9	C9	33	13.09	6.29	41.77	8.35	20.88	76.63	4.1	15.33
2	9	C23	2	40.17	18.73	773.63	154.73	386.82	1419.63	77.36	283.93
2	9	C13	3	31.27	14.60	426.49	85.30	213.25	782.62	42.65	156.53
2	9	C21	1	7.05	6.24	10.35	2.07	5.18	19.01	1.04	3.82
2	10	C1	8	25.71	14.49	262.60	52.52	131.3	481.87	26.26	96.37
2	10	C2	6	20.78	12.60	151.35	30.27	75.68	277.74	15.14	55.56
2	10	C16	24	5.94	4.70	9.80	1.96	4.90	17.98	0.98	3.59
2	10	C24	11	6.85	4.21	10.13	2.03	5.07	18.6	1.02	3.74
2	10	C13	1	35.07	16.53	561.94	112.39	280.97	1031.16	56.19	206.22
2	10	C25	12	7.19	3.65	10.53	2.11	5.27	19.34	1.06	5.87
2	10	C17	5	14.22	7.05	52.99	10.60	26.49	97.22	5.30	19.45
3	11	C22	27	5.08	2.55	10.49	2.10	5.24	19.23	1.05	3.85
3	11	C26	13	27.65	9.35	315.16	63.03	157.58	578.32	31.51	115.65
3	11	C23	4	39.15	18.66	728.55	145.71	364.27	1336.87	72.85	267.36
3	11	C1	6	37.07	11.00	640.87	128.17	320.43	1175.98	64.08	235.17
3	11	C27	17	5.12	1.95	10.44	2.09	5.22	19.16	1.04	3.82
3	11	C28	1	43.14	6.12	912.71	182.54	456.35	1674.80	91.27	334.96
3	11	C14	2	18.06	13.70	103.69	20.74	51.84	190.25	10.37	38.06
3	12	C2	18	5.24	3.32	10.29	2.06	5.14	18.86	1.03	3.78
3	12	C9	29	7.65	5.18	11.32	2.26	5.66	20.77	1.13	4.15
3	12	C23	4	35.12	19.20	563.85	112.77	281.92	1034.66	56.38	206.91
3	12	C13	3	32.66	14.31	473.83	94.76	236.91	869.46	47.38	173.88
3	12	C1	2	58.04	13.70	1785.85	357.17	892.92	3277.02	178.58	655.39
3	12	C17	7	13.97	6.26	50.36	10.07	25.18	92.41	5.03	18.46
3	13	C16	15	6.02	4.30	9.79	1.96	4.89	17.95	0.98	3.59
3	13	C11	2	43.06	22.70	908.81	181.76	454.40	1667.65	90.88	333.53
3	13	C29	17	5.07	7.35	10.51	2.10	5.25	19.27	1.05	3.85
3	13	C23	5	38.19	17.69	687.38	137.48	343.69	1261.34	68.74	252.28
3	13	C30	3	29.25	15.24	362.24	72.45	181.12	664.71	36.22	132.93
3	13	C31	6	10.24	8.08	20.95	4.19	10.47	38.42	2.09	7.67
3	14	C2	9	23.56	11.79	210.15	42.03	105.07	385.61	21.01	77.11
3	14	C1	5	33.04	15.51	487.22	97.44	243.61	894.05	48.72	178.80
3	14	C32	17	8.91	5.72	14.90	2.98	7.45	27.34	1.49	5.47
3	14	C18	12	15.24	6.43	64.56	12.91	32.28	118.47	6.45	23.67

Transect No	Plot No	Species code	No of Tr /Sh	Average DBH(cm)	Average height(m)	AGB (ton/ha)	BGB (ton/ha)	AGC (ton/ha)	AG CO_2 (ton/ha)	BGC (ton/ha)	BG CO_2 (ton/ha)
3	14	C25	10	8.90	3.77	14.86	2.97	7.43	27.27	1.48	5.43
3	14	C10	8	6.07	2.18	9.78	1.96	4.89	17.95	0.98	3.59
3	15	C3	35	6.14	4.35	9.79	1.96	4.89	17.95	0.98	3.60
3	15	C1	6	19.78	9.32	132.70	26.54	66.35	243.50	13.27	48.70
3	15	C16	7	5.65	4.65	9.92	1.98	4.96	18.20	0.99	3.63
3	15	C23	5	34.50	21.20	540.41	108.08	270.20	991.63	54.04	198.33
3	15	C13	2	29.15	17.28	359.20	71.84	179.60	659.13	35.92	131.83
3	15	C33	18	12.81	5.86	39.25	7.85	19.62	72.00	3.92	14.39
3	16	C1	11	26.09	12.40	272.50	54.50	136.25	500.04	27.25	100.00
3	16	C34	28	31.42	7.59	431.48	86.30	215.74	791.77	43.15	158.36
3	16	C2	3	16.54	10.67	81.30	16.26	40.65	149.19	8.13	29.84
3	16	C35	4	27.06	12.18	298.65	59.73	149.32	548.00	29.86	109.59
3	16	C29	22	5.67	6.12	9.91	1.98	4.96	18.20	0.99	3.63
3	16	C17	13	12.71	6.72	38.38	7.68	19.19	70.43	3.84	14.09
3	17	C11	3	31.48	29.17	433.48	86.70	216.74	795.44	43.35	159.09
3	17	C24	9	6.02	3.73	9.78	1.96	4.89	17.95	0.98	3.60
3	17	C32	22	7.73	5.24	11.48	2.30	5.74	21.06	1.15	4.22
3	17	C1	6	29.38	10.79	366.21	73.24	183.10	671.99	36.62	134.39
3	17	C36	21	5.62	3.32	9.94	1.99	4.97	18.24	0.99	3.63
3	17	C10	4	8.09	5.10	12.33	2.47	6.16	22.61	1.23	4.51
3	17	C37	10	5.21	2.77	10.33	2.07	5.16	18.94	1.03	3.78
4	18	C35	3	27.73	11.62	317.43	63.49	158.71	582.47	31.74	116.49
4	18	C29	14	6.04	7.11	9.78	1.96	4.89	17.95	0.98	3.59
4	18	C13	2	30.45	13.65	399.76	79.95	199.88	733.56	39.97	146.69
4	18	C24	16	8.92	6.35	14.94	2.99	7.47	27.41	1.49	5.47
4	18	C4	7	16.71	6.44	83.65	16.73	41.82	153.48	8.36	30.68
4	18	C30	3	19.16	15.75	121.79	24.36	60.89	223.47	12.18	44.70
4	18	C14	4	19.33	11.16	124.31	24.86	62.15	228.10	12.43	45.62
4	19	C34	26	27.05	6.39	298.37	59.67	149.18	547.49	29.83	109.48
4	19	C3	42	5.52	4.70	10.02	2.00	5.01	18.39	1.00	3.68
4	19	C5	3	29.05	17.85	356.17	71.23	178.08	653.56	35.62	130.71
4	91	C16	11	5.73	3.15	9.88	1.98	4.94	18.13	0.99	3.63
4	19	C14	3	26.08	8.86	272.24	54.45	136.12	499.56	27.22	99.91
4	20	C32	20	6.64	5.57	9.95	1.99	4.97	18.26	0.99	3.65
4	20	C1	7	27.09	11.22	299.48	59.89	149.74	549.55	29.94	109.89
4	20	C35	3	22.79	8.17	319.14	63.83	159.57	585.62	31.91	117.12
4	20	C29	16	5.74	7.32	9.87	1.974	4.93	18.11	0.99	3.62
4	20	C25	21	9.03	3.64	15.35	3.07	7.67	28.16	1.53	5.61
4	20	C37	10	5.15	3.02	10.40	2.08	5.20	19.08	1.04	3.82
4	21	C11	3	24.25	18.41	226.32	45.26	113.16	415.29	22.63	83.05
4	21	C34	9	19.08	7.50	120.42	24.08	60.21	220.97	12.04	44.19
4	21	C32	16	8.83	6.45	14.61	2.92	7.30	26.81	1.46	5.36
4	21	C9	13	12.04	6.61	32.85	6.57	16.42	60.28	3.28	12.06

Transect No	Plot No	Species code	No of Tr /Sh	Average DBH(cm)	Average height(m)	AGB (ton/ha)	BGB (ton/ha)	AGC (ton/ha)	AG CO_2 (ton/ha)	BGC (ton/ha)	BG CO_2 (ton/ha)
4	21	C13	1	37.13	10.25	643.32	128.66	321.66	1180.49	64.33	236.09
4	21	C27	15	5.41	2.43	10.11	2.02	5.05	18.55	1.01	3.71
4	21	C38	14	5.02	1.55	10.58	2.11	5.29	19.14	1.06	3.89
4	21	C31	5	24.71	11.61	237.45	47.48	118.72	435.72	23.74	78.13
4	22	C54	2	6.62	4.13	9.94	1.99	4.97	18.24	0.99	3.65
4	22	C20	12	31.09	7.66	420.55	84.11	210.27	771.71	42.05	154.34
4	22	C8	4	5.62	3.15	9.94	1.99	4.97	18.24	0.99	3.65
4	22	C18	10	10.73	2.28	23.77	4.75	11.88	43.62	2.37	8.72
4	22	C30	2	22.67	18.73	190.21	38.04	95.10	349.03	19.02	69.81
4	22	C39	21	12.55	3.38	37.01	7.40	18.50	67.91	3.70	13.58
4	22	C38	17	5.05	1.60	10.53	2.11	5.26	19.32	1.05	3.87
4	23	C1	6	30.36	9.31	396.88	79.37	198.44	728.27	39.68	145.65
4	23	C20	19	18.71	7.05	114.19	22.84	57.09	209.53	11.42	41.91
4	23	C12	5	32.05	25.00	452.74	90.54	226.37	830.77	45.27	116.15
4	23	C23	2	39.73	19.85	754.02	150.80	377.01	1383.62	75.40	276.72
4	23	C25	25	7.72	4.53	11.46	2.29	5.73	21.03	1.15	4.22
4	23	C40	4	23.41	6.70	206.71	41.34	103.35	379.31	20.67	75.86
4	23	C31	7	17.23	15.67	91.08	18.21	45.54	167.13	9.10	33.41
4	24	C11	2	36.12	29.77	602.72	120.54	301.36	1105.99	60.27	221.19
4	24	C20	8	21.45	8.65	164.59	32.92	82.29	302.02	16.46	60.41
4	24	C34	16	30.94	6.94	415.63	83.13	207.81	762.68	41.56	152.54
4	24	C33	17	6.25	2.72	9.79	1.96	4.90	17.98	0.98	3.59
4	24	C25	18	5.06	3.06	10.52	2.10	5.26	19.30	1.05	3.86
4	24	C30	3	26.76	12.53	290.36	58.07	145.18	532.81	29.03	106.56
4	24	C14	2	21.70	11.25	169.68	33.93	84.84	311.36	16.96	62.27
4	25	C20	10	13.62	10.65	46.82	9.36	23.41	85.91	4.68	17.18
4	25	C1	5	32.17	7.95	456.85	91.37	228.42	838.31	45.68	167.66
4	25	C16	19	5.07	4.11	10.51	2.10	5.25	19.28	1.05	3.86
4	25	C35	6	21.24	11.25	160.38	32.07	80.19	294.29	16.04	58.86
4	25	C23	11	20.05	16.32	137.60	27.52	68.80	252.49	13.76	50.50
4	25	C13	2	39.36	14.71	737.72	147.54	368.86	1353.72	73.77	270.74
4	25	C41	23	9.51	5.30	17.34	3.47	8.67	31.82	1.73	6.35
4	26	C24	24	5.09	3.93	10.48	2.10	5.24	19.23	1.05	3.85
4	26	C34	17	21.53	7.85	166.21	33.24	83.10	304.99	16.62	61.00
4	26	C32	19	5.06	4.05	10.52	2.10	5.26	19.30	1.05	3.86
4	26	C42	2	33.40	13.20	500.07	100.01	250.03	917.63	50.00	183.52
4	26	C28	1	53.24	6.15	1472.63	294.53	736.31	2702.28	147.26	540.45
4	26	C39	18	9.61	3.27	17.79	3.56	8.89	32.64	1.78	6.53
5	27	C1	6	37.05	18.41	640.06	128.01	320.03	1174.51	64.00	234.90
5	27	C34	11	29.17	7.25	359.80	71.96	179.9	660.23	35.98	132.04
5	27	C16	16	5.80	3.79	9.85	1.97	4.92	18.07	0.98	3.61
5	27	C29	10	6.75	7.35	10.04	2.01	5.02	18.42	1.00	3.69
5	27	C15	3	35.15	8.96	564.99	112.99	282.49	1036.76	56.49	207.35

Transect No	Plot No	Species code	No of Tr /Sh	Average DBH(cm)	Average height(m)	AGB (ton/ha)	BGB (ton/ha)	AGC (ton/ha)	AG CO_2 (ton/ha)	BGC (ton/ha)	BG CO_2 (ton/ha)
5	27	C43	4	15.29	17.53	65.16	13.03	32.58	119.57	6.52	23.91
5	27	C21	7	17.71	7.61	98.26	19.65	49.13	180.31	9.82	36.06
5	28	C20	16	17.09	8.51	89.05	17.81	44.52	163.41	8.90	32.68
5	28	C32	13	6.78	4.67	10.06	2.01	5.03	18.46	1.01	3.69
5	28	C9	8	10.02	5.53	19.80	3.96	9.9	36.33	1.98	7.27
5	28	C1	7	33.60	17.44	507.28	101.46	253.64	930.86	50.73	186.18
5	28	C18	16	14.27	5.65	53.53	10.70	26.76	98.22	5.35	19.64
5	28	C30	4	29.12	11.45	358.29	71.65	179.14	657.46	35.83	131.49
5	28	C41	9	8.32	6.13	12.96	2.59	6.48	23.78	1.29	4.76
5	29	C20	17	19.20	7.61	122.49	24.49	61.24	24.77	12.25	44.95
5	29	C1	5	10.78	13.75	24.08	4.81	12.04	44.19	2.41	8.84
5	29	C22	19	5.61	1.70	9.95	1.99	4.97	18.25	0.99	3.65
5	29	C42	3	46.58	15.95	1088.32	217.66	544.16	1997.06	108.83	399.41
5	29	C23	2	27.00	14.00	296.99	59.39	148.49	544.98	29.69	108.99
5	29	C17	16	17.32	6.35	92.41	18.48	46.20	169.57	9.24	33.91
5	29	C41	8	7.62	5.28	11.26	2.25	5.63	20.66	1.13	4.13
5	30	C20	23	12.45	6.65	36.17	7.23	18.08	66.37	3.62	13.27
5	30	C4	5	15.78	5.74	71.24	14.25	35.62	130.72	7.12	26.15
5	30	C35	4	29.08	13.36	357.07	71.41	178.53	655.22	35.71	131.04
5	30	C36	27	6.25	3.11	9.79	1.96	4.89	17.96	0.98	3.59
5	30	C30	2	37.46	15.62	656.88	131.38	65.69	241.08	65.69	241.08
5	30	C21	6	17.01	10.70	87.89	17.58	8.79	32.26	8.79	32.26
5	31	C12	6	31.05	27.22	419.23	83.84	41.92	153.85	41.92	153.86
5	31	C11	4	24.25	19.66	226.3.2	45.26	113.16	415.29	22.63	83.05
5	31	C32	25	9.25	6.02	16.23	3.25	8.11	29.78	1.62	5.94
5	31	C23	3	42.68	16.63	890.41	178.08	445.20	1633.88	89.04	326.78
5	31	C40	5	36.07	6.21	600.35	120.07	300.17	1101.62	60.03	220.30
5	31	C31	7	32.16	11.61	456.51	91.30	228.25	837.69	45.65	167.54
5	32	C34	12	20.44	7.65	144.86	28.97	72.43	265.82	14.48	53.16
5	32	C1	15	16.04	9.50	74.59	14.92	37.29	136.87	7.46	27.38
5	32	C22	23	5.06	1.77	10.52	2.10	5.26	19.30	1.05	3.86
5	32	C42	1	40.16	13.45	773.18	154.63	386.59	1418.78	77.31	283.75
5	32	C13	3	32.78	15.63	478.04	95.61	239.02	877.20	47.80	175.44
5	32	C28	2	45.02	7.52	1006.75	201.35	503.37	1847.38	100.67	369.47
5	32	C43	4	19.34	12.65	124.90	24.98	62.45	229.19	12.49	45.84
5	32	C14	3	17.45	7.22	94.34	18.87	47.17	173.11	9.43	34.61
5	33	C20	26	19.32	10.70	124.56	24.91	62.28	228.57	12.45	45.69
5	33	C19	8	29.67	8.65	375.15	75.03	187.57	688.40	37.51	137.68
5	33	C18	17	20.11	9.40	138.71	27.74	69.35	254.53	13.87	50.90
5	33	C23	5	33.40	18.30	500.07	100.01	250.03	917.63	50.00	183.5
5	33	C17	10	18.37	6.08	108.63	21.73	54.31	199.32	10.86	39.86
5	33	C30	3	36.07	17.62	600.75	120.15	300.37	1102.36	60.07	220.46
5	34	C1	5	24.31	12.70	227.75	45.55	113.87	417.92	22.77	83.58

Transect No	Plot No	Species code	No of Tr /Sh	Average DBH(cm)	Average height(m)	AGB (ton/ha)	BGB (ton/ha)	AGC (ton/ha)	AG CO_2 (ton/ha)	BGC (ton/ha)	BG CO_2 (ton/ha)
5	34	C2	20	17.64	11.15	97.19	19.44	48.59	178.34	9.72	35.67
5	34	C12	2	47.04	35.36	1112.98	222.59	556.49	2042.32	111.29	408.45
5	34	C29	13	5.63	5.75	9.94	1.99	4.97	18.24	0.99	3.65
5	34	C23	3	34.93	18.87	556.61	111.32	278.30	1021.36	55.6	204.05
5	34	C44	14	7.35	3.57	129.36	25.87	64.68	237.37	12.94	47.49
5	34	C14	3	19.06	7.20	120.08	24.02	60.04	220.35	12.01	44.08
5	35	C3	21	7.92	5.62	11.91	2.38	5.95	21.85	1.19	4.37
5	35	C1	7	19.52	10.90	128.06	25.61	64.03	234.99	12.81	46.99
5	35	C42	2	31.51	7.75	434.48	86.89	217	796.39	43.44	159.44
5	35	C43	6	18.77	15.19	115.19	23.04	57.59	211.37	11.52	42.28
5	35	C11	3	39.51	41.32	744.31	148.86	372.15	1365.81	74.43	273.16
5	35	C44	15	8.33	3.75	12.99	2.60	6.49	23.84	1.30	4.77
5	35	C31	9	26.12	13.60	273.29	54.66	136.64	501.48	27.33	100.29
5	35	C14	5	19.02	14.25	119.39	23.88	59.69	219.08	11.94	43.82
5	36	C15	1	34.07	12.85	524.45	104.89	262.22	962.36	52.44	192.43
5	36	C2	14	13.85	6.65	49.13	9.83	24.56	90.14	4.91	18.04
5	36	C35	9	19.09	8.66	120.59	24.12	60.29	221.26	12.06	44.26
5	36	C18	11	18.22	8.05	106.22	21.24	53.11	194.91	10.62	38.97
5	36	C30	4	29.31	15.32	364.07	72.81	182.03	668.07	36.41	133.61
5	36	C39	26	9.15	3.62	15.82	3.16	7.91	29.03	1.58	5.08
5	36	C45	3	27.21	15.69	302.50	60.56	151.25	555.08	30.28	111.23
5	37	C15	16	28.18	10.25	330.38	66.07	165.19	606.24	33.03	121.24
5	37	C19	6	19.75	9.60	132.16	26.43	66.08	242.51	13.21	48.50
5	37	C4	3	16.19	4.55	76.57	15.31	38.28	140.50	7.66	28.11
5	37	C5	19	12.37	6.80	35.50	7.10	17.75	65.14	3.55	13.03
5	37	C42	2	32.06	10.20	453.08	90.62	226.54	831.40	45.31	166.28
5	37	C28	2	41.05	6.24	813.63	162.72	406.81	1493.01	81.36	298.60
5	37	C21	7	20.01	10.45	136.87	27.37	68.43	251.14	13.68	50.21
5	38	C1	16	17.49	7.52	94.93	18.98	47.46	174.19	9.49	34.84
5	38	C13	1	30.62	10.79	405.23	81.05	202.61	743.59	40.52	148.71
5	38	C11	3	42.80	15.66	896.19	179.24	448.09	1644.51	89.62	328.90
5	38	C46	8	15.67	6.51	69.85	13.97	34.92	128.17	6.98	25.66
5	38	C43	3	19.13	14.62	121.27	24.25	60.63	222.53	12.13	44.50
5	38	C40	6	21.05	6.73	156.62	31.32	78.31	287.39	15.66	57.47
5	38	C31	10	23.15	12.18	200.83	40.16	100.41	368.52	20.08	73.71
6	39	C15	5	30.12	8.60	389.25	77.85	194.62	714.25	38.92	142.85
6	39	C2	7	21.24	7.05	160.38	32.08	80.19	294.29	16.04	58.86
6	39	C1	6	13.52	7.35	45.84	9.17	22.92	84.12	4.58	16.82
6	39	C16	25	8.15	8.11	12.49	2.49	6.24	22.90	1.23	4.58
6	39	C18	9	14.08	7.29	51.51	10.30	25.75	94.52	5.15	18.90
6	39	C30	4	31.50	9.09	434.15	86.83	217.07	796.66	43.41	159.33
6	39	C10	16	6.03	3.72	9.78	1.95	4.89	17.95	0.97	3.56
6	39	C45	3	19.17	15.75	121.96	24.39	60.98	223.79	12.19	44.75

Transect No	Plot No	Species code	No of Tr /Sh	Average DBH(cm)	Average height(m)	AGB (ton/ha)	BGB (ton/ha)	AGC (ton/ha)	AG CO_2 (ton/ha)	BGC (ton/ha)	BG CO_2 (ton/ha)
6	40	C5	3	34.21	19.20	529.62	105.92	264.81	971.85	52.96	194.37
6	40	C11	4	50.57	28.20	1311.54	262.31	655.77	2406.67	131.15	481.33
6	40	C19	7	22.71	9.05	191.08	38.21	95.54	350.63	19.10	70.12
6	40	C29	18	8.33	7.62	12.99	2.59	6.49	23.84	1.29	4.73
6	40	C28	2	32.52	5.96	468.95	93.79	234.47	860.50	46.89	172.10
6	40	C43	11	19.48	12.44	127.36	25.47	63.68	233.70	12.75	46.74
6	40	C14	5	19.73	8.65	131.79	26.36	65.89	241.82	13.18	48.37
6	41	C20	18	26.05	9.21	271.45	54.29	135.72	498.10	27.14	99.62
6	41	C4	5	10.64	5.55	23.23	4.64	11.61	42.62	2.32	8.52
6	41	C32	24	6.08	4.13	9.78	1.95	4.89	17.95	0.97	3.56
6	41	C13	3	40.15	18.92	772.74	154.55	386.37	1417.98	77.27	283.60
6	41	C43	4	19.60	10.34	129.48	25.89	64.74	237.59	12.94	47.50
6	41	C14	1	16.33	8.91	78.44	15.69	39.22	143.94	7.84	28.79
6	42	C1	9	29.30	8.96	363.76	72.75	181.88	667.49	36.38	133.51
6	42	C2	10	17.66	8.51	97.50	19.50	48.75	178.91	9.45	35.78
6	42	C3	35	6.08	4.25	9.78	1.96	4.89	17.95	0.98	3.60
6	42	C42	1	31.71	13.56	441.20	88.24	220.6	809.60	44.12	161.92
6	42	C28	2	52.18	6.76	1407.55	281.51	703.77	2582.85	140.75	516.57
6	42	C47	6	21.33	5.79	162.18	32.44	81.09	297.60	16.22	59.52
6	43	C20	14	17.52	6.59	95.38	19.08	47.69	175.02	9.54	35.00
6	43	C5	7	24.06	16.45	221.80	44.36	110.90	407.00	22.18	81.40
6	43	C23	3	38.17	19.81	686.53	137.31	343.26	1259.78	68.65	251.95
6	43	C30	4	18.42	7.47	109.45	21.89	54.72	200.84	10.94	40.16
6	43	C10	19	9.07	3.95	15.51	3.10	7.75	28.46	1.55	5.69
6	43	C14	3	15.06	7.61	62.42	12.48	31.21	114.54	6.24	22.91
6	44	C19	9	30.15	8.32	390.20	78.04	195.1	716.02	39.02	143.20
6	44	C11	3	64.27	27.51	2237.67	447.53	1118.83	4106.12	223.76	821.23
6	44	C43	5	15.09	5.96	62.77	12.55	`31.38	115.18	6.28	23.09
6	44	C44	18	7.78	4.12	11.59	2.32	5.79	21.26	1.56	4.25
6	44	C47	13	19.16	7.2	121.79	24.36	60.89	223.48	12.18	44.69
6	44	C31	7	30.15	10.7	390.20	78.04	195.10	716.02	39.02	143.20
6	45	C2	6	18.37	15.37	108.63	21.72	54.31	199.33	10.86	39.87
6	45	C1	17	23.30	9.16	204.22	40.84	102.11	374.74	20.42	74.95
6	45	C53	5	16.72	6.85	83.79	16.76	41.89	153.75	8.38	30.75
6	45	C16	21	7.07	3.98	10.37	2.07	5.18	19.03	1.03	3.79
6	45	C42	2	50.05	15.45	1281.26	256.25	640.63	2351.11	128.13	470.22
6	45	C48	12	16.35	5.73	78.71	15.74	39.35	144.43	7.87	28.88
6	45	C45	4	27.36	16.35	306.98	61.39	153.49	563.31	30.69	112.62
6	46	C20	9	15.42	9.15	66.75	13.35	33.37	122.48	6.67	24.49
6	46	C1	8	27.21	7.59	302.80	60.66	151.40	555.64	30.28	111.13
6	46	C19	7	29.08	10.21	357.07	71.41	178.53	655.22	35.71	131.05
6	46	C3	44	5.78	4.15	9.85	1.97	4.93	18.23	0.98	3.62
6	46	C45	6	22.74	13.64	191.75	38.35	95.87	351.86	19.17	70.37

Transect No	Plot No	Species code	No of Tr /Sh	Average DBH(cm)	Average height(m)	AGB (ton/ha)	BGB (ton/ha)	AGC (ton/ha)	AG CO_2 (ton/ha)	BGC (ton/ha)	BG CO_2 (ton/ha)
6	47	C11	2	39.09	24.75	725.94	145.19	362.5	133.37	72.59	266.42
6	47	C20	20	18.27	8.64	107.02	21.40	53.51	196.38	10.70	39.27
6	47	C34	1	40.05	10.51	768.26	153.65	384.13	1409.76	76.83	281.95
6	47	C32	10	8.67	5.16	14.06	7.03	7.03	25.80	3.51	11.83
6	47	C22	17	5.12	1.99	10.44	2.09	5.22	19.16	1.04	3.83
6	47	C18	11	19.06	6.69	120.08	24.02	60.04	220.35	12.01	44.08
6	47	C47	8	15.22	6.33	64.32	12.86	32.16	118.03	6.43	23.60
6	48	C1	12	23.26	10.22	203.31	40.66	101.65	373.07	20.33	4.61
6	48	C5	15	27.08	19.65	299.20	59.84	149.6	549.03	29.92	109.81
6	48	C42	4	35.42	16.21	575.37	115.07	287.68	1055.78	57.54	211.16
6	48	C13	2	29.17	12.70	359.80	71.96	179.9	660.23	35.98	132.05
6	48	C48	10	14.30	4.95	53.85	10.77	26.92	98.79	5.38	19.74
6	48	C14	5	16.67	6.25	83.09	16.62	41.54	152.47	8.31	30.49
6	49	C20	13	24.50	11.20	232.33	46.47	116.16	426.30	23.23	85.25
6	49	C3	8	5.34	3.71	10.18	2.04	5.09	18.68	1.02	3.74
6	49	C29	14	7.15	6.32	10.48	2.09	5.24	19.23	2.59	9.51
6	49	C43	4	28.24	12.35	332.13	66.43	166.06	609.46	33.21	121.89
6	49	C35	5	26.01	9.17	270.40	54.08	135.20	496.18	27.04	99.24
6	49	C38	12	5.11	1.25	10.45	2.09	5.22	19.17	1.04	3.84
6	49	C45	7	22.53	6.79	187.18	37.44	93.59	343.47	18.72	68.70
6	50	C12	7	28.36	15.66	335.63	67.13	167.81	615.88	33.56	123.17
6	50	C11	5	44.15	32.41	962.65	192.53	481.32	1766.44	96.26	353.27
6	50	C23	4	26.04	16.41	271.19	54.24	135.59	497.63	27.12	99.53
6	50	C43	3	31.42	10.15	431.48	86.29	215.74	791.76	43.14	158.32
6	50	C48	16	9.13	5.67	15.74	3.15	7.87	28.88	1.57	5.78
6	50	C38	11	24.16	2.11	224.17	44.83	112.08	411.35	22.42	82.28
6	50	C45	4	29.73	17.30	377.02	75.40	188.51	691.83	37.70	138.37
6	51	C19	11	29.73	8.95	377.02	75.40	188.51	691.83	37.70	138.37
6	51	C1	13	25.54	9.41	258.23	51.65	129.11	473.85	25.82	94.76
6	51	C42	3	30.16	16.50	390.52	78.10	195.26	716.60	39.05	143.32
6	51	C28	2	26.13	6.25	273.56	54.71	136.78	501.98	27.36	100.41
6	51	C5	5	31.07	22.16	419.89	83.98	209.94	770.48	41.99	154.10
6	51	C52	10	16.12	11.75	75.65	15.13	37.82	138.80	7.56	27.74
6	51	C45	9	28.10	9.34	328.06	65.61	164.03	601.99	32.80	120.39
6	52	C46	15	12.05	4.95	32.94	6.59	16.47	60.44	3.29	12.07
6	52	C2	8	27.12	7.42	300.31	60.06	150.15	55.07	30.03	110.21
6	52	C35	7	30.29	12.60	394.65	78.93	197.32	724.18	39.46	144.82
6	52	C23	4	37.67	21.17	665.58	133.12	332.79	1221.34	66.56	244.27
6	52	C48	17	12.50	4.44	36.58	7.32	18.29	67.12	3.66	13.43
6	52	C40	3	41.20	6.32	820.55	164.11	410.27	1505.71	82.05	301.14
6	52	C49	11	19.77	12.36	132.52	26.50	66.26	243.17	13.25	48.63
7	53	C24	23	5.75	3.36	9.87	1.97	4.93	8.09	0.99	3.62
7	53	C1	4	34.09	11.73	525.19	105.04	262.59	963.72	52.52	192.75

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7	53	C34	2	25.16	6.17	248.60	49.72	124.3	456.18	24.86	91.24
7	53	C29	7	10.11	9.05	20.26	4.05	10.13	37.18	2.03	7.45
7	53	C40	5	31.21	5.50	424.51	84.90	212.25	778.98	42.45	155.79
7	53	C43	3	17.30	10.66	92.11	18.42	46.05	169.00	9.21	33.80
7	53	C15	15	19.05	7.47	119.91	23.98	59.95	220.03	11.99	44.00
7	54	C50	2	20.66	9.50	149.04	29.81	74.52	273.49	14.90	54.70
7	54	C19	6	34.08	10.62	524.82	104.96	262.41	963.04	52.48	192.60
7	54	C12	9	24.41	21.39	230.16	46.03	115.08	422.34	23.01	84.45
7	54	C29	23	6.45	7.22	9.85	1.97	4.92	18.74	0.98	3.60
7	54	C42	5	28.13	11.75	328.93	65.79	164.46	603.58	32.89	120.72
7	54	C45	6	22.70	10.15	190.87	38.17	95.43	350.23	19.08	70.02
7	55	C1	11	25.23	7.99	250.36	50.07	125.18	459.41	25.04	91.90
7	55	C20	13	23.46	8.76	207.86	41.57	103.93	381.42	20.79	76.30
7	55	C38	2	5.04	1.65	10.55	2.11	5.27	19.34	1.05	3.87
7	55	C23	3	42.08	19.90	861.74	172.35	432.37	1586.79	86.17	316.26
7	55	C13	2	17.60	10.53	96.59	19.32	48.29	17.72	9.66	35.5
7	55	C49	21	21.06	11.55	156.81	31.36	78.40	287.74	15.68	57.55
7	55	C45	3	26.17	9.71	274.61	54.92	137.30	503.91	27.46	100.78
7	56	C11	5	75.26	30.15	3159.39	613.88	1579.69	5797.48	306.94	1126.47
7	56	C2	11	18.33	9.12	107.98	21.59	53.99	198.14	10.79	39.60
7	56	C35	8	21.27	11.06	160.78	32.16	80.39	295.03	16.08	59.01
7	56	C23	6	41.16	16.75	818.70	163.74	409.35	1502.31	81.87	300.46
7	56	C48	12	14.17	5.23	52.46	10.49	26.23	96.26	5.25	19.25
7	57	C11	2	42.53	28.95	883.19	176.64	441.59	1620.65	88.32	324.13
7	57	C3	24	6.08	3.72	9.78	1.96	4.89	17.95	0.98	3.59
7	57	C5	9	26.86	19.12	293.16	58.63	146.58	537.95	29.32	107.59
7	57	C1	8	24.10	12.00	222.75	44.55	111.37	408.73	22.27	81.4
7	57	C52	11	19.41	7.96	126.13	25.23	63.06	213.49	12.61	46.29
7	57	C47	7	21.63	9.53	168.25	33.05	84.12	308.74	16.52	60.64
7	58	C24	64	6.01	3.77	9.78	1.96	4.89	17.95	0.98	3.59
7	58	C34	2	36.74	7.80	627.49	125.49	313.74	1151.43	62.75	230.28
7	58	C53	7	16.05	8.61	74.73	14.95	37.36	137.11	7.47	27.43
7	58	C12	4	32.36	21.21	463.40	92.68	231.70	850.34	46.34	170.07
7	58	C43	3	26.28	15.33	277.59	55.52	138.79	509.37	27.76	101.88
7	58	C45	12	21.12	10.59	157.99	31.60	78.99	289.91	15.8	57.99
8	59	C1	14	19.09	7.92	120.59	24.12	60.29	221.28	12.06	44.26
8	59	C20	7	24.15	9.73	223.93	44.79	111.6	410.90	22.39	82.17
8	59	C34	1	39.02	8.41	722.71	144.54	361.35	13.26.17	72.27	265.23
8	59	C24	71	5.74	4.16	9.87	1.97	4.94	18.23	0.98	3.59
8	59	C4	9	12.60	6.01	37.43	7.48	18.71	68.68	3.74	13.73
8	59	C47	6	20.13	8.77	139.08	27.81	69.54	255.21	13.90	51.01
8	60	C19	2	31.63	11.40	438.51	87.70	219.25	804.65	43.85	160.93
8	60	C5	17	20.62	12.72	148.28	29.65	74.14	272.09	14.82	54.39

Transect No	Plot No	Species code	No of Tr /Sh	Average DBH(cm)	Average height(m)	AGB (ton/ha)	BGB (ton/ha)	AGC (ton/ha)	AG CO_2 (ton/ha)	BGC (ton/ha)	BG CO_2 (ton/ha)
8	60	C11	5	33.81	27.03	514.92	102.98	257.46	944.88	51.49	188.97
8	60	C12	2	19.70	14.01	131.26	26.25	65.63	240.86	13.12	48.15
8	60	C29	43	5.04	5.18	10.55	2.11	5.27	19.34	1.05	3.87
8	60	C42	4	30.41	8.90	398.48	79.69	199.24	731.21	39.84	146.21
8	61	C20	6	19.70	10.50	131.26	26.25	65.62	240.82	13.12	48.15
8	61	C1	3	46.02	13.65	1058.67	211.73	529.33	1942.66	105.88	388.58
8	61	C2	4	16.21	12.05	76.84	15.37	38.42	141.00	7.68	28.20
8	61	C29	16	7.38	6.14	10.82	2.16	5.41	19.85	1.08	3.96
8	61	C55	23	5.62	4.4	9.94	1.99	4.97	18.24	0.99	3.63
8	61	C43	2	23.41	13.01	206.71	41.34	103.35	379.29	20.67	75.86
8	62	C50	2	10.71	5.41	23.65	4.73	11.82	43.39	2.36	8.66
8	62	C34	3	31.15	672	422.52	84.50	211.26	775.32	42.25	155.06
8	62	C19	5	20.11	7.90	138.71	27.74	69.35	254.51	13.87	50.91
8	62	C12	14	27.05	15.66	298.37	59.67	149.18	547.49	29.83	109.48
8	62	C43	4	24.65	17.62	235.98	47.19	117.99	433.02	23.59	86.58
8	62	C49	22	17.14	5.79	89.77	17.95	44.88	164.71	8.97	32.92
8	63	C46	9	15.96	6.31	73.56	14.71	36.78	134.98	7.36	27.01
8	63	C34	2	31.19	7.60	423.85	84.77	211.92	777.76	42.38	155.55
8	63	C24	28	5.32	3.71	10.20	2.04	5.1	18.72	1.02	3.74
8	63	C35	7	19.20	8.34	122.48	24.50	61.24	224.75	12.25	44.96
8	63	C23	8	20.16	14.04	139.63	27.93	69.81	256.20	13.96	51.23
8	63	C31	10	26.15	9.62	274.09	54.82	137.04	502.95	27.41	100.59
8	64	C19	5	43.21	8.15	916.13	183.23	458.06	1681.08	91.61	336.21
8	64	C15	6	37.02	13.70	638.83	127.77	319.41	1172.23	63.88	234.44
8	64	C35	6	27.13	10.22	300.58	60.11	150.29	551.56	30.06	110.32
8	64	C46	11	12.43	6.33	36.00	7.20	13.21	48.48	3.6	13.21
8	64	C54	16	6.19	3.72	9.78	1.96	4.89	17.95	0.98	3.60
8	64	C55	20	5.05	2.11	10.53	2.11	5.26	19.30	1.05	3.85
8	65	C20	19	18.19	9.18	105.74	21.15	52.87	194.03	10.57	38.79
8	65	C34	2	27.50	6.40	310.92	62.18	155.46	570.54	31.09	114.10
8	65	C1	21	38.45	8.06	698.41	139.68	349.20	1281.56	69.84	256.31
8	65	C24	39	6.01	4.21	9.79	1.96	4.89	17.95	0.98	3.60
8	65	C5	10	19.20	20.23	122.48	24.50	61.24	224.75	12.25	44.96
8	65	C28	2	25.27	6.10	251.37	50.27	125.68	461.25	25.13	92.23
8	66	C11	1	61.04	35.11	1997.04	399.41	998.52	3664.57	199.70	732.91
8	66	C1	14	27.02	8.75	297.82	59.56	148.91	546.50	29.78	109.29
8	66	C3	16	6.63	4.8	9.95	1.99	4.97	18.24	0.99	3.63
8	66	C5	6	26.05	13.77	271.45	54.29	135.72	498.09	27.14	99.60
8	66	C42	3	35.41	18.93	572.57	114.51	286.28	1050.65	57.25	210.11
8	66	C49	5	19.75	9.66	132.16	26.43	66.08	242.51	13.21	48.48
8	67	C2	13	16.07	8.46	75.00	15.00	37.50	137.62	7.50	27.52
8	67	C15	7	24.16	14.33	224.17	44.83	112.08	44.33	22.41	82.24
8	67	C19	3	35.40	9.76	574.60	114.92	287.30	1054.39	57.46	210.88

Transect No	Plot No	Species code	No of Tr /Sh	Average DBH(cm)	Average height(m)	AGB (ton/ha)	BGB (ton/ha)	AGC (ton/ha)	AG CO_2 (ton/ha)	BGC (ton/ha)	BG CO_2 (ton/ha)
8	67	C35	5	40.53	13.64	789.87	157.97	394.93	1449.39	78.98	289.88
8	67	C24	46	5.08	2.77	10.49	2.10	5.24	19.23	1.05	3.85
8	67	C28	1	37.31	6.40	650.70	130.14	325.35	1194.03	65.07	238.81
8	68	C2	9	19.61	11.72	129.66	25.93	64.83	237.93	12.96	47.56
8	68	C1	5	39.06	15.65	724.64	144.93	362.32	1329.71	72.46	265.92
8	68	C46	10	12.16	7.30	33.79	6.76	16.89	61.99	3.38	12.40
8	68	C5	3	18.35	10.65	108.30	21.66	54.15	198.73	10.83	39.75
8	68	C23	6	29.67	15.44	375.15	75.03	187.57	688.38	75.53	277.19
8	68	C34	15	21.22	6.31	160.18	32.04	80.09	293.93	16.02	58.79
9	69	C15	10	11.21	6.05	26.84	5.37	13.42	49.25	2.68	9.84
9	69	C11	3	29.70	18.79	376.09	75.23	188.04	690.11	37.61	138.03
9	69	C1	12	27.85	12.73	320.86	64.17	160.43	588.79	32.08	117.73
9	69	C46	14	9.98	4.31	19.59	3.92	9.79	35.93	1.96	7.19
9	69	C5	7	30.11	18.10	388.94	77.79	194.47	413.70	38.89	142.73
9	69	C42	4	23.45	7.15	207.63	41.53	103.81	380.98	20.76	76.19
9	69	C13	1	12.76	8.20	38.81	7.76	19.40	71.23	3.88	14.24
9	70	C15	9	20.67	10.77	149.24	29.85	74.62	273.85	14.93	54.79
9	70	C46	19	10.37	5.24	21.67	4.33	10.83	39.64	2.16	7.93
9	70	C19	4	12.39	4.78	35.67	7.13	17.83	65.44	3.56	13.06
9	70	C4	3	17.07	5.38	88.76	17.75	44.38	162.87	8.88	32.59
9	70	C55	21	6.08	2.49	9.78	1.96	4.89	17.95	0.98	3.59
9	70	C43	3	19.22	8.96	122.82	24.56	61.41	225.37	12.28	45.08
9	71	C46	25	7.69	4.62	11.40	2.28	5.70	20.92	1.14	4.18
9	71	C5	5	17.29	14.06	91.96	18.39	45.98	168.75	9.19	33.75
9	71	C23	4	36.08	16.39	601.14	120.23	300.57	1103.09	60.11	220.62
9	71	C55	27	6.23	3.27	9.79	1.96	4.89	17.95	0.98	3.59
9	71	C15	8	20.11	10.65	138.71	27.74	69.35	254.51	13.87	50.90
9	71	C43	1	18.07	6.47	103.84	20.77	51.92	190.55	10.38	38.09

7.4 APPENDIX 4: Litter Carbon Stock Estimation Data

Plot No	Field Code	Wet Wt(g)	Fresh Wt (g)	Oven-dry Wt (g)	% of Or.C (ton/ha)	LB	LC	L CO_2 (ton/ha)
1	WL/C1	220	100	68.1055	41.3612	0.015	0.620418	2.276934
2	WL/C2	335	100	70.3341	43.5248	0.0236	1.027185	3.76977
3	WL/C3	555	100	81.3990	50.0314	0.0452	2.261419	8.299409
4	WLC/4	445	100	80.3157	45.4321	0.0357	1.621926	5.952468
5	WL/C5	330	100	79.4176	47.8743	0.0262	1.254307	4.603305
6	WL/C6	570	100	80.5918	44.9240	0.0459	2.062012	7.567583
7	WL/C7	585	100	79.4503	46.1542	0.0465	2.14617	7.876445
8	WL/C8	650	100	70.6334	39.5744	0.0459	1.816465	6.666426
9	WL/C9	730	100	86.8415	41.3610	0.0634	2.622287	9.623795
10	WL/C10	515	100	82.4141	50.4005	0.0424	2.136981	7.842721
11	WL/C11	545	100	84.3915	48.7277	0.046	2.241474	8.22621
12	WL/C12	960	100	80.3782	48.2484	0.0772	3.724776	13.66993
13	WL/C13	470	100	88.6119	51.0983	0.0416	2.125689	7.80128
14	WL/C14	990	100	89.2793	49.9656	0.01	0.499656	1.833738
15	WL/C15	1005	100	90.2635	50.1427	0.015	0.752141	2.760356
16	WL/C16	885	100	78.6975	43.7295	0.0696	3.043573	11.16991
17	WL/C17	765	100	83.3173	46.6090	0.139	6.478651	23.77665
18	WL/C18	1030	100	90.3819	50.9357	0.0931	4.742114	17.40356
19	WL/C19	675	100	78.4926	48.4838	0.053	2.569641	9.430584
20	WL/C20	590	100	83.0679	49.1462	0.049	2.408164	8.837961
21	WL/C21	875	100	89.8433	47.2079	0.0786	3.710541	13.61769
22	WL/C22	710	100	84.8435	49.7954	0.0602	2.997683	11.0015
23	WL/C23	940	100	89.5697	48.2287	0.0842	4.060857	14.90334
24	WL/C24	615	100	81.1590	50.0647	0.0499	2.498229	9.168499
25	WL/C25	1020	100	88.9678	46.9114	0.0907	4.254864	15.61535
26	WL/C26	740	100	80.1393	49.8054	0.0593	2.95346	10.8392
27	WL/C27	620	100	85.0431	45.1079	0.13	5.864027	21.52098
28	WL/C28	995	100	88.7319	50.9112	0.0937	4.58012	16.8093
29	WL/C29	1025	100	84.9718	49.9626	0.0871	4.351742	15.97089
30	WL/C30	685	100	82.5731	44.8346	0.002	0.089669	0.329086
31	WL/C31	1015	100	86.9567	46.0359	0.003	0.138108	0.506855
32	WL/C32	775	100	80.6152	40.7906	0.006	0.244744	0.898209
33	WL/C33	590	100	87.6695	49.5618	0.009	0.446056	1.637026
34	WL/C34	770	100	88.2105	50.4081	0.007	0.352857	1.294984
35	WL/C35	660	100	85.0185	50.1276	0.0561	2.812158	10.32062
36	WL/C36	720	100	87.7134	47.4897	0.0662	3.143818	11.53781
37	WL/C37	800	100	78.5762	46.2005	0.0629	2.906011	10.66506
38	WL/C38	870	100	84.9835	51.7223	0.1658	8.575557	31.4723
39	WL/C39	985	100	89.4771	50.8279	0.1734	8.813558	32.34576
40	WL/C40	560	100	85.7336	49.6940	0.1242	6.171995	22.65122
41	WL/C41	675	100	90.4356	44.0059	0.061	2.68436	9.851601
42	WL/C42	795	100	87.3219	47.5621	0.0694	3.30081	12.11397
43	WL/C43	890	100	83.3568	48.9711	0.0742	3.633656	13.33552
44	WL/C44	610	100	88.9590	45.2940	0.0543	2.459464	9.026234

Plot No	Field Code	Wet Wt(g)	Fresh Wt (g)	Oven-dry Wt (g)	% of Or.C (ton/ha)	LB	LC	L CO_2 (ton/ha)
45	WL/C45	735	100	92.7622	53.1178	0.0682	3.622634	13.29507
46	WL/C46	965	100	88.1511	48.0303	0.0851	4.087379	15.00068
47	WL/C47	1050	100	91.1126	50.1006	0.0957	4.794627	17.59628
48	WL/C48	630	100	84.1694	47.4078	0.053	2.512613	9.221291
49	WL/C49	1010	100	85.1697	46.8645	0.086	4.030347	14.79137
50	WL/C50	680	100	87.6738	49.9051	0.0596	2.974344	10.91584
51	WLC51	860	100	79.5297	48.7659	0.0684	3.335588	12.24161
52	WL/C52	1000	100	86.8167	51.2254	0.149	7.632585	28.01159
53	WL/C53	795	100	88.3262	48.0419	0.1267	6.086909	22.33896
54	WL/C54	1070	100	90.5198	49.1720	0.0969	4.764767	17.48669
55	WL/C55	915	100	87.7016	48.0817	0.004	0.192327	0.705839
56	WL/C56	580	100	81.2783	46.1249	0.009	0.415124	1.523505
57	WL/C57	640	100	86.0621	47.7924	0.008	0.382339	1.403185
58	WL/C58	720	100	87.6368	50.1207	0.003	0.150362	0.551829
59	WL/C59	840	100	83.9422	47.0094	0.005	0.235047	0.862622
60	WLC60	1120	100	90.0529	50.3319	0.009	0.452987	1.662463
61	WL/C61	690	100	85.3095	51.9781	0.0589	3.06151	11.23574
62	WL/C62	870	100	89.3724	50.0509	0.0777	3.888955	14.27246
63	WL/C63	560	100	87.8947	48.1715	0.0919	4.426961	16.24695
64	WL/C64	905	100	89.9424	49.2927	0.1195	5.890478	21.61805
65	WLC65	1030	100	82.1129	50.3461	0.0846	4.25928	15.63156
66	WL/C66	945	100	87.0980	48.0813	0.0823	3.957091	14.52252
67	WL/C67	570	100	89.0621	50.1547	0.0508	2.547859	9.350642
68	WL/C68	695	100	88.2607	45.0390	0.1084	4.882228	17.91778
69	WL/C69	960	100	90.7391	47.4110	0.1451	6.879336	25.24716
70	WL/C70	770	100	87.4548	50.9013	0.0634	3.227142	11.84361
71	WL/C71	650	100	85.9840	47.0762	0.1214	5.715051	20.97424
Mean					**48.03**	**0.06**	**3.12**	**11.63**

7.5 APPENDIX 5: Carbon stock estimation in soil pool

Plot No	Soil volume (cm^3)	Soil Depth (cm)	Bulk-density (g/cm^3)	% of Organic Carbon	Oven-dry Wt (g)	SOC	Soil CO_2 (ton/ha)
1	100	10	0.858537	12.3	85.85	105.6	387.552
2	100	10	0.882688	12.65	88.27	111.66	409.7922
3	100	10	0.946189	13.25	94.62	125.37	460.1079
4	100	10	1.319864	10.32	83.54	136.21	499.8907
5	100	10	0.347896	21.15	82.07	73.58	270.0386
6	100	10	0.838943	10.22	83.89	85.74	314.6658
7	100	10	0.286937	6.66	28.7	19.11	70.1337
8	100	10	0.90121	14.05	90.12	126.62	464.6954
9	100	10	0.896674	13.23	89.67	118.63	435.3721
10	100	10	1.556713	9.98	75.51	155.36	570.1712
11	100	10	0.783918	12.25	78.39	96.03	352.4301
12	100	10	0.843926	10.29	84.39	86.84	318.7028
13	100	10	0.723849	9.77	72.38	70.72	259.5424
14	100	10	1.553981	8.753	40.01	136.02	499.1934
15	100	10	0.444037	6.54	44.4	29.04	106.5768
16	100	10	0.823284	19.67	82.33	161.94	594.3198
17	100	10	0.834684	16.29	83.47	135.97	499.0099
18	100	10	1.221437	8.63	75.79	105.41	386.8547
19	100	10	0.776823	15.36	77.68	119.32	437.9044
20	100	10	0.783431	10.2	78.34	79.91	293.2697
21	100	10	0.75806	7.258	75.81	55.02	201.9234
22	100	10	0.831209	9.1	83.12	75.64	277.5988
23	100	10	0.775362	8.97	77.54	69.55	255.2485
24	100	10	1.4139	9.64	79.15	136.3	500.221
25	100	10	1.34076	11.58	90.9	155.26	569.8042
26	100	10	0.826388	13.15	82.64	108.67	398.8189
27	100	10	0.915083	10.21	91.51	93.43	342.8881
28	100	10	0.644018	15.88	83.92	102.27	375.3309
29	100	10	0.848482	10.54	84.85	89.43	328.2081
30	100	10	0.366566	13.28	36.66	48.68	178.6556
31	100	10	0.511242	9.34	51.12	47.75	175.2425
32	100	10	0.431205	6.89	43.12	29.71	109.0357
33	100	10	0.378841	7.94	37.89	30.08	110.3936
34	100	10	0.489189	9.25	48.92	45.25	166.0675
35	100	10	0.412601	16.11	85.33	66.47	243.9449
36	100	10	0.826915	14.23	82.69	117.67	431.8489
37	100	10	0.349215	17.19	81.46	60.03	220.3101
38	100	10	1.088332	9.77	78.13	106.33	390.2311
39	100	10	0.81503	11.51	81.5	93.81	344.2827
40	100	10	0.840582	10.99	84.06	92.38	339.0346
41	100	10	0.799201	8.76	79.92	70.01	256.9367

Plot No	Soil volume (cm^3)	Soil Depth (cm)	Bulk-density (g/cm^3)	% of Organic Carbon	Oven-dry Wt (g)	SOC	Soil CO_2 (ton/ha)
42	100	10	0.361024	19.14	88.35	69.1	253.597
43	100	10	0.837134	12.28	83.71	102.8	377.276
44	100	10	1.653128	9.11	55.54	150.6	552.702
45	100	10	0.388566	5.16	38.85	20.05	73.5835
46	100	10	1.316604	10.6	27.89	139.56	512.1852
47	100	10	0.345614	4.56	34.56	15.76	57.8392
48	100	10	0.49778	10.81	49.78	53.81	197.4827
49	100	10	0.849493	18.75	84.95	159.28	584.5576
50	100	10	0.741115	13.45	74.11	99.68	365.8256
51	100	10	0.825994	19.12	82.6	157.93	579.6031
52	100	10	0.870888	16.11	87.09	140.3	514.901
53	100	10	0.838944	11.17	83.89	93.71	343.9157
54	100	10	0.486058	16.21	85.62	78.79	289.1593
55	100	10	0.378927	10.44	37.89	39.56	145.1852
56	100	10	0.389412	17.85	38.94	69.51	255.1017
57	100	10	0.456926	11.19	45.69	51.13	187.6471
58	100	10	0.612323	13.39	61.23	81.99	300.9033
59	100	10	0.978286	12.25	39.87	119.84	439.8128
60	100	10	0.58537	16.2	58.54	94.83	348.0261
61	100	10	0.86524	9.58	86.52	82.89	304.2063
62	100	10	0.714467	14.17	71.45	101.24	371.5508
63	100	10	0.469068	15.13	86.56	70.97	260.4599
64	100	10	0.759592	13.71	75.96	104.14	382.1938
65	100	10	0.425247	18.22	97.41	77.48	284.3516
66	100	10	0.929573	14.27	92.96	132.65	486.8255
67	100	10	0.948288	16.94	94.83	160.64	589.5488
68	100	10	0.876297	19.28	87.63	168.95	620.0465
69	100	10	0.914372	13.22	91.44	120.88	443.6296
70	100	10	0.694183	18.05	91.58	125.3	459.851
71	100	10	0.606615	14.21	95.85	86.2	316.354
Mean			**0.77**	**12.50**	**73.11**	**94.9632**	**348.5151**

7.6 APPENDIX 6: Summary of mean biomass and carbon stock in each carbon pools and total carbon stock per plots of the Gendo forest forests.

Plot No	AGB (ton ha^{-1})	BGB (ton ha^{-1})	AGC (ton ha^{-1})	BGC (ton ha^{-1})	LB (ton ha^{-1})	LC (ton ha^{-1})	SOC (ton ha^{-1})	TOTAL Carbon Stock (ton ha^{-1})
1	113.7440	22.7480	51.4740	11.3760	0.015	0.620418	105.6	169.07
2	62.3220	12.4600	31.1620	6.2340	0.0236	1.027185	111.66	150.086
3	203.8100	40.7614	101.9057	20.3800	0.0452	2.261419	125.37	249.9157
4	220.7671	44.1543	110.3814	22.0771	0.0357	1.621926	136.21	270.2885
5	143.2300	28.6450	71.6150	14.3233	0.0262	1.254307	73.58	160.7683
6	203.2760	40.6540	101.6384	20.3260	0.0459	2.062012	85.74	209.7644
7	204.4500	40.8900	102.2250	20.4450	0.0465	2.14617	19.11	143.93
8	494.5833	98.9183	247.2650	49.4583	0.0459	1.816465	126.62	425.1633
9	240.2214	48.0443	120.1129	24.0129	0.0634	2.622287	118.63	265.3758
10	151.3343	30.2686	75.6686	15.1357	0.0424	2.136981	155.36	248.3043
11	388.8443	77.7686	194.4186	38.8814	0.046	2.241474	96.03	331.57
12	482.5833	96.5150	241.2883	48.2550	0.0772	3.724776	86.84	380.1033
13	333.2800	66.6567	166.6367	33.3267	0.0416	2.125689	70.72	272.8134
14	133.5783	26.7150	66.7883	13.3550	0.01	0.499656	136.02	216.6633
15	181.8783	36.3750	90.9367	18.1867	0.015	0.752141	29.04	138.9134
16	188.7033	37.7417	94.3517	18.8700	0.0696	3.043573	161.94	278.2017
17	121.9357	24.3900	60.9657	12.1929	0.139	6.478651	135.97	215.6086
18	153.0943	30.6200	76.5443	15.3071	0.0931	4.742114	105.41	202.0014
19	189.3360	37.8660	94.6660	18.9320	0.053	2.569641	119.32	235.488
20	110.6983	22.1390	55.3467	11.0667	0.049	2.408164	79.91	148.7334
21	161.9575	32.3875	80.9763	16.1938	0.0786	3.710541	55.02	155.9001
22	100.2786	20.0557	50.1357	10.0243	0.0602	2.997683	75.64	138.8
23	289.5829	57.9129	144.7900	28.9557	0.0842	4.060857	69.55	247.3557
24	237.6129	47.5214	118.8057	23.7586	0.0499	2.498229	136.3	281.3643
25	223.8886	44.7757	111.9429	22.3871	0.0907	4.254864	155.26	293.84
26	362.9500	72.5900	181.4717	36.2933	0.0593	2.95346	108.67	329.385
27	249.7371	49.9457	124.8671	24.9700	0.13	5.864027	93.43	249.1271
28	150.1386	30.0257	75.0671	15.0129	0.9376	47.73434	102.27	240.08
29	235.0714	47.0100	117.5329	23.5057	0.0871	4.351742	89.43	234.8186
30	203.1733	40.6350	51.9333	20.3183	0.002	0.089669	48.68	121.0216
31	397.1217	86.9667	189.4683	43.4817	0.003	0.138108	47.75	280.84
32	338.3975	67.6788	169.1975	33.8363	0.006	0.244744	29.71	232.9838
33	307.9783	61.5950	153.9850	30.7933	0.009	0.446056	30.08	215.3083
34	321.9871	64.3971	160.9914	32.1886	0.007	0.352857	45.25	238.78
35	229.9525	45.9900	114.9425	22.9950	0.0561	2.812158	66.47	207.2175
36	211.8257	42.3729	105.9100	21.1857	0.0662	3.143818	117.67	247.9057
37	282.5986	56.5171	141.2971	28.2571	0.0629	2.906011	60.03	232.4942
38	277.8457	55.5671	138.9186	27.7829	0.1658	8.575557	106.33	281.6115
39	153.1700	30.6325	76.5825	15.3113	0.1734	8.813558	93.81	194.5138
40	396.1900	79.2357	198.0929	39.6171	0.1242	6.171995	92.38	336.26
41	214.1867	42.8350	107.0917	21.4133	0.061	2.68436	70.01	201.195

Plot No	AGB (ton ha^{-1})	BGB (ton ha^{-1})	AGC (ton ha^{-1})	BGC (ton ha^{-1})	LB (ton ha^{-1})	LC (ton ha^{-1})	SOC (ton ha^{-1})	TOTAL Carbon Stock (ton ha^{-1})
42	413.6617	82.7333	206.8300	41.3167	0.0694	3.30081	69.1	320.5467
43	198.5150	39.7033	99.2550	19.8500	0.0742	3.633656	102.8	225.535
44	535.7033	107.1400	262.6183	53.6367	0.0543	2.459464	150.6	469.315
45	296.2800	59.2529	148.1371	29.6257	0.0682	3.622634	20.05	201.4328
46	185.6440	37.1480	92.8200	18.5620	0.0851	4.087379	139.56	255.032
47	258.5886	52.3200	129.2271	26.1586	0.0957	4.794627	15.76	175.9357
48	262.4367	52.4867	131.2150	26.2433	0.053	2.512613	53.81	213.7783
49	150.4500	30.0914	75.2229	15.2643	0.086	4.030347	159.28	253.7972
50	373.9829	74.7957	186.9886	71.5429	0.0596	2.974344	99.68	361.1815
51	303.2757	60.6543	151.6357	30.3257	0.0684	3.335588	157.93	343.2314
52	340.4471	68.0900	170.2214	34.0429	0.149	7.632585	140.3	352.1943
53	205.7786	41.1543	102.8857	20.5786	0.1267	6.086909	93.71	223.2643
54	238.9450	47.7883	119.4700	23.8900	0.0969	4.764767	78.79	226.91
55	265.5029	53.1000	132.9629	26.5500	0.004	0.192327	39.56	199.2629
56	859.8620	168.3720	429.9300	84.1860	0.009	0.415124	69.51	584.046
57	283.8767	56.6767	141.9350	28.3367	0.008	0.382339	51.13	221.7817
58	268.4967	53.7000	134.2450	26.8500	0.003	0.150362	81.99	243.235
59	208.9350	41.7850	104.4050	20.8900	0.005	0.235047	119.84	245.375
60	273.6667	54.7300	136.8317	27.3617	0.009	0.452987	94.83	259.4734
61	249.0400	49.8067	124.5167	24.9033	0.0589	3.06151	82.89	235.37
62	201.5000	40.2967	100.7467	20.1450	0.0777	3.888955	101.24	226.0217
63	173.9683	34.7950	86.9817	17.3967	0.0919	4.426961	70.97	179.7784
64	318.6417	63.7300	158.5200	31.8633	0.1195	5.890478	104.14	300.4133
65	249.7850	49.9567	124.8900	24.9767	0.0846	4.25928	77.48	231.6067
66	546.8317	109.3650	273.4133	54.6783	0.0823	3.957091	132.65	464.7016
67	387.4717	77.4933	193.7333	38.7450	0.0508	2.547859	160.64	395.6683
68	255.2867	51.0583	127.6417	31.8633	0.1084	4.882228	168.95	333.335
69	196.9657	39.3957	98.4800	19.6943	0.1451	6.879336	120.88	245.9343
70	71.3233	14.2633	35.6600	7.1317	0.0634	3.227142	125.3	171.3217
71	159.4733	31.8950	79.7350	15.9450	0.1214	5.715051	86.2	187.6
	259.18	**51.90**	**128.5992**	**26.52082**	**0.076**	**3.12**	**94.9632**	**564.96**

7.7 APPENDIX 7: Summary of mean carbon stocks and CO_2 sequestration in each carbon pools and total carbon stock per plots of the Gendo forest forests.

Plot no	AGC (ton/ha)	BGC (ton/ha)	AG CO_2 (ton/ha)	BG CO_2 ton/ha)	LC (ton/ha)	SOC (ton/ha)	TOTAL (ton/ha)
1	51.4740	11.3760	188.9096	41.74992	0.620418	105.6	169.0704
2	31.1620	6.2340	114.3645	22.87878	1.027185	111.66	150.0832
3	101.9057	20.3800	373.9939	74.7946	2.261419	125.37	249.9171
4	110.3814	22.0771	405.0997	81.02296	1.621926	136.21	270.2904
5	71.6150	14.3233	262.8271	52.56651	1.254307	73.58	160.7726
6	101.6384	20.3260	373.0129	74.59642	2.062012	85.74	209.7664
7	102.2250	20.4450	375.1658	75.03315	2.14617	19.11	143.9262
8	247.2650	49.4583	907.4626	181.512	1.816465	126.62	425.1598
9	120.1129	24.0129	440.8143	88.12734	2.622287	118.63	265.3781
10	75.6686	15.1357	277.7038	55.54802	2.136981	155.36	248.3013
11	194.4186	38.8814	713.5163	142.6947	2.241474	96.03	331.5715
12	241.2883	48.2550	885.5281	177.0959	3.724776	86.84	380.1081
13	166.6367	33.3267	611.5567	122.309	2.125689	70.72	272.8091
14	66.7883	13.3550	245.1131	49.01285	0.499656	136.02	216.663
15	90.9367	18.1867	333.7377	66.74519	0.752141	29.04	138.9155
16	94.3517	18.8700	346.2707	69.2529	3.043573	161.94	278.2053
17	60.9657	12.1929	223.7441	44.74794	6.478651	135.97	215.6073
18	76.5443	15.3071	280.9176	56.17706	4.742114	105.41	202.0035
19	94.6660	18.9320	347.4242	69.48044	2.569641	119.32	235.4876
20	55.3467	11.0667	203.1224	40.61479	2.408164	79.91	148.7316
21	80.9763	16.1938	297.183	59.43125	3.710541	55.02	155.9006
22	50.1357	10.0243	183.998	36.78918	2.997683	75.64	138.7977
23	144.7900	28.9557	531.3793	106.2674	4.060857	69.55	247.3566
24	118.8057	23.7586	436.0169	87.19406	2.498229	136.3	281.3625
25	111.9429	22.3871	410.8304	82.16066	4.254864	155.26	293.8449
26	181.4717	36.2933	666.0011	133.1964	2.95346	108.67	329.3885
27	124.8671	24.9700	458.2623	91.6399	5.864027	93.43	249.1311
28	75.0671	15.0129	275.4963	55.09734	47.73434	102.27	196.93
29	117.5329	23.5057	431.3457	86.26592	4.351742	89.43	234.8203
30	51.9333	20.3183	190.5952	74.56816	0.089669	48.68	121.0213
31	189.4683	43.4817	695.3487	159.5778	0.138108	47.75	280.8381
32	169.1975	33.8363	620.9548	124.1792	0.244744	29.71	232.9885
33	153.9850	30.7933	565.125	113.0114	0.446056	30.08	215.3044
34	160.9914	32.1886	590.8384	118.1322	0.352857	45.25	238.7829
35	114.9425	22.9950	421.839	84.39165	2.812158	66.47	207.2197
36	105.9100	21.1857	388.6897	77.75152	3.143818	117.67	247.9095
37	141.2971	28.2571	518.5604	103.7036	2.906011	60.03	232.4902
38	138.9186	27.7829	509.8313	101.9632	8.575557	106.33	281.6071
39	76.5825	15.3113	281.0578	56.19247	8.813558	93.81	194.5174
40	198.0929	39.6171	727.0009	145.3948	6.171995	92.38	336.262
41	107.0917	21.4133	393.0265	78.58681	2.68436	70.01	201.1994
42	206.8300	41.3167	759.0661	151.6323	3.30081	69.1	320.5475

Plot no	AGC (ton/ha)	BGC (ton/ha)	AG CO_2 (ton/ha)	BG CO_2 ton/ha)	LC (ton/ha)	SOC (ton/ha)	TOTAL (ton/ha)
43	99.2550	19.8500	364.2659	72.8495	3.633656	102.8	225.5387
44	262.6183	53.6367	963.8092	196.8467	2.459464	150.6	469.3145
45	148.1371	29.6257	543.6632	108.7263	3.622634	20.05	201.4354
46	92.8200	18.5620	340.6494	68.12254	4.087379	139.56	255.0294
47	129.2271	26.1586	474.2635	96.00206	4.794627	15.76	175.9403
48	131.2150	26.2433	481.5591	96.31291	2.512613	53.81	213.7809
49	75.2229	15.2643	276.068	56.01998	4.030347	159.28	253.7975
50	186.9886	71.5429	686.2482	262.5624	2.974344	99.68	361.1858
51	151.6357	30.3257	556.503	111.2953	3.335588	157.93	343.227
52	170.2214	34.0429	624.7125	124.9374	7.632585	140.3	352.1969
53	102.8857	20.5786	377.5905	75.52346	6.086909	93.71	223.2612
54	119.4700	23.8900	438.4549	87.6763	4.764767	78.79	226.9148
55	132.9629	26.5500	487.9738	97.4385	0.192327	39.56	199.2652
56	429.9300	84.1860	1577.843	308.9626	0.415124	69.51	584.0411
57	141.9350	28.3367	520.9015	103.9957	0.382339	51.13	221.784
58	134.2450	26.8500	492.6792	98.5395	0.150362	81.99	243.2354
59	104.4050	20.8900	383.1664	76.6663	0.235047	119.84	245.37
60	136.8317	27.3617	502.1723	100.4174	0.452987	94.83	259.4764
61	124.5167	24.9033	456.9763	91.39511	3.06151	82.89	235.3715
62	100.7467	20.1450	369.7404	73.93215	3.888955	101.24	226.0207
63	86.9817	17.3967	319.2228	63.84589	4.426961	70.97	179.7754
64	158.5200	31.8633	581.7684	116.9383	5.890478	104.14	300.4138
65	124.8900	24.9767	458.3463	91.66449	4.25928	77.48	231.606
66	273.4133	54.6783	1003.427	200.6694	3.957091	132.65	464.6987
67	193.7333	38.7450	711.0012	142.1942	2.547859	160.64	395.6662
68	127.6417	31.8633	468.445	116.9383	4.882228	168.95	333.3372
69	98.4800	19.6943	361.4216	72.27808	6.879336	120.88	245.9336
70	35.6600	7.1317	130.8722	26.17334	3.227142	125.3	171.3188
71	79.7350	15.9450	292.6275	58.51815	5.715051	86.2	187.5951
Mean	**128.5992**	**26.52082**	**471.96**	**97.33**	**3.12**	**94.9632**	**164.96**

7.8 APPENDIX 8: ONEWAY AGC BGC LC SOC BY Altitude group

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ANOVA

		Sum of Squares	Df	Mean Square	F	Sig.
AGC	Between Groups	3357.177	2	1678.589	.410	.665
	Within Groups	278334.601	68	4093.156		
	Total	281691.778	70			
BGC	Between Groups	143.218	2	71.609	.379	.686
	Within Groups	12851.795	68	188.997		
	Total	12995.013	70			
LC	Between Groups	453.749	2	226.874	8.530	**.000**
	Within Groups	1808.515	68	26.596		
	Total	2262.263	70			
SOC	Between Groups	30661.008	2	15330.504	13.939	**.000**
	Within Groups	74788.131	68	1099.825		
	Total	105449.139	70			

ONEWAY **AGC BGC LC SOC** BY Slope group

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ANOVA

		Sum of Squares	Df	Mean Square	F	Sig.
AGC	Between Groups	5629.659	2	2814.829	.693	.503
	Within Groups	276062.120	68	4059.737		
	Total	281691.778	70			
BGC	Between Groups	222.283	2	111.141	.592	.556
	Within Groups	12772.730	68	187.834		
	Total	12995.013	70			
LC	Between Groups	39.581	2	19.790	.605	.549
	Within Groups	2222.682	68	32.687		
	Total	2262.263	70			
SOC	Between Groups	58322.914	2	29161.457	42.078	**.000**
	Within Groups	47126.226	68	693.033		
	Total	105449.139	70			

ONEWAY **AGC BGC LC SOC** BY Aspect group
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ANOVA

		Sum of Squares	Df	Mean Square	F	Sig.
AGC	Between Groups	32458.255	7	4636.894	1.172	.332
	Within Groups	249233.523	63	3956.088		
	Total	281691.778	70			
BGC	Between Groups	1188.243	7	169.749	.906	.508
	Within Groups	11806.770	63	187.409		
	Total	12995.013	70			
LC	Between Groups	265.037	7	37.862	1.194	.319
	Within Groups	1997.226	63	31.702		
	Total	2262.263	70			
SOC	Between Groups	23369.331	7	3338.476	2.562	**.002**
	Within Groups	82079.808	63	1302.854		
	Total	105449.139	70			