ESTIMATION OF BIOMASS AND SOIL CARBON STOCK ALONG ALTITUDINAL GRADIENT OF ANCHEBBI DRY AFROMONTANE FOREST IN DANNO DISTRICT WEST SHEWA ZONE, ETHIOPIA

MSc. THESIS

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A THESIS SUBMITTED TO

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN FOREST RESOURCE ASSESSMENT AND MONITORING

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Approval Sheet - I

This is to certify that the thesis entitled ‟Estimation of Biomass and Soil Carbon Stock Along Altitudinal Gradient of Anchebbi Dry Afromontane Forest in Danno District West Shewa Zone, Ethiopia" submitted in partial fulfillment of the requirements for the degree of Master of Science with specialization in Forest Resource Assessment and Monitoring of the graduate program under the school of natural resources and environment studies, department of general forestry, Wondo Genet College of Forestry and Natural Resources, Hawassa University, Ethiopia and is recorded of original thesis has been carried out by Lechisa Mosisa Kenea ID No. MSc/FrAm/R013/10, under my supervision; and no part of the thesis has been submitted for any other degree or diploma. Therefore, I recommended that it be acceptable as fulfilling of the thesis requirements.

Submitted by: Lechisa Mosisa _______________ _____________________

Approved by	Signature	Date
Dr. Motuma Tolera	__________________	____________________
Main advisor	Signature	Date
Dr. Mulugeta Zewdie	__________________	___________________
Co-advisor advisor	Signature	Date

Approval Sheet - II

We, the undersigned, members of the board of examiners of the final open defense by Lechisa Mosisa Kenea have read and evaluated his thesis entitled "Estimation of Biomass and Soil Carbon Stock Along Altitudinal Gradient of Anchebbi Dry Afromontane Forest in Danno District West Shewa Zone, Ethiopia", and examined the candidate. This is therefore, to certify that the thesis has been accepted in partial fulfillment of the degree of master science.

Name of Chairperson	Signature	Date
Name of Internal Examiner	Signature	Date
Name of External Examiner	Signature	Date
SGS Approval	Signature	Date

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List of Abbreviations and Acronyms

ADAF	Anchebbi Dry Afromontane Forest
AGB	Aboveground Biomass
AGC	Aboveground Carbon
BGB	Belowground Biomass
BGC	Belowground Carbon
C	Carbon
CO_2	Carbon dioxide
CSA	Central Statistics Agency
DANRO	Danno Agriculture and Natural Resource Office
DBH	Diameter at Breast Height
ECRGE	Ethiopia Climate Recilience Green Economy
FAO	Food and Agriculture Organization of the Unite Nation
GHG	Greenhouse Gas
GPS	Global Positioning System
Gt.	Giga ton
ha	Hectare

Ht	Height
ICIMOD	International Centre for Integrated Mountain Development
IPCC	Intergovernmental Panel on Climate Change
LHG	Litter Herb Grass
LHGB	Litter, Herb and Grass Biomass
LHGC	Litter herb grass carbon
MEFCC	Ministry of Environment, Forest and Climate Change
OFWE	Oromia Forest and Wildlife Enterprise
QGIS	Quantum Geographical Information System
REDD+	Reducing Emissions from Deforestation and Forest Degradation, Forest Conservation, Sustainable Management of Forests, and Enhancement of Forest Carbon Stocks
SOC	Soil Organic Carbon
UNFCCC	United Nations Framework Convention on Climate Change

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Estimation of Biomass and Soil Carbon Stock Along Altitudinal Gradient of Anchebbi Dry Afromontane Forest in Danno District West Shewa Zone, Ethiopia. By Lechisa Mosisa, Email: lechisamq@gmail.com

Abstract

Forests play an important role in storing biomass carbon and soil organic carbon to mitigate the risk of global climate change. However, the carbon stocking process was affected by various environmental factors such as: elevation, aspect and slope. Thus, the present study was aimed to estimate the potential of carbon stock variation along altitudinal gradients in the study area. Based on altitude gradient and digital elevation model, the study area was stratified into two strata (lower and higher altitude). A systematic transect sampling method was laid and navigated using compass, meter tape and GPS to identify and locate each 60 representative sampling plots (15mx20m each) with an interval of 250m between transect line and consecutive plots. Litter and soil sample were collected from five and three sub- plots respectively (1m^2 each) at four corners and one at the center of the main plot. Allometric equation was used to estimate AGB while, BGB was determined using root-to-shoot ratio method. The data were analyzed by using Minitab statistical software. The result of the present study revealed that the total mean carbon stock density of 287.35 ton/ha whereas, AGB and BGB carbon shares 110.4 ± 12 ton/ha and 28.75 ± 3.12 ton/ha respectively. Also the share of litter carbon was 1.28 ± 0.08 ton/ha and soil organic carbon were 146.92 ± 8.75 ton/ha (up to 60cm depth). The higher AGC and BGC stock was estimated in higher altitude than the lower altitude gradient while; higher litter carbon and soil organic carbon stock was estimated in lower altitude than higher altitude class. However, except soil organic carbon stock, the carbon storage in all carbon pools was not show significant difference. Therefore, the final result of the study area was indicated an important carbon reservoir in all carbon pools and can play a major role to mitigate the current climate change.

Keywords: Higher altitude, Lower altitude, Anchebbi forest, Biomass carbon, Allometric equation.

1. Introduction

1.1. Background

An increases in the concentration of carbon dioxide (CO_2) and other greenhouse gases (GHGs) within the atmosphere is currently recognized as the major cause of climate change (IPCC, 2007a). The continued increase in its concentration within the atmosphere is believed to be accelerated by human activities like burning of fossil fuels and deforestation (IPCC, 2007b; Mensah *et al.*, 2016). However, a healthy ecosystem can provide a variety of essential services for public goods, such as clean water provision, nutrient cycling, climate regulation and food security (FAO, 2011). Particularly, forest play a significant role in global climate change mitigation by sequestering and storing more carbon (C) from the atmosphere than any other terrestrial ecosystem (Tulu Tolla and Zewdu Eshetu, 2013).

The vegetation of tropical forest is a large and globally significant reservoir of C because, tropical forest contains more C per unit area than any other land cover (Hairiah *et al.*, 2011; Kumar *et al.*, 2013; Spracklen and Righelato, 2014). Nowadays, there have been growing interests in the estimation of forest C, mainly in the context of the rules established in the Kyoto Protocol. Accordingly, the CO_2 emissions limit for every countries and must be estimated by taking the C sinks and sources under consideration, including the CO_2 absorbed and keep by forest (Zhang *et al*., 2007; Baul *et al*., 2017). Thus, the estimation of accumulated biomass C in the forest ecosystem is an important to evaluate the productivity and sustainability of forest. It also gives an awareness on the potential amount of C that can be emitted in the form of CO_2 when forests are being cleared or burned (Vashum and Jayakum, 2012).

Ethiopia is one of the country's that has been projected to realize 50% of the national GHG emissions reduction successfully in the forest sector through the implementation of REDD+ and CRGE strategy by 2030 to mitigate current climate change (ECRGE, 2011). Although, the country's forest resources play an important role by storing about 2.76 billion tons of C in the AGB (Yitebitu Moges *et al*., 2010). Among forest vegetation's in Ethiopia, Dry Afromontane forest have a major potential in ecosystem service such as: habitat provision, biodiversity conservation, nutrient cycling and climate regulation (MEFCC, 2017). Despite the fact that, carbon stocking process in a forest could vary depending upon various factors such as: physical factor (rainfall, temperature, and soil type), biological factors (tree species composition, stand age and density), environmental factors (altitude, aspect and slope) and anthropogenic factors (Abreha Kidanemariam *et al*., 2012; Korner, 2007; Alefu Chinasho *et al*., 2015; Tibebu Yelemfrhat *et al*., 2014; Hamere Yohannes *et al*., 2015; Adugna Feyissa *et al*., 2013 and Ali *et al*., 2014). Even though, altitude is among the powerful environmental factor that affects C stock potential of the forest.

Anchebbi Dry Afromontane forest is one of the remaining pocket forests located in Danno district and covers about 462 ha of land. This natural forests, plays a main role to mitigate the risk of current climate changes by sequestering and storing C in their biomass and soil. However, no study has been conducted on the role of altitude gradient to determine the quality and potential of forest biomass C and SOC stock in Anchebbi Dry Afromontane forest (especially in Danno district). To reduce the gaps of information, the estimation of C stocks by considering altitude variation is an important concern to mitigate GHG emission. Therefore, the estimation of biomass C and SOC stock along altitudinal gradients using the direct field inventory without tree destruction was conducted in the study area.

1.2. Statement of the problem

The continued GHG emissions at current rates would cause further warming and encourage many changes in the global climate system (IPCC, 2007a). An increases in the concentration of CO_2 in the atmosphere has a higher effect on climate change and caused due to the consumption of fossil fuel, deforestation and other anthropogenic factors (Mensah *et al*., 2016). Deforestation and forest degradation are the major cause of global warming and responsible for about 15% of global GHG emissions, which makes the loss and depletion of forests and a major cause of climate change (IPCC, 2007a). According to IPCC Good practice guidance, countries are encouraged to develop inventories of GHG emission on the way of well transparent, documented, and consistent over time. Also, measuring, verifying, and reporting the changes in forest C stocks and human-caused GHG emission is an important issues (IPCC, 2006).

However, Ethiopia has been carried out a very limited forest C stock study by considering environmental factors like altitude variation which influence carbon stock's potential (Hamere Yohannes *et al*., 2015). Also, spatially explicit estimates of forest biomass C stock over large areas may be limited by the altitudinal range of the forest inventory relative to the area of interest (Tibebu Yelemfrhat *et al.*, 2014). Thus, the same is true for Anchebbi Dry Afromontane forest. Anchebbi Dry Afromontane forest is a natural forest that needs further studies on the potential of carbon stock along altitudinal gradients to focus on sustainable conservation and management. However, the study has not yet been conducted in the Anchebbi Dry Afromontane forest on the estimation of biomass C and SOC stock.

Thus, the estimation of C stock by considering the environmental factor (altitude variation) which affects the C stock's potential was conducted to reduce the problem. Similarly, the estimating and organizing C stock data of the study area have play a significant role to mitigate current climate change. Therefore, this study was conducted through quantifying the potential of C stock in the study area by considering biomass C and SOC in relation to altitudinal gradients.

1.3. Objectives of the study

1.3.1. General objective

The overall objective of this study is to quantify carbon stocks of Anchebbi Dry Afromontane forest ecosystem along altitudinal gradients in different carbon pools.

1.3.2. Specific objective

The specific objectives of this study are;

1. To estimate the amount of biomass carbon stock along altitudinal gradient in the study area,
2. To estimate soil organic carbon of the study area along altitudinal gradient,
3. To quantify the total carbon stocks of forest ecosystem in the study area.

1.4. Research question

Particularly, this study answered the following research questions:

1. How much carbon is stored in biomass along altitudinal gradient in the study area?
2. How much carbon is stored in soil organic matter along altitudinal gradient in the study area?
3. How much carbon is stored in the whole forest ecosystem of the study area?

1.5. Significance of the study

Nowadays, the importance of forest in carbon cycling is an increasing attention. By the existing interests in GHG emissions and their impacts on global climate change, an accurate and precise investigation of carbon stocks in forest has obviously required. Thus, the estimation of carbon stock has increased significantly due to the role of forests in the mitigation of global climate change through carbon storage in their biomass and soil (Ruiz-Peinado *et al.*, 2012).

Therefore, the significance of the study was provided information about the current status of Anchebbi Dry Afromontane forest and addresses the role of this forest in climate change mitigation by sequestering and storing carbon from the atmosphere. Also, this study fills the gap of awareness toward the influence of the environmental factors like altitude on forest biomass carbon and SOC stock.

The data of carbon stock estimation based on altitude variation is important to know the potential of Anchebbi Dry Afromontane forest. It also gives meaningful information for Jibat-Gedo Forest District to emphasis on sustainable forest management for carbon stocks and climate change mitigation by reducing GHG emission in the atmosphere. It also provides organized and documented carbon stock data about this forest for the district, researcher, decision maker, government and non-government organization and other concerned body for climate change mitigation.

2. Literature Review

2.1. Overview of global climate change

Global climate change is a change in either the mean state of the climate or in its variability, continuing for several decades which are attributed directly or indirectly to human activity that alters the composition of the global atmosphere. The impact also definite and representing one of the greatest environmental, social and economic challenges that exists on the Earth are currently facing (IPCC, 2007b). Nowadays, the concept of human induced climate change is accepted as reality and indicated at the top of the list alarming issue, for instance; global warming, having attentions from the local level to the stages of international higher level government forum (IPCC, 2007b).

The current unfamiliar global climate change is observed due to anthropogenic greenhouse gas (GHG) emissions, mainly CO_2 concentration which is rising in the atmosphere by irresponsible activities of fossil fuel combustion and deforestation. As a result, the natural balance of CO_2 sequestration and release that takes place between sinks and sources has been disturbed by which global net annual emission exceeds annual sequestration. Which is beyond an acceptable level of GHGs accumulation in the atmosphere and therefore, causes global climate change (IPCC, 2014). According to IPCC report (2007a), the amount of CO_2 in the atmosphere increased from 280 ppm (part per million) in the pre-industrial era (1750) to 379 ppm in 2005, and is increasing by 1.5 ppm per year (IPCC, 2007a).

2.2. Forest stratification and definition

Forest stratification refers to the division of any heterogeneous forest landscape into separate sub sections (or strata) based on some common grouping factor (Pearson *et al.*, 2005). In this case, the grouping factor is the stock of carbon in the vegetation (Tadesse Woldemariam, 2015). If multiple forest types are across a country, stratification is the first step in a well-designed sampling scheme for estimating carbon emission associated with deforestation and degradation over both large and small areas. Stratification is the critical step that will allow the association of a given area of deforestation and degradation with an appropriate vegetation carbon stock for calculation of emissions (Pearson *et al*., 2005; Tadesse Woldemariam, 2015).

The forest definition agreed on by the United Nations Framework Convention on Climate Change (UNFCCC) in the context of the Kyoto Protocol refers to a country-specific choice for a threshold canopy cover (10 to 30%), tree height (2 to 5 m) and area (0.05 to 1 hectare) has been widely discussed and accepted in general (Hairiah *et al*., 2011). As a result, a new forest definition was adopted in Ethiopia by MEFCC on Feb. 2015. Accordingly, forest refers to: 'Land spanning at least 0.5 ha covered by trees (including bamboo) attaining a height of at least 2 meter and a canopy cover of at least 20% or trees with the potential to reach these thresholds in situ in due course' (EFRL, 2016).

2.3. Measurements of forest biomass carbon stocks

Globally, forest covers about 4 billion hectares of land or nearly 31% of the earth's land surface that has been estimated to hold a total of 289 Gt. of carbon in their biomass only (FAO, 2010). Rapid deforestation and heavy industrialization increase the amount of greenhouse gas in the atmosphere. Hence, essential forest management has been focused on altering deforestation and forest degradation targeting to get benefit from reducing emission from deforestation and forest degradation (REDD+) program in response to climate change (Jaman *et al*., 2016). The estimation of forest carbon stocks has increased importance due to the role of forests in the mitigation of global climate change through carbon storage in biomass and soil (Ruiz-Peinado *et al*., 2012). Forest biomass, expressed in terms of dry weight of living organisms, is an important measure for analyzing ecosystem productivity and also for assessing energy potential and the role of forests in the carbon cycle (FAO, 2010).

2.4. Carbon pools

Carbon pools are components of the ecosystem that can either accumulate or release carbon and have typically been split into five main categories (figure 1): A = living aboveground biomass (AGB), B = living belowground biomass (BGB), C = dead organic matter (DOM) in wood, D = DOM in litter and E = soil organic matter (Watson Charlene, 2009).

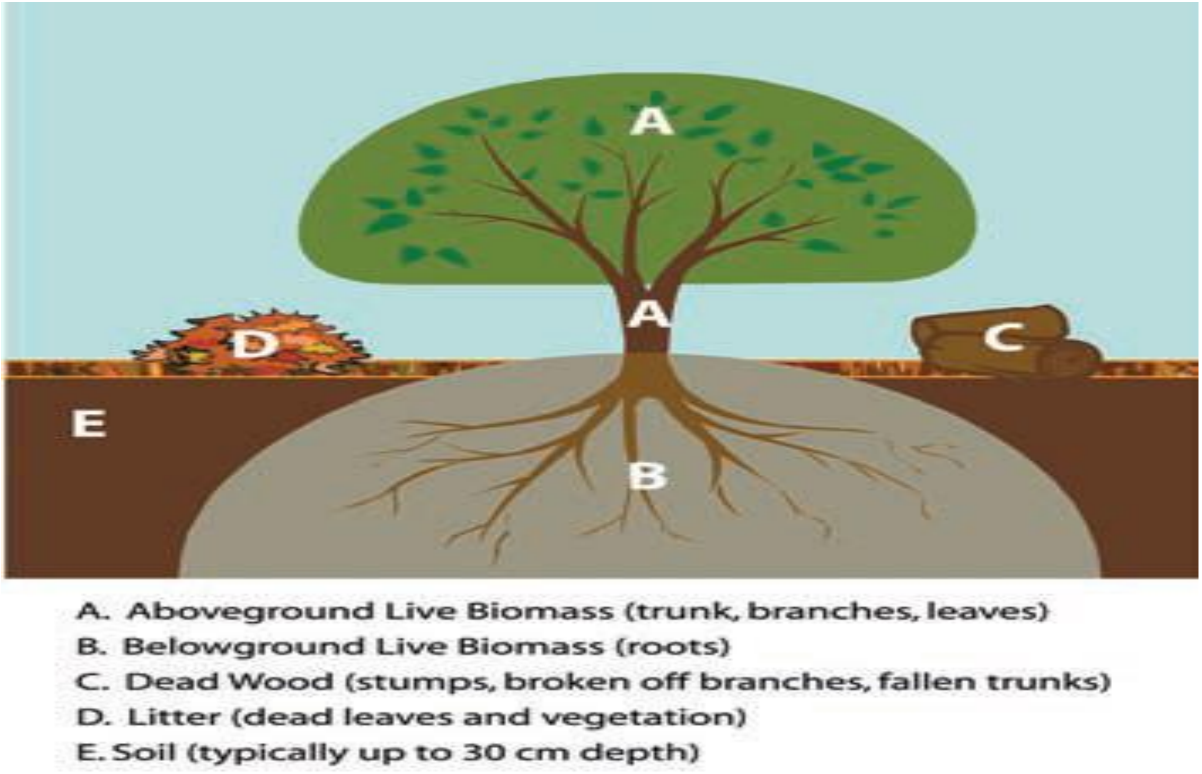

Figure 1 : Diagrammatic representation of carbon pools (Source: REDD+, 2009).

2.4.1. Aboveground biomass carbon

The AGB carbon pool consists the comprehensive of living biomass above the soil, including stem, stump, branches, barks, seeds and foliage (Pearson *et al*., 2005; UNFCCC, 2015). The AGB accounting is broadly divided into two that in trees and that in the understory. The most comprehensive method to establish the biomass of this carbon pool is destructive sampling, where by vegetation is harvested, dried to a standardized mass and the dry-to-wet biomass ratio well-known. Destructive case in point of trees, on the other hand over, is both well-appointed and somewhat burden and hinder in the construction of promoting carbon appropriation (Schroeder *et al*., 1997). The other method which used for above and below ground biomass estimation is using a different Allometric equation that has been developed and used by many researchers. Some of those equations were species specific while the others were geographical location dependent and others were not specified (Negi *et al*., 2003).

About 50% of plant biomass consists of carbon (Pearson *et al*., 2005). The carbon stored in the aboveground living biomass of trees is typically the largest pool and the most directly impacted by deforestation and forest degradation (Hairiah *et al*., 2011). Generally, aboveground biomass (AGB) represent the largest sources of emissions than the other carbon pools with the exception of organic soils (UNFCCC, 2015). The estimation of AGB carbon is, therefore, the most critical step in quantifying carbon stocks and fluxes from tropical forests (Hairiah *et al*., 2011; Kumar and Sharma, 2015).

Thus, an Allometric equation is a statistical relationship between key characteristic dimension(s) 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 (Bhishma *et al*., 2010). Allometric equations are established in a purely empirical way on the basis of exact measurements from a relatively large sample of typical trees. They permit an estimate of quantities that is difficult or costly to measure on the basis of a single (or at most a few) measurement. The selection of the appropriate Allometric equation is a crucial step in estimating aboveground tree biomass (AGB) Allometric equations for biomass usually include information on trunk diameter at breast height DBH (in cm), total tree height (in m), and wood-specific gravity (in g/cm³) (Bhishma *et al*., 2010). So, wood-specific gravity is an important predictive variable in the regression model.

2.4.2. Belowground biomass carbon

The BGB carbon pool consists of the biomass restricted within live roots. Fine roots of less than 2 mm diameter are sometimes excluded because these often cannot be distinguished empirically from soil organic matter or litter (UNFCCC, 2015). As with AGB, even if less data exist, regression equations from root biomass data have been formulated which predict root biomass based on aboveground biomass carbon (Brown, 1997; Cairns *et al*., 1997). According to Cairns *et al*. (1997) cited in IPCC, 2003 review 160 studies casing tropical, temperate and boreal forests and find a mean root-to-shoot ratio of 0.26, ranging between 0.18 and 0.30 (IPCC, 2003). Although roots are believed to depend on climate and soil characteristics (Brown and Lugo, 1982; Cairns *et al*., 1997) found that root-to-shoot were stable between latitude (tropical, temperate and boreal), soil texture (fine, medium and coarse), and tree-type (angiosperm and gymnosperm) (Cairns *et al*., 1997). As with AGB, the application of default root-to-shoot ratios represents a trade-off between expenses of time, resources and accurateness. BGB can also be assessed locally by taking soil cores from which roots are extracted; the oven dries weight of these roots can be related to the cross-sectional area of the trial, and so to the BGB on a per area basis (MacDicken, 1997).

2.4.3. Deadwood and litter organic carbon

Deadwood contains all non-living woody biomass not contained in the litter, either standing or lying on the ground or in the soil. Deadwood also includes wood lying on the surface, dead roots, and stumps larger than or equal to 10 cm in diameter (Pearson *et al*., 2005; UNFCCC, 2015). Litter biomass include all non-living biomass with a diameter less than a minimum diameter chosen by the host country (for example, 10 cm), lying dead or in various states of decomposition above the mineral or organic soil. Live fine roots (of less than the suggested diameter limit for belowground biomass) are included in a litter where they cannot be distinguished from it empirically (UNFCCC, 2015). The values of the default adjustment factors reflecting the effect of management intensity or disturbance regime are 1.0. Sometimes data on litter pools are collected in terms of dry matter, not carbon. To convert to dry matter mass of litter to carbon, multiply the mass by a default value of 0.370 (IPCC, 2003), not the carbon fraction used for biomass.

2.4.4. Soil organic carbon:

Soils are the largest carbon reservoir of the terrestrial carbon cycle. Globally, they contain three or four times more organic carbon (1500 Gt. up to 1 m depth, 2500 Gt. up to 2 m depth) than vegetation (610 Gt.) and twice or three times as much carbon as the atmosphere (750 Gt) (Petrokofsky *et al*., 2012). Carbon storage in soils is the balance between the input of dead plant material (leaf, root litter, and decaying wood) and losses from decomposition and mineralization of organic matter (‘heterotrophic respiration’) (Petrokofsky *et al.*, 2012). Soil carbon organic includes carbon in both mineral and organic soils (including compost) to a specified depth chosen by the host country and applied consistently through the time series. Live fine roots (of less than the suggested diameter limit for belowground biomass) are included with soil organic matter where they cannot be distinguished from it empirically (UNFCCC, 2015). On the other hand, the wooded area administration has superior impact on natural carbon and so in untreated carbon collisions are for the most part unaccounted (Eggleston *et al* ., 2006).

Soil carbon is a significant determinant of site fruitfulness due to its role in maintaining soil physical and substance property such as comprehensive immovability, caution switch over and water investment capability (Davidson *et al*., 2000). Soil stores 2 or 3 periods more carbon than that which exists in the idea as CO2 and 2.5 to 3 times as much as that store in the plants in the possible natural balance. Land-use and soil-management practice can significantly pressure Soil Organic Carbon (SOC) dynamics and carbon flux on or after the soil. Spatially disseminated estimate of SOC pools and flux are vital necessities for thoughtful the responsibility of soils in the worldwide carbon cycle and for assessing likely biosphere answer to climatic transform or change (Schimel *et al*., 2000).

2.5. The role of forest resources

The vegetation of tropical forest is a large and globally significant storage of carbon because tropical forest contains more carbon per unit area than any other land cover (Hairiah *et al*., 2011). The main carbon pools in tropical forest ecosystems are the living biomass of trees and understory vegetation and the dead mass of litter, woody debris and soil organic matter (Hairiah *et al*., 2011). Ethiopia has a significant amount of forest resources and play critical roles in providing valuable ecological service and economic resources for the country’s overall development, and for the rural population in forest regions which are heavily dependent on these resources for their livelihoods (FDRE, 2018). Moreover, the forest and woody vegetation of Ethiopia play an important ecosystem service such as: habitat provision, watershed conservation, biodiversity conservation and climate regulation in sequestering anthropogenic atmospheric carbon and other socioeconomic roles (Yitebitu Moges *et al*., 2010).

2.6. Afromontane forest of Ethiopia

The dry evergreen Afromontane forests are occurring especially in the centeral and highlands of the floristic regions of Ethiopia at altitudes between 1500 and 2700 m and, with annual rainfall between 700 and 1100 millimeters Friis *et al*., 2010). Sometimes, it is difficult to define these based on parameters as altitude or rainfall, nor to draw boundaries between them manually, based on personal observations. The canopy is usually dominated by *Juniperus procera (Cupressaceae), Podocarpus falcatus (Podocarpaceae), Olea europaea subsp. cuspidata (Olcaceae), Croton macrostachyus (Euphorbiaceae),* and *Ficus* species *(Moraceae)* (Friis *et al*., 2010).Whereas, the moist evergreen Afromontane forest represents the most diverse forest ecosystem in Ethiopia, occurs mainly in the Southwest and Western highlands between (1500 to 1800 and 2600 to 3000) meters, and receiving the highest mean annual rainfall in the country, with an annual rainfall between 700 and 2000 mm. (or more). The Harenna forest on the southeastern slopes of Bale Mountains is the eastern-moist example of this forest. These forests predominantly contain broad-leaved evergreen species in the multilayered canopy (Friis *et al*., 2010). These forests are recognized as high forests with closed continuous canopy cover (OFWE, 2014).

2.7. Factors affecting forest carbon stock

Carbon stocking process in a forest could vary depending upon various factors such as: species distribution, solar radiation, land use changes and deforestation (Korner, 2007). Similarly, forest carbon stock could be affected by different environmental factors such as: altitude, slope and aspect gradients. It is also well-known carbon stock variations due to the presence of different tree species, soil nutrient availability, climate, disturbance and management regime (Houghton, 2005). In Ethiopia, different studies also showed that forest carbon stock had affected by such factors (Asersie Mekonnen and Motuma Tolera, 2019; Belay Melese *et al.*, 2014; Muluken Nega *et al.*, 2015 and Mohammed Gedefaw *et al.*, 2014).

2.8. Biomass and soil carbon stock trends along an altitude gradient

Changes in forest soil carbon inputs could be one factor underlying the association fixed between forest soil carbon stocks and elevation. Greater soil carbon stocks at higher elevations could be the product of increased carbon inputs in combination with a relatively constant rate of soil carbon loss through decomposition of organic matter (Garten Jr, 2004). Aboveground litter fall and root mortality are the two primary processes that contribute to soil carbon inputs along altitude gradients, and relatively little is known about how belowground carbon inputs might vary with elevation (Garten Jr, 2004). Slope gradient is another environmental variable that can influence the distribution of carbon in different forest carbon pools. The carbon partitioning among forest C pools along slope gradients is important in knowing the possible change in C stock and thus, C sequestration potential in response to the future climate change in mountain regions (Zhu *et al.*, 2010). Although the SOC density tended to be low in the higher slope and higher in lower slope areas. The SOC and solar radiation is negatively correlated due to the high negative correlation between solar radiation and slope gradient. Flatter areas receive more all year radiation than steeper slopes, which are sheltered for some of the day (Adugna Feyissa and Teshome Soromessa, 2017).

2.9. Plot size and shape

The size of sample plot impacts both the efficiency of statistical estimation and the practical considerations such as the cost and ease of measurement. If trees are relatively homogeneous size, small plots will be more efficient. If trees are of widely different sizes, as in a mixed, uneven-aged plantation or an old-growth forest, local variability will be higher and therefore larger plots will be more efficient (UNFCCC, 2015). To balance the twin objectives of capturing enough local variability and ensuring ease of plot measurement, selection of the plot size can be guided by this rule of thumb: select a plot size so that, on average, a sample plot is likely to include 10 to 15 trees in a relatively homogeneous stand and 15 to 20 trees in a more heterogeneous stand. Representative plot sizes used in forest inventory are 200m^2, 400m^2, and 500m^2, but any size could possibly be used. Cluster plot designs can be used under appropriate conditions for reducing the plot size (UNFCCC, 2015).

3. Materials and Methods

3.1. General descriptions of the study area

3.1.1. Location of the study area

This study was conducted in Danno district, which is located between 8° 34’ to 8° 56’ N and 37° 8’ to 37° 29’ E (figure 2). Danno is one of the 22 Districts of West Shewa Zone Oromia National Regional State and about 239 km away from Addis Ababa and 125 km from the zonal capital (Ambo) to southwest direction. According to data taken from Danno Agriculture and Natural Resource Office (DANRO), the district is bounded by the Jibat district in the east and Chaliya and Ilugelan district in the north, Ilugelan district in the northwest, Nonno district in the southeast, East Wellega zone Boneya Boshe district in the west and Jimma Zone Nonno-Benja district which is delineated by the Gibe River in the southwest.

The total area of the district is 65,387 ha and contains a total of 22 rural and 5 urban kebele administrations. Anchebbi Dry Afromontane forest is one of the natural forests belongs to Jibat-Gedo District of the Oromia Forest and Wildlife Enterprise (OFWE) under Finfinne branch. This forest is located between 8° 46’ to 8° 48’ N and 37° 16’ to 37° 19’ E (figure 2) and bounded by Seyo town in south, Direhareyu kebele in the west, Gidda Abbu kebele in north and Anchebbibadeso kebele in east bearing. The study area far away about 2 km to the north from the district center of Seyo town and cover about 462 ha of land.

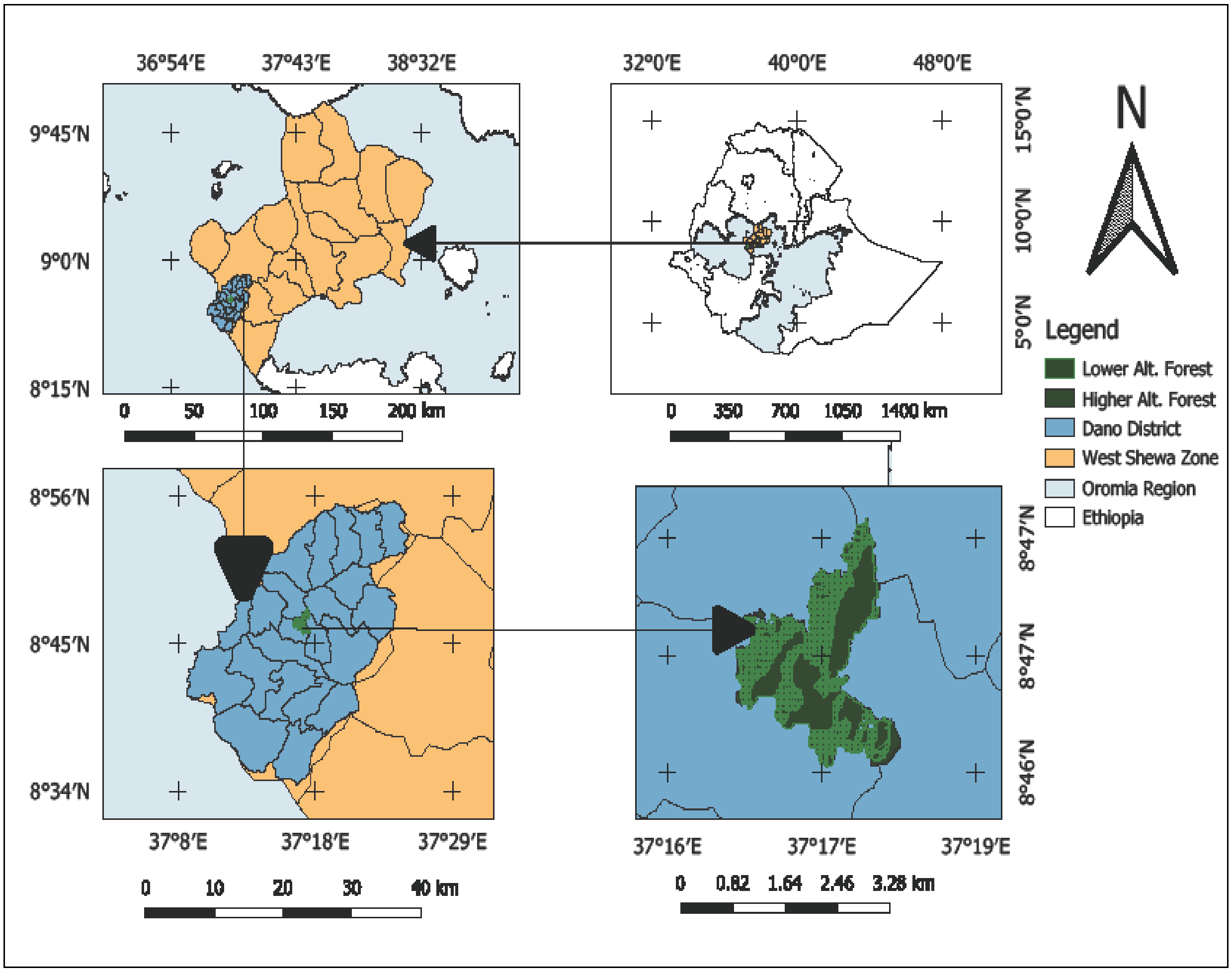

Figure 2 : Location Map of Anchebbi Dry Afromontane forest in Danno district.

3.1.2. Population density and farming system of the district

Based on the national census report of population projection values at zonal and woreda levels, Danno district has the total populations of 125,759 of these 62,621 are males and 63,138 are females (CSA, 2013). From the total population, about 92% are rural residences and 8% are urban residences. The district has an estimated population density of 124 people per square kilometer, which is less than the zone average of 153 people per square kilometer (CSA, 2013). The livelihood of the population depends primarily on agriculture, mostly on crop production and livestock farming. The type of annual crop production in this district includes maize, sorghum, teff, wheat, barley and bean. Chat *(Chata edulis*) and Coffee (*Coffee arabica*) are the perennial bushes of cash crops and spices such as ginger and pepper are produced for income generation; next to the above activities. A variety of domestic animals such as Cattle's, sheep's, Goats, Horses, Mules, Donkeys and Poultry productions are undertaken in the district.

3.1.3. Topography

According to data taken from DANRO, topography of the district is characterized by different land forms that relatively from up and down gradients to flat terrain. The elevation variation ranges from 1400 to 2500 m .a .s. l.

3.1.4. Climate

The secondary data of DANRO indicated that the mean annual temperature of the district was ranged between 18°C to 29°C and it consists of three Agro-ecological zones, namely Dega (5%), *Woinadega* (85%), while the remaining area (10%) falls under Wet *Kolla*. The climate of this district is characterized by long rainy season from April to October and dry seasons from November to March. Average annual rainfall of the district is ranged between 900mm to 1400mm.

3.1.5. Vegetation of the study area

According to Ethiopia forest vegetation classification carried out by Friis *et al*. (2010), vegetation type of Anchebbi forest falls under Dry Afromontane forest. The study area was extremely covered by *Euclea racemosa subsp. Schimperi, Schrebera alata, Millettia ferruginea, Olea capensis subsp. Macrocarpa, Bersama abyssinica, Olea europaea subsp. Cuspidata, Combretum molle, Croton macrostachyus, Strychnos spinosa* and *Osyris compressa* tree species (appendix 1).

This indicated that, *Euclea racemosa subsp. Schimperi* tree species are densely populated and shares about 34.85% in number of trees rather than carbon storage.

3.2. Methodology

3.2.1. Site selection and delineation

Based on the potential of forest coverage, the study area was subjectively selected from the district. Previously, there was no related study's conducted in the study area. Thus, to reduce the gap of information, the study area was selected to investigate the potential of carbon stored in Anchebbi Dry Afromontane forest. Before data collection, reconnaissance survey was carried out to delineate and stratify the study area. The collection of secondary data's from Jibat-Gedo forest district and DANRO were conducted during a survey. The spatial boundaries of the study site were clearly defined and well recognized to facilitate an accurate measurement. Global positioning system (GPS) tracking and QGIS software were used for boundary delineation and mapping respectively.

3.2.2. Sampling design

A stratified systematic line transect sampling method was adopted in the study area to establish a representative sampling plot. Sample plots were laid along line transects from the bottom of the mountain to the top of the mountain at different altitude range. Based on altitude gradient and digital elevation model, the whole forest of the study area was stratified into two strata (Lower altitude from 1644 to 1834m.a.s.l and Higher altitude from an elevation of 1835 to 2025m.a.s.l) with 8 transects line. The stratification was used to obtain homogenous units, increase the precision of measuring and estimating carbon stock with minimum cost. In order to avoid an edge effect, all the plots were laid 75 meters away from nearest roads and edges to facilitate measurements. The plot was laid with the distance of 250m apart between transect line and the consecutive plots. Data collection was conducted from February to March, 2019 in the study area.

3.2.3. Plot intensity, shape and size

The first step is identifying the number of plots needed to reach the desired precision and accuracy (Pearson *et al*., 2005). To design a forest inventory that is statistically and practically efficient, enough sampling unit should be measured to obtain the desired standard of precision using allowable error, coefficient of variation, population size (N) and t-value (Avery and Burkhart, 2015). Therefore, the following data were taken into consideration to compute coefficient of variation (CV).

Table 1: Secondary data of mean AGC ton ha^{-1} in different places

No.	Study place	AGC ton ha^{-1}	Reference
1	Gedo forest	280.00	Hamere Yohannes *et al*., 2015
2	Menagasha Suba State forest	133.00	Mesfin Sahile, 2011
3	Gara Mukitar forest	156.60	Asaminew Wodajo, 2018
4	Church forests	129.86	Tulu Tolla and Zewdu Eshetu, 2013
5	Ethiopia Dry Afromontane forest	113.00	FRL, 2017
6	Gera forest	112.66	Nesru Hassen, 2017
Coefficient of Variation (CV)		**41.32**	

By considering the above six secondary data of mean AGC ton ha^{-1}, 41.32 CV was calculated. Based on these data, 60 representative plots were calculated using the formula recommended by Avery and Burkhart, (2015) as follow.

$$\mathbf{n} = \frac{1}{\frac{1}{N} + (\frac{A}{t*CV})^2} = \frac{1}{\frac{1}{462} + (\frac{10}{2*41.32})^2} = \mathbf{59.5} \approx \mathbf{60} \quad \textbf{-------------------- (equ.1)}$$

Where: n = total number of plots,

N = total area of the forest in ha (population size),

A = allowable error (the recommended level of accuracy is ±10% of the average, but can be up to ± 20%),

t = statistical sample of the t distribution for 95% level of confidence (usually a value of 2 is used) and

CV = Weight of coefficient of variation (calculated from secondary data of AGC ton ha^{-1}).

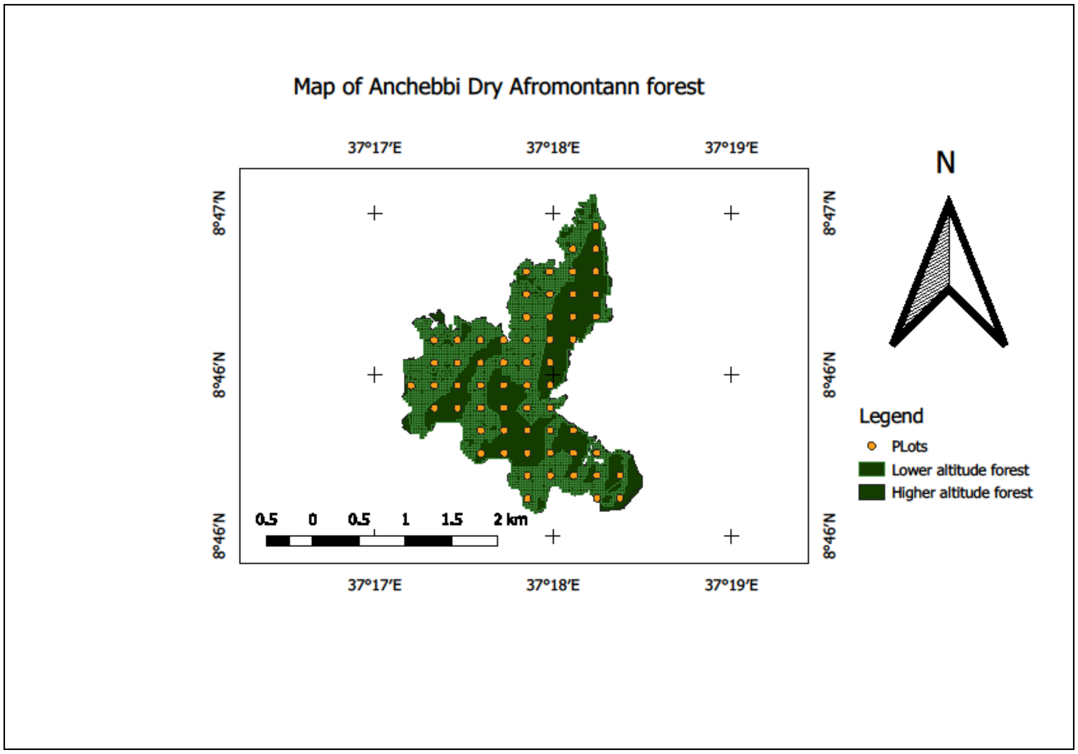

Figure 3 : Map of Anchebbi Dry Afromontane forest with plot distribution.

From the total of 60 representative sample plots 32 sample plots were surveyed from lower altitude and 28 sample plots were measured from higher altitude based on proportional area. In general, a rectangular shape of 15mx20m ($300m^2$) was used for tree vegetation sampling. Within the main plots, there were five nested sub-plots with the size of $1m^2$ (one from the center and four from corners) were used for litter sampling. Similarly, one from the center was used for soil bulk density sampling and two from the corner were used for soil organic composite collection diagonally from the top left corner to the right bottom corner (figure 3).

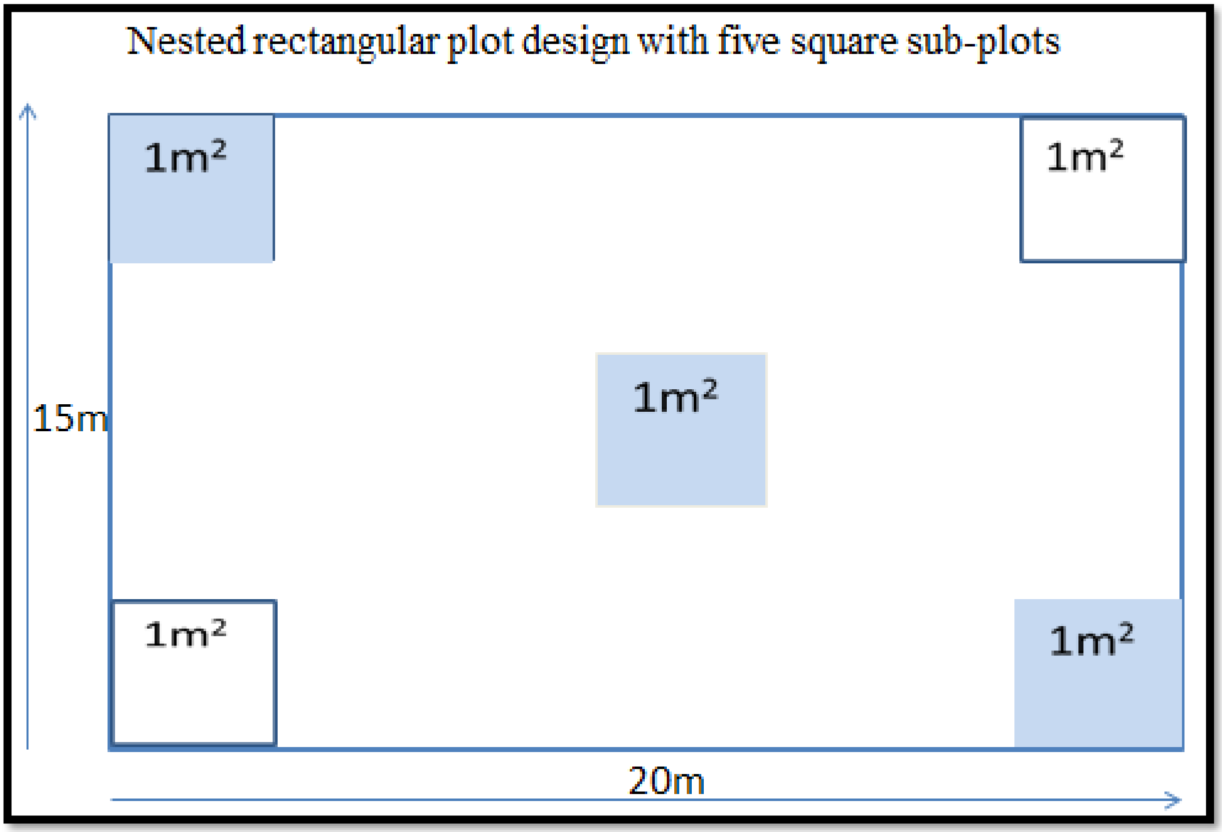

Figure 4: Plot shape and design for litters and soil samples within the main plot

3.3. Data collection and field measurement techniques

3.3.1. Tree inventory

Reconnaissance survey was conducted during October to November, 2018. The inventory of all tree species was conducted depending on tree diameter and height. Tree diameter at breast height (1.3 m) was measured and recorded for every individual tree having DBH ≥5cm using caliper and diameter tape. Suunto hypsometer and range finder were used for tree height measurement in a position that possible to observe the tips and bottom of the trees. For trees forking below 1.3 m from the ground, each stem was treated as an individual tree (Felfili, 1997; Appiah, 2013 and NFI, 2013).

3.3.2. Dead wood sampling methods

The dead wood carbon pool includes all non-living woody biomass and consist of standing and fallen dead trees, roots and stumps with the diameter above 10cm (Pearson *et al*., 2005; UNFCCC, 2015). Both standing and fallen dead wood was measured in the study area by recording the status of branches and decay position on the field respectively.

3.3.3. Species identification

The estimation of aboveground and belowground carbon were depends on the aboveground biomass of living trees. To estimate the aboveground and belowground carbon of all tree species having DBH ≥5cm and height ≥2m was identified, measured and recorded in the study area. Accordingly, plant identification was conducted in the field by using secondary reference materials of Useful trees and shrubs of Ethiopia and A glossary of Ethiopian plant names (Azene Bekele, 2007 and Wolde Michael Kelecha, 1987).

3.3.4. Litter sampling technique

According to Pearson *et al*. (2005) the litter biomass includes herb, grass and dead plant material such as twigs, fruit, leaves, bark, and small branches <2.5cm DBH). The representative sampling of the 20mx15m rectangular plot was used for tree measurement. However, litter samples were collected from nested sub-plots that selected from the center and four corners within 1m^2. Litter samples from each sub-plot were collected for each plot in the field for fresh weight separately on the site and 100g of sub-samples from composites was taken to the laboratory and placed in an oven-dry for 24 hours at 70 °C and weighed for dry weight separately (Pearson *et al*., 2005).

3.3.5. Soil sampling technique

Soil sample was collected from 20 main plots (10 from lower and 10 from higher altitude) by jumping every two plots. To estimate SOC stock, soil samples were collected from sample plots which laid for litter sampling with a clean steel core sampler. Therefore, one soil sample from the center was taken using 20cm height and 5cm diameter core sampler (392.5 cm^3) for bulk density at three layers and two soil samples from the two corners were taken from each of three soil layer for soil composite. The two cores per layer were mixed homogeneously and 100g samples were taken from each sub-sample per layer to form a composite sample. All composite soil samples were taken to the laboratory analysis to determine soil organic carbon using Walkley-Black method (Walkley and Black 1934). For soil bulk density determination, the samples were oven-dried at 105°C for 48 hours (Pearson et al., 2005). Coarse and rocky fragments were separately collected and weighed after oven-dried for soil bulk density treatment.

3.4. Carbon stock estimation

3.4.1. Aboveground biomass carbon stock estimation

The aboveground biomass (AGB) consists of all living vegetation above the soil that includes stems, stumps, branches, bark, seeds and foliage (Hairiah *et al*., 2011). To estimate the AGB carbon, tree DBH ≥5cm (at 1.3m) and height of individual trees ≥2m were measured in each sample plot. An Allometric models that recommended by Chave *et al*. (2014) to estimate aboveground biomass has been used in the present investigation due to its compatibility with the life zone of the study area without tree destruction. It also fits with the method that used to estimate carbon stock during the Ethiopia's national forest inventory submission to the UNFCCC (FRL, 2017). Thus, the equation to be used to calculate the aboveground biomass was given below (Chave *et al*., 2014).

$AGB = 0.0673 *(WD * DBH^{2} * H)^{0.976}$ -- (equ.2).

Where: AGB = above ground biomass (in kg dry matter)

WD = wood density (g/cm^3)

DBH = diameter at breast height (in cm)

H = total height of the tree (in m)

Accordingly, the carbon content of tree vegetation in the study area was estimated by taking a carbon fraction of the biomass by multiplying 0.47 (IPCC, 2006). C = 0.47* AGB.

Wood density: The above equation contains basic wood density and height of the trees. Hence, to carry out the estimation of AGB, specific wood density was used for all tree species separately from secondary data of 420 tree species stated in Ethiopia National Forest Inventory for the present study (FRL, 2017).

3.4.2. Belowground biomass carbon stock estimation

To estimate the carbon stock of belowground biomass, the application of a root to shoot ratio method that recommended by IPCC guidelines for tropical forest was used (IPCC, 2003). The equations that have been used to calculate the belowground biomass is given below:

$BGB = AGB * 0.26$ --- (equ.3).

Where, BGB is belowground biomass, AGB is aboveground biomass, 0.26 is the conversion factor (or 26% of AGB). The biomass of stock density were converted to carbon stock density by multiplying default value of 0.47 carbon fraction (IPCC, 2006).

*3.4.*3. Dead wood carbon stock estimation

The dead wood in the study area was separately measured by classifying in to standing dead wood and fallen dead wood. For both standing and fallen dead wood, the decomposition status was recorded in the field (Pearson *et. al.*, 2005).

Standing dead wood

The Allometric equation that recommended in REDD+ methodology (2009) was used to estimate the amount of biomass in standing dead wood.

$$\mathbf{BSDW} = \sum_{i=0}^{n} \frac{1}{3}\left(\frac{D}{200}\right)^{2} \mathbf{h} * \mathbf{s} \text{ -- } \mathbf{(equ.4)}$$

Where, BSDW = biomass standing dead wood is expressed in kg,

h = length (m),

D = tree diameter (cm) and

s = specific gravity of wood (g/cm^{-3}).

The specific wood density of the study site was estimated by using 0.5 g/cm^{-3} of default value (Hairiah *et al.*, 2001). The carbon content in dead wood was calculated by multiplying total biomass of dead wood with the default value carbon fraction of 0.47 (IPCC, 2006).

Fallen dead wood

Fallen dead wood was measured in the study area to determine lying dead wood biomass using the formula that recommended by Pearson *et al*. (2005) as shown below:

$$\mathbf{V = \frac{\pi^2 \sum d^2}{8L}} \text{ --- } \textbf{(equ.5)}$$

Where: V = volume per hectare of dead wood (m^3/ha),

π = 3.14,

d = diameters of intersecting pieces of dead wood in cm and

L = length of the transect line in meter.

Volume is converted to dry biomass using an appropriate wood density (Pearson *et al*., 2005).

Biomass of lying dead wood (ton ha^{-1}) = Volume x Specific Wood density (default value of 0.5 g/cm^3 was used).

3.4.4. Litter biomass carbon stock estimation

All litter such as: dead leaves, twigs, fruit, bark, and small branches (< 2.5cm DBH) and live components (herbs and grass) on the forest floor were collected in a destructive manner from five nested sub-plot of $1m^2$ (one from the center and four from corners). Thus, the amount of biomass in the LHG was calculated by using the method of Karki *et al*. (2016). Accordingly, the LHG biomass was estimated by using the following formula for the study area;

$$\mathbf{LHG = \frac{W\ field}{A} * \frac{W\ sub-sample\ (dry)}{W\ sub-sample\ (fresh)} * 10,000} \text{ ------------------------------- } \textbf{(Equ.6)}$$

Where: LHG = biomass of leaf litter, herbs, and grass (ton ha^{-1});

W field = weight of the fresh field sample of leaf litter, herbs, and grass, destructively sampled within an area of size A (g);

A = size of the area in which leaf litter, herbs, and grass were collected (m^2);

W sub-sample, dry = weight of the oven-dry sub-sample of leaf litter, herbs, and grass taken to the laboratory to determine moisture content (g); and

W sub-sample, wet = weight of the fresh sub-sample of leaf litter, herbs, and grass taken to the laboratory to determine moisture content (g).

Finally, the carbon content in the LHG was estimated by multiplying with the default carbon fraction 0.37, as recommended by IPCC (2003). Then, the totals carbon content of litter (ton ha^{-1}) = total dry litter biomass multiply by carbon fraction:

CL = LHGB * 0.37 --- (equ.7).

Where, CL is total carbon stocks in the litter (ton ha^{-1}), LHGB = oven dry litter, herb, and grass biomass and 0.37 is default value carbon fraction of litter biomass (IPCC, 2003).

3.4.5. Soil carbon stock estimation

To determine SOC stocks on an equal mass basis, three types of variables must be measured: concentration of SOC within the sample, bulk density and soil depth (Ermias Aynekulu *et al.*, 2011). For convenience and cost-efficiency, the total of 60cm depth of the soil sample was taken from 20 main plots (10 from lower and 10 plots from higher altitude) at three different layers. SOC were determined through samples collected from the depth of 60cm as recommended by the IPCC, (2006) with the help of the standardized core sampler. All samples were placed in plastic bags with appropriate labels. Three equal weights of sub-soil samples from each sub-plot at different layers were taken and mixed homogeneously, while a composite sub-sample from each layer was taken for laboratory analysis. For soil C determination, the soil sample was air dried, grinded by mortar and sieved through a 2mm sieve and systematically mixed. Then, the C fraction was determined by using Walkley-Black method in Wondo Genet College of Forestry and Natural resources soil laboratory (Walkley and Black, 1934).

Bulk density:

Soil bulk density was calculated after oven-dried and the weight of soil from a known volume of ($392.5 cm^3$) sampled soil. Thus, the laboratory dried the samples in an oven at 105°C for 48 hours. The rocky and coarse fragments >2mm were extracted and subtracted from the total core volume. The C stock density of SOC was calculated as recommended by Pearson *et al.* (2005) from the volume as follow:

$$\mathbf{V = h \times \boldsymbol{\pi r^2}} \text{ -- } \textbf{(equ.8)}$$

Where, V is volume of the soil in the core sampler in cm^3, h is the height of core sampler in cm, and r is the radius of core sampler in cm and π = 3.14 (Pearson *et al*., 2005). Finally, bulk density of a soil sample and SOC of the study area was calculated using the following formula respectively (Pearson *et al*., 2007).

$$\textbf{Bulk density } (\mathbf{g/cm^3}) = \frac{\textbf{Oven dry mass (g)}}{\textbf{Core volume}(\mathbf{cm^3}) - \frac{\textbf{Mass of Coarse fragment (g)}}{\textbf{Density of rock fragments}(\mathbf{g/cm^3})}} \text{ ---------- } \textbf{(equ.9)}$$

$$\mathbf{SOC = BD * D * \%\, C} \text{ --- } \textbf{(equ.10)}$$

Where, SOC- Soil Organic Carbon stock per unit area (ton ha^{-1}),

BD = soil bulk density (g/cm^3),

D = the total depth at which the sample was taken (60cm) and

% C = Carbon concentration (%) determined in the laboratory

3.4.6. Total carbon stock estimation of the forest ecosystem

The total C stock of the study area was estimated by summing the C stock densities of the individual C pools of the forest ecosystem using Pearson *et al*. (2007) procedure;

CT = AGC + BGC + LHGC + SOC; --- (equ.11).

Where, CT = Total carbon stock for all pools (ton ha^{-1}),

AGC = Aboveground biomass carbon stock (ton ha^{-1}),

BGC = Belowground biomass carbon stock (ton ha^{-1}),

LHGC = Litter herb and grass carbon stock (ton ha^{-1}) and

SOC = Soil organic carbon (ton ha^{-1}).

3.5. Statistical data analysis

The collected data of tree DBH, tree height, fresh and dry weight of litter and soil sample were recorded, organized and compiled in excel sheets. The C stock ton ha^{-1} of tree vegetation, litter and soil were calculated. The influence of altitude variation on C stock was tested using an independent t-test at 95% confidence interval. The least significance difference test was performed to separate means by using t-test when the result showed the presence of significant differences along an altitude gradient on biomass C and SOC stock. All statistical tests were implemented by using Minitab statistical software version 17 and the statistical mean difference was considered as a significant difference when P-value < 0.05 level.

4. Result and Discussion

4.1. Result

Vegetation characteristics

A total of 1,334 individual trees representing 34 tree species with height ≥2m and DBH ≥5cm were measured for the estimation of aboveground and belowground biomass carbon. The present study showed different tree population among the stratum with average density of 656 and 742 trees per hectare in lower and higher altitude respectively. In both forest stratus, the study revealed that a top five dominant tree species such as: *Euclea racemosa subsp. Schimperi, Millettia ferruginea, Bersama abyssinica, Olea europaea subsp. Cuspidata and Schrebera alata* in lower altitude and *Euclea racemosa subsp Schimperi, Schrebera alata, Olea europaea subsp. Cuspidata, Olea capensis subsp. Macrocarpa* and *Millettia ferruginea* in higher altitude. *Euclea racemosa subsp. Schimperi* was the leading dominant tree species in both forest stratums by their distribution with 465 individual trees. The frequency distributions of different tree species were illustrated on appendix 1. Among the total tree species, 10 tree species were observed only in lower altitude and *Ekebergia capensis* was a single tree species recorded only in higher altitude, while the remain 23 tree species were observed in both lower and higher altitude (figure 5).

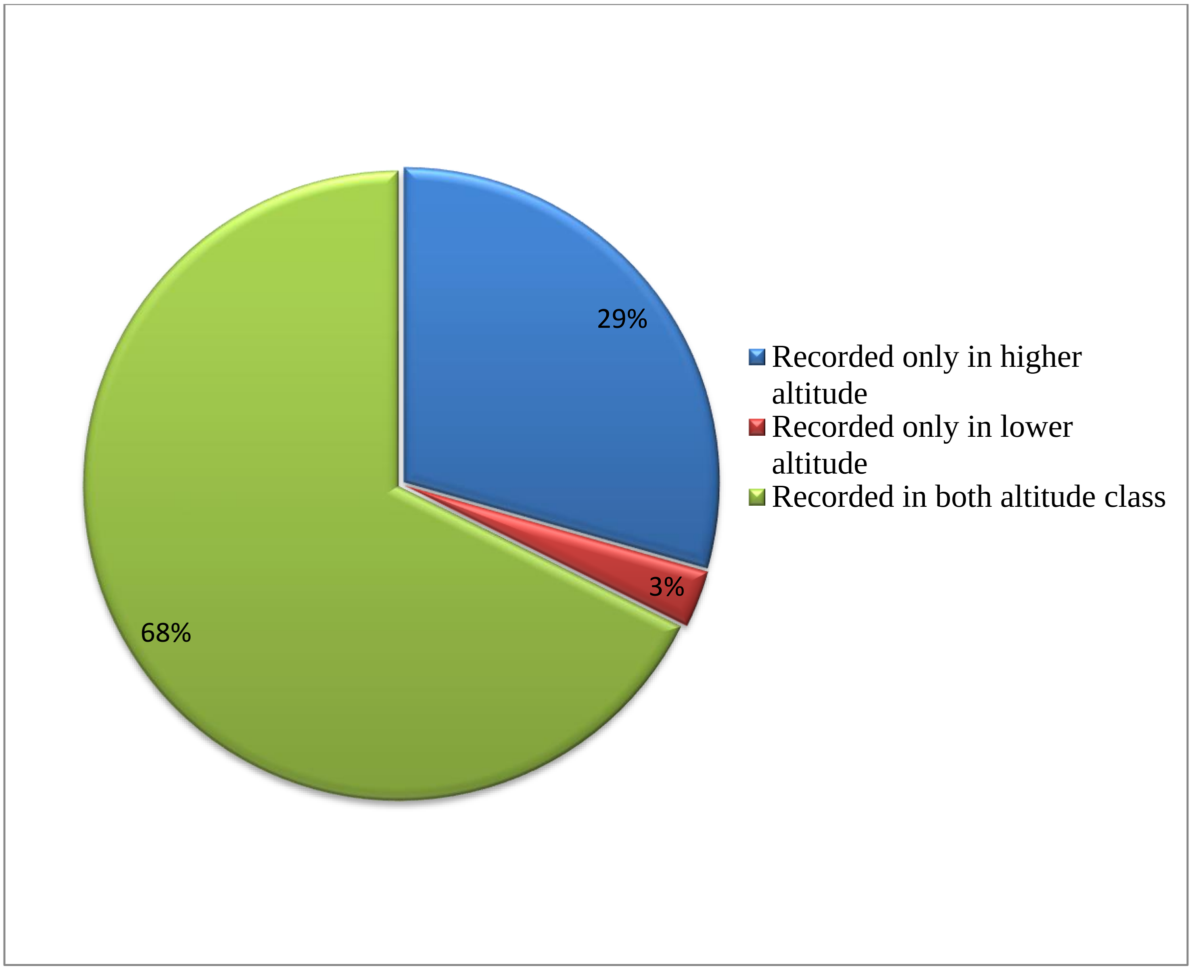

Figure 5: Summary of species recorded in lower altitude, higher altitude and in both altitude.

A number of tree species with large DBH class was measured in lower altitude than higher altitudinal gradient. However, large numbers of trees with lower DBH class (5-20cm) were recorded in higher altitude than lower altitude forest stratum (figure 6).

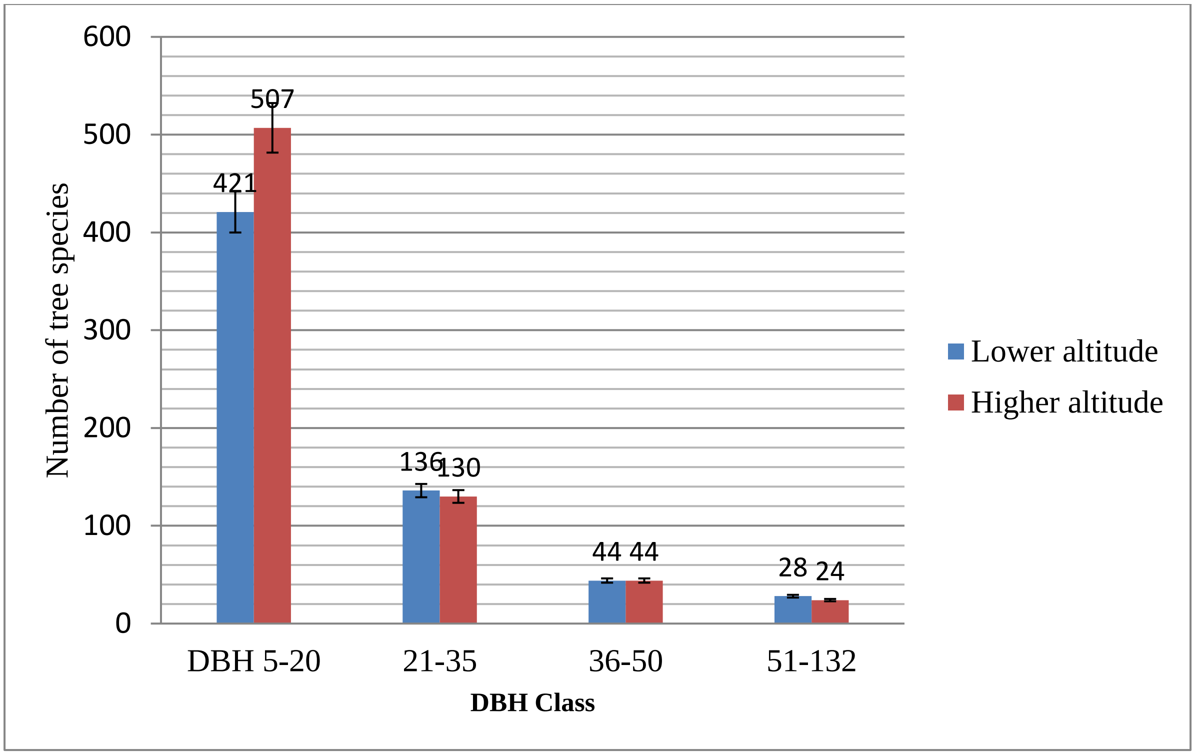

Figure 6 : DBH class distributions of trees in lower and higher altitude of the study area.

Dead wood carbon stocks

In the lower altitude forest stratum, small numbers of standing and fallen dead woods were estimated and more stumps (20 stumps) were measured as compared with higher altitude forest stratum (8 stumps). The number of dead woods and stumps measured in lower altitude gradients indicated the existence of human interference in lower altitude class. In general, the ultimate result of dead woods and stumps indicated the total mean C of 0.00031 and 0.00022 ton ha^{-1} in both lower and higher altitude gradient respectively. However, the mean total C density in both lower and higher altitude forest stratum showed insignificant amount of dead wood C stock value as compared to other C pools. Due to this insignificance, result was omitted from the lists of mean C pools summary of table 2.

4.1.1. Aboveground and belowground biomass carbon stock

Aboveground biomass C stock of Anchebbi Dry Afromontane forest showed the mean total of 110.4 ± 12 ton ha^{-1}. The result indicated higher mean tree population (742 trees ha^{-1}) in higher altitude gradient, while lower mean tree population (656 trees ha^{-1}) were detected in lower altitude forest stratum (appendix 1). Similarly, the higher AGB C stock was revealed in the higher altitude gradient than that of the lower altitude forest stratum with the mean total of 118.69 ± 24.2 ton ha^{-1} whereas, the lower AGB carbon was estimated in lower altitude forest stratum with the mean total of 103.13 ± 15.6 ton ha^{-1}. This indicated that the aboveground biomass C stock increases with increase in altitude (table 2). Similar to AGB carbons, the higher BGB carbon of the present study was estimated in higher altitude gradient with the mean total of 30.86 ± 4.46 ton ha^{-1}. Since BGB carbon was derived from AGB carbon, it had the same increasing pattern with AGB carbon stock. However, the result of AGB carbon and BGB carbon in relation to the altitude variation was not significantly different.

Table 2 : Summary of mean carbon stock density (ton ha^{-1}) in both lower and higher altitudinal gradient of the study area

Altitude	Altitude Range (m)	Carbon Pools				
		AGC	BGC	LHG	SOC	Total
Lower	1644 - 1834	103.13	26.91	1.41	164.37	260.92
Higher	1835 - 2025	118.69	30.86	1.12	129.47	314.04
P-value	-	0.52	0.53	0.050	0.045*	-

Note: * is indicated the significant difference.

On the other hand, the higher litter, herb and grass (LHG) carbon was estimated in the lower altitude gradient than that of higher altitude forest stratum with the mean total of 1.41 ± 0.09 ton ha^{-1}. The lower litter biomass C was calculated in higher altitude of forest stratum with the mean total of 1.12 ± 0.11 ton ha^{-1}. However, this result was not showed a significance difference along altitudinal gradient with P-value = 0.05 (table 2).

Table 3 : Summary of minimum, maximum and mean carbon density (ton ha^{-1}) in lower and higher altitude of forest stratum in different carbon pools of the study area:

Descriptive statistics	Lower altitude				Higher altitude			
	AGC	BGC	LHG	SOC	AGC	BGC	LGHC	SOC
N	32	32	32	10	28	28	28	10
Minimum	28.09	7.3	0.39	51.84	37.42	9.73	0.37	54.98
Maximum	426.35	110.85	2.92	294.61	468.95	125.57	2.76	279.39
Mean	103.13 ±16.9	26.81 ±4.40	1.41± 0.09	164.37 ±13.4	118.69 ±17.2	30.86± 4.46	1.12 ±0.11	129.47 ±10.5
StDev	95.8	24.87	0.53	73.6	90.9	23.63	0.60	57.5
Lower bound at 95%	70.0	18.31	1.21	140.2	83.3	21.67	0.90	105.3
Upper bound at 95%	136.2	35.50	1.61	1885	154.1	40.05	1.33	153.6

(N = number of plots measured, AGC = Aboveground carbon, BGC = Belowground carbon, LHGC = Litter herb grass carbon and SOC = Soil organic carbon) ton ha^{-1}.

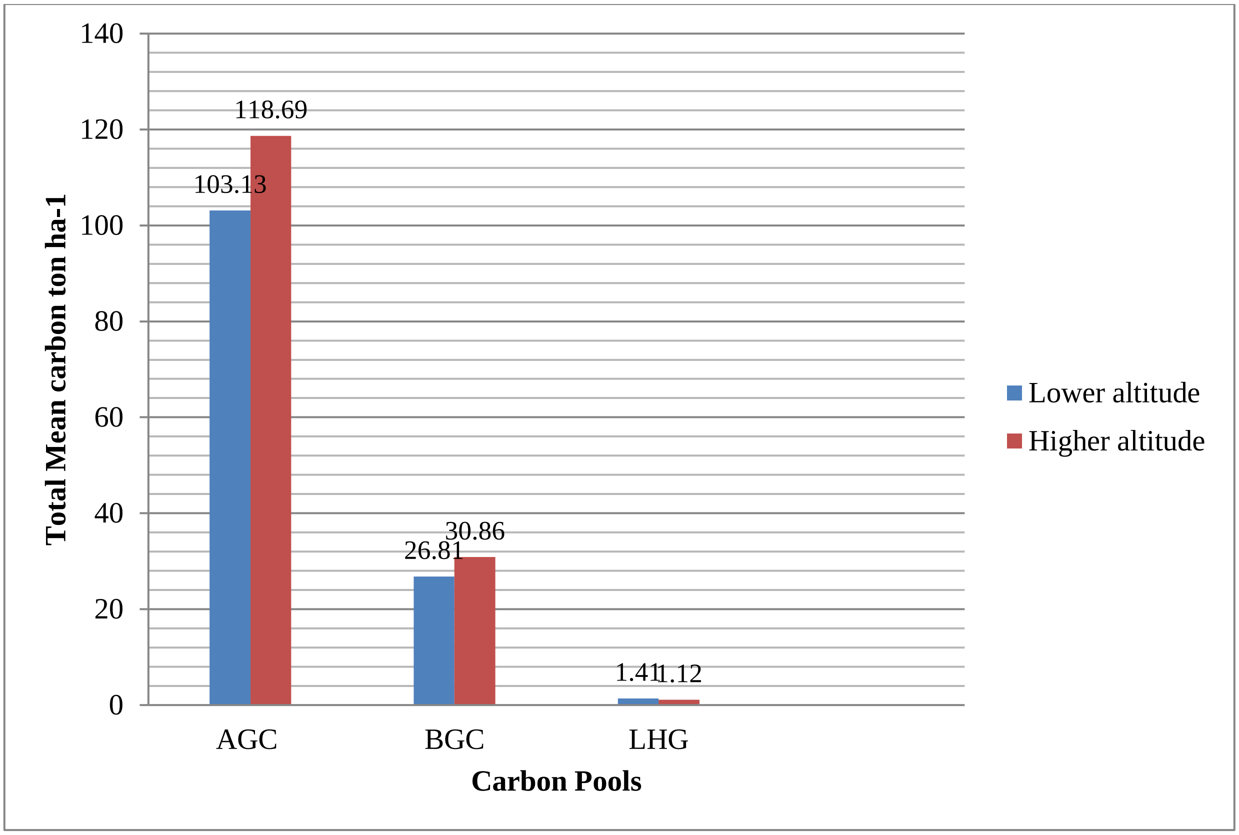

Figure 7 : Summary of mean carbon stock (ton ha^{-1}) of different carbon pools in lower and higher altitude forest stratum.

4.1.2. Soil organic carbon stock

The higher soil organic carbon (SOC) was observed in lower altitude gradient with the mean total of 164.37 ± 13.4 ton ha^{-1}, while the lower SOC stock value was estimated in higher altitude forest stratum with mean total of 129.47 ± 10.5 ton ha^{-1}. Thus, this investigation was indicated an increasing pattern of SOC from bottom to top in all soil layers. Therefore**,** the result of SOCs showed a significant difference among the forest strata with P-value = 0.045 (figure 8). In the study area, fine bulk density of the soil was increased from the depth 0-20cm, 20-40cm and 40-60cm and 0.87, 0.96 and 1.01 g/cm^3 in average respectively.

Table 4 : Mean summary of fine bulk density (BD) and SOC in lower and higher altitude gradient

No.	Soil depth in (cm)	Lower altitude		Higher altitude	
		BD g/cm^3	SOC ton ha^{-1}	BD g/cm^3	SOC ton ha^{-1}
1	0-20	0.86	82.24 ± 3.13	0.88	63.08 ± 6.15
2	20-40	0.93	46.49 ± 4.96	0.99	36.92 ± 2.49
3	40-60	0.97	35.64 ± 5.25	1.05	29.47 ± 2.25
4	**0-60**	**0.92**	**164.37 ± 13.4**	**0.97**	**129.47 ± 10.5**

Also, the results of soil organic carbon density was showed variation along altitudinal gradients among the three different soil layers. Higher, medium and lower SOC stocks were revealed in upper, middle and lower soil depth respectively.

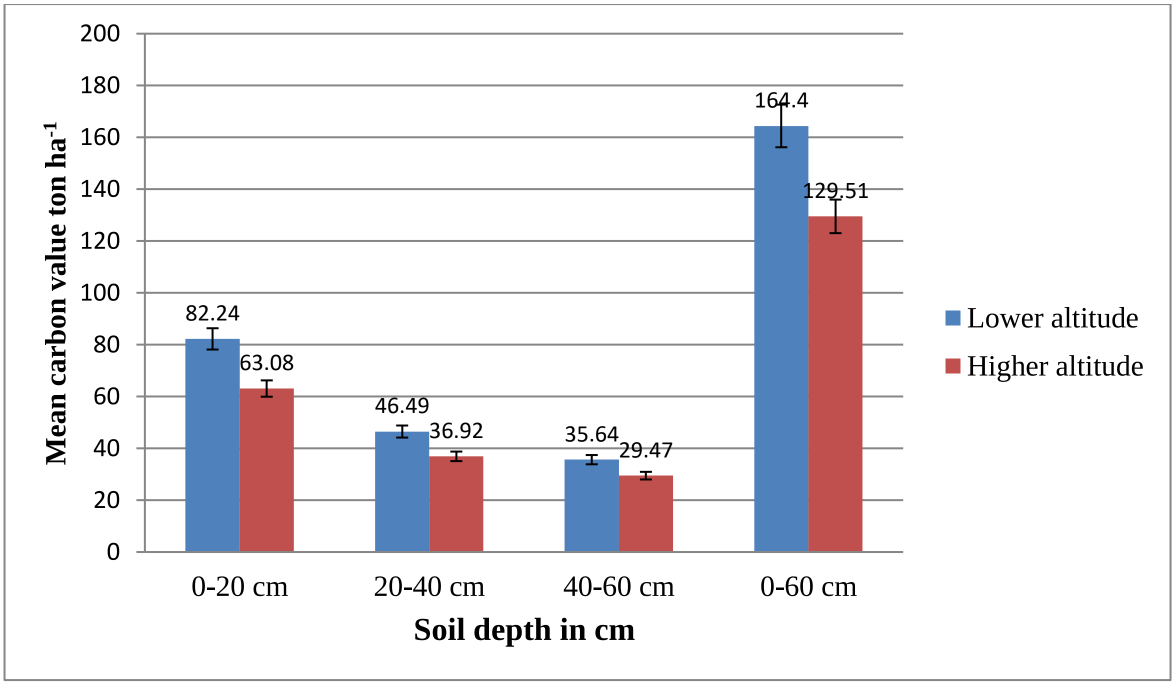

Figure 8: Mean carbon stock of soil organic carbon at three different layers in both lower and higher altitude forest stratum.

4.1.3. Total carbon stock estimation of the forest ecosystem

The total carbon density of the forest ecosystem was calculated by summing each carbon pools estimated in the study area. As a result, the present study revealed that the total mean carbon density of 287.35 ton ha^{-1} in the whole forest ecosystem. Biomass carbon and SOC estimation of the study area was showed variation in carbon storage in different carbon pools. The highest carbon stock was estimated in SOC with 51.13% of the total forest ecosystem, whereas the lower carbon stock density was revealed in AGC, BGC, and LHG carbon pools with 38.42%, 10% and 0.45% respectively. In general, belowground part contains the total of 61.13% and the aboveground share takes 38.87% (table 5).

Table 5 : Summary of mean total carbon stocks (ton ha^{-1}) of Anchebbi Dry Afromontane forest ecosystem:

Carbon	Statistical description						
Pools	N	Mean	SE Mean	StDev	Minimum	Maximum	CD in %
AGC	60	110.4	12.0	93.1	28.1	482.9	38.42
BGC	60	28.75	3.12	24.17	7.30	125.57	10
LHGC	60	1.28	0.08	0.58	0.37	2.92	0.45
SOC	20	146.92	8.75	67.81	51.84	294.61	51.13
Total		**287.35**					**100%**

(AGC = Aboveground biomass carbon, BGC = Belowground biomass carbon, SOC = soil organic carbon and LHGC = Litter herb grass carbon ton ha^{-1}, and N = Number of plots, CD in % = Carbon density in percent).

4.2. Discussion

4.2.1. Aboveground and belowground carbon stocks

Anchebbi natural forest was categorized under Dry Afromontane forest which is a subsection of Jibat forest priority area (Young, 2012). The present investigation was a kind of study conducted in Anchebbi Dry Afromontane forest on carbon stock estimation by considering carbon stock potential of the forest at different altitudinal gradient. It was an important finding to get relevant information on carbon stock and to identify the factors affecting carbon stock process. The investigation was depicted various carbon stock density at different carbon pools among the forest stratus. Hence, the present study showed higher AGC and BGC stock values in the higher altitude gradient than lower altitude forest stratum (table 2). The carbon stock variation among the two strata was happened due to the human intervention (20 stumps recorded) in the lower altitude gradient and densely populated tree species was surveyed (742 trees ha^{-1}) in higher altitude gradient.

A similar trend was observed and reported in Sekele-Mariam Dry Evergreen Montane forest of Northwestern Ethiopia and in the Manipur forest of Northeast India (Asersie Mekonnen and Motuma Tolera, 2019; Thokchom and Yadava, 2017). The present study of AGC and BGC stock result was agreed with the earlier study of Gara-Muktar forest, Weiramba Forest, and Ethiopia National Forest Inventory reports (Asaminew Wodajo, 2018; Zelalem Teshager *et al*., 2018 and FRL, 2017) respectively. However, the present study showed lower carbon stock density as compared with previous studies of Ades forest and Chilimo dry afromontane natural forest (Kidanemariam Kassahun *et al*., 2015 and Mehari Alebachew *et al*., 2019) respectively. The variation may be happened due to biological factors, physical factor and the difference in elevation ranges among the forest studies. For instance, Ades forest altitude ranges from 2513 to 2743m above sea level, whereas Anchebbi Dry Afromontane forest ranges from 1644 to 2025m.a.s.l. Similarly, the AGC and BGC stock density of the study area was disagreed as compared with Gedo forest (Hamere Yohannes *et al*., 2015). This variation may be happened due to anthropogenic effect and field measurement error.

The LHG carbon value of the study area (1.28 ton ha^{-1}) was agreed with previous study of Weiramba forest (1.30 ton ha^{-1}) that had been reported by Zelalem Teshager *et al*. (2018). However, the present investigation of LHG carbon density was lower than the value reported in IPCC, (2006) about 2.1 ton/ha of tropical dry forests. LHG carbon density of the study area also lower as compared to Gara-Muktar forest and Ades forest of the earlier studies reported by (Asaminew Wodajo, 2018; and Kidanemariam Kassahun *et al*., 2015) respectively. The variation may be happened due to edaphic factor. On the other hand, the present investigation was showed higher LHG carbon value than the result of Sekele-Mariam Dry Evergreen Montane forest (0.02 ton ha^{-1}) and Gedo forest (0.41 ton ha^{-1}) of earlier study reported by Asersie Mekonnen and Motuma Tolera, (2019) and Hamere Yohannes *et al*., (2015). This disagreement may be happened due to difference in forest management practice, the rate of decomposition status and species characteristics (table 6).

Table 6 : Comparison of carbon stock density ton/ha of the present study with previous studies.

Study Area	Carbon pools					Reference
	AGC	BGC	LHGC	SOC	Total	
ADAF	**110.4**	**28.75**	**1.28**	**146.92**	**287.35**	**Present study**

GMF	156.60	31.32	2.72	125.86	316.50	Asaminew Wodajo, 2018
WF	152.33	41.13	1.30	129.11	323.87	Zelalem Teshager *et al*., 2018
SMDEMF	37.54	9.76	0.02	138.39	185.71	Asersie Mekonnen and Motuma Tolera, 2019
ENFI	113	27.12	-	-	140.12	FRL, 2017

Notes: ADAF = Anchebbi Dry Afromontane Forest, SMDEMF = Sekele-Mariam Dry Evergreen Montane Forest, GMF = Gara-Muktar Forest, WF = Weiramba Forest, ENFI = Ethiopia National Forest Inventory, AGC = Aboveground carbon, BGC = Belowground carbon, LHGC = Litter herb grass carbon and SOC = Soil organic carbon.

4.2.2. Soil organic carbon stock along altitudinal gradient

The overall mean values of fine bulk density in the study area were 0.87, 0.96, 1.01 and 0.95 g/cm^3 in 0-20cm, 20-40cm, 40-60cm and 0-60cm soil depth respectively, which have an impact on the soil organic carbon stock values. Soil organic carbon stock density of the present study was higher at the upper layer (0-20cm), moderate in the middle layer (20-40cm) and lower in the lower layer (40-60cm) (figure 7). The reason for the higher soil organic carbon value in the upper soil layer was due to the high accumulation of organic matter and rapid decomposition of the forest litter in top soil. The similar trend was reported in the previous study of Tsegede Highlands of Northern Ethiopia (Abreha Kidanemariam *et al*., 2012). In the present study, with an increase in soil depth the concentration of soil organic carbon was inversely decreased. Similar to the present study, the previous studies also reported that as the bulk density increased while, the soil organic carbon was decreased with increasing soil depth in the forests (Getaneh Gebeyehu *et al*., 2019). It may be happened since the SOC stock was mainly influenced by land-use types and soil depth (Mehari Alebachew *et al.*, 2019). The higher SOC stock was estimated in the lower altitudinal gradient than higher altitude gradient of the study area. This was probably due to decreasing in soil erosion and high decomposition rate of soil organic matter in the lower altitudinal gradient (Abreha Kidanemariam et al., 2012).

On the other hand, the soil organic carbon result of Anchebbi Dry Afromontane forest (146.92 ton ha^{-1}) was lower than Gedo forest (183.69 ton ha^{-1}), Egdu forest (278.08 ton ha^{-1}) and Ades forest (271.69 ton ha^{-1}) of the previous study reported by (Hamere Yohannes *et al*., 2015; Adugna Feyissa *et al*., 2013 and Kidanemariam Kassahun *et al*., 2015) respectively. The variation might be happened due to physical factors (rainfall, temperature, and soil type). However, SOC value of the present study was proportional as compared with Sekele-Mariam Dry Evergreen Montane forest (138.39 ton ha^{-1}) and Weiramba forest (129.11 ton ha^{-1}) of previous study reported by Asersie Mekonnen and Motuma Tolera, (2019) and Zelalem Teshager *et al*. (2018) respectively (table 6).

4.2.3. Ecosystem level total carbon stocks

Anchebbi Dry Afromontane forest ecosystem contains the total mean C density of 287.35 ton ha^{-1} from AGC, BGC, LHG carbon and SOC with 38.42%, 10%, 0.45% and 51.13% respectively. The forest ecosystem of the present investigation was revealed different C stock density among the C pools. For instance AGC and BGC were higher in the higher altitudinal gradient whereas, lower in lower altitude forest stratum. While, LHG carbon and SOC were higher in lower altitude gradient and lower in higher altitude forest class. Therefore, the result showed a fluctuation among the plots rather than showing a similar pattern. Based on the similarities in forest biome and agro-ecological region for their carbon storage capacity, Anchebbi Dry Afromontane forest was compared with other Dry Evergreen Afromontane forests of Ethiopia such as: Gedo forest, Egdu forest, Sekele-Mariam Dry Evergreen Montane forest, Ades forest, Weiramba forest and ENFI reported by (Hamere Yohannes *et al*., 2015; Adugna Feyissa *et al*., 2013; Kidanemariam Kassahun *et al*., 2015; Asersie Mekonnen and Motuma Tolera, 2019; Zelalem Teshager *et al*., 2018 and FRL, 2017) respectively. Except Sekele-Mariam Dry Evergreen Montane forest of the previous studies, all of the above previous studies were stored higher total carbon density than Anchebbi Dry Afromontane forest (table 6). These differences may be happened due to the stand age, stand density and variation in forest management practice. However, the present study was proportional with the earlier assessment of the National Forest Inventory (NFI) conducted in Ethiopia's Dry Afromontane forest that reports 113 ton ha^{-1} of aboveground biomass carbon stock (FRL, 2017).

5. Conclusion and Recommendations

5.2. Conclusion

In general, forest has a capacity to store large amount of carbon within their biomass and soil. The forest resources of the study area consists an estimated mean total of 287.35 carbon ton ha^{-1} in the entire ecosystem. These were specifically contained about 110.4, 28.75, 1.28 and 146.92 tons ha^{-1} in ABC, BGC, LHG carbon and SOC respectively. However, forest carbon stocks would be affected by different factors such as: environmental factors, physical factors, biological factors and anthropogenic factors. From these factors, the present study was influenced by altitude variation of the environmental factor. Accordingly, the study area showed that higher carbon stock estimation in higher altitude gradient than lower altitude forest stratum in AGC and BGC pools. While, more carbon stocks were estimated in lower altitude gradient than higher altitude forest stratum in the LHG carbon and SOC pools. Therefore, the result of the present study showed that an altitude variation have a significant effect on SOC stock concentration. Finally, Anchebbi Dry Afromontane forest have a potential of accumulating an important carbon stock to mitigate the risk of current climate change and play a significant role in carbon stock balance.

5.2. Recommendations

Based on the result that was carried out on the study area, the following recommendations have been made:

- This study can contribute as a base line research for the establishment of carbon stock databank for climate change mitigation.

- To sustain forest in the study area, it needs awareness creation for the local community, forest guards and other concerned government bodies on forest carbon related issues.
- The present study was restricted on carbon stock estimation based on altitude variation. Therefore, further studies on human induced factors and other environmental factor in the study area is recommended.
- It is better to enhance the availability of an alternative energy source for the local community to satisfy their firewood demand and to protect forest of the study area.
- On the other hand, using species specific models increases the acceptance and accuracy of biomass estimation of a given forest. Therefore, species specific models for natural forest species should be developed by further study for biomass estimation.

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Appendices

Appendix 1 Frequency distribution of all tree species in both lower and higher altitude forest stratums of the study area:

No.	Local name	*Scientific name*	Altitude classes		Number of trees	Frequency in %
			Lower	Higher		
1	Mi'eessaa	*Euclea racemosa subsp*	145	320	465	34.86
2	Qana'ee	*Schrebera alata*	48	66	114	8.55
3	Sootalloo	*Millettia ferruginea*	68	32	100	7.50
4	Gajjaa	*Olea capensis subsp. macrocarpa*	55	36	91	6.82
5	Lolchiisaa	*Bersama abyssinica*	61	17	78	5.85
6	Ejersa	*Olea europaea subsp. cuspidata*	14	60	74	5.55
7	Addajaboo	*Combretum molle*	39	13	52	3.90
8	Bakkanniisa	*Croton macrostachyus*	35	17	52	3.90
9	Baddeessaa	*Strychnos spinosa*	15	17	32	2.40
10	Waatoo	*Osyris compressa*	31	-	31	2.32
11	Imalaa	*Albizia gummifera*	10	18	28	2.10
12	Qumbaala	*Apodytes dimidiata*	3	23	26	1.95
13	Cayii	*Celtis africana*	13	11	24	1.80
14	Akuukkuu	*Oncoba spinosa*	18	5	23	1.72
15	Birbirsa	*Podocarpus falcatus*	2	21	23	1.72
16	Hadheessa	*Teclea nobilis*	4	9	13	0.97
17	Xaaxessaa	*Rhus glutinosa*	5	8	13	0.97
18	Bahaa	*Olea welwitschii*	6	6	12	0.90
19	Luqqee	*Schefflera abyssinica*	11	-	11	0.82
20	Waddeessa	*Cordia africana*	5	6	11	0.82
21	Somboo	*Ekebergia capensis*	-	8	8	0.60
22	Abbayyii	*Maesa lanceolata*	6	-	6	0.45

23	Bosoqa	*Sapium ellipticum*	6	-	6	0.45
24	Harbuu	*Ficus sycomorus*	4	2	6	0.45
25	Urgeessaa	*Premna schimperi*	1	5	6	0.45
26	Botoroo	*Stereospermum kunthianum*	4	1	5	0.37
27	Dambbii	*Ficus thonningii*	4	1	5	0.37
28	Laaftoo	*Acacia abyssinica*	5	-	5	0.37
29	Adaamii	*Euphorbia abyssinica*	1	3	4	0.30
30	Qilxuu	*Ficus vasta*	4	-	4	0.30
31	Doddota	*Acacia seyal*	2	-	2	0.15
32	Hoomii	*Prunus africana*	2	-	2	0.15
33	Anbabbeesa	*Albizia schimperiana*	1	-	1	0.07
34	Kombolcha	*Maytenus senegalensis*	1	-	1	0.07
	Total		**629**	**705**	**1,334**	**100.00**

Appendix 2 Field form 1 Life tree measurement in Anchebbi Dry Afromontane forest with DBH ≥ 5 cm height ≥ 2m within main plot (300m^2) area for above ground biomass carbon stock estimation

Name of data collector ___________ Date___________ Slope____________ Altitude __________

Latitude____________ Longitude _______________ Name of data collector _________________

Strata No	Trans. No.	Plot No.	Tree No.	Species name		Tree DBH. (cm)	Tree height (m)		
				Local Name	Scientific Name		Top	Bottom	Total

Appendix 3 Field form 2 dead wood measurement of Anchebbi Dry Afromontane forest

No. Strata	Transect No.	Plot No.	Tree No.	Dead wood							
				Standing			Felled				Decomposition status (decay class 1, 2, or 3)
				Dbh (cm)	DSH (cm)	Ht. (m	Dbh (cm)	Mid. Diam.cm	Ht. m	Length (m)	

Appendix 4 Field form 3 Litter carbon stock data collection sheet:

Name of data collector ____________ Date ___________ UTM zone____ Altitude___________

Latitude ________________ Longitude ________________

No. of Strata	Transect No.	Plot No.	Sub-plot No.	Total field wet Weight (g)	Litter (g/m^2) Weight		Remark
					Fresh weight	Oven dried weight	

Appendix 5 Field form 4 soil organic carbon (SOC) data collection sheet:

Study place______________ Name of Data collector ___________________________________

Date ___________________________

No. Transect	No. Strata	No. Plot	Soil samples weight					
			Soil organic carbon depth (cm)					
			depth 0-20 cm		depth 20-40cm		depth 40-60cm	
			Fresh weight (g)	DSW (g)	Fresh weight (g)	DSW (g)	Fresh weight (g)	DSW (g)

Appendix 6 Lower and higher altitude forest stratum x-coordinates and y-coordinates of plots in the study area

Plot No.	**X-coordinate in meter**	**Y-coordinate in meter**	**Altitude in meter**
1	312649	971986	1810
2	312399	971736	1835
3	312649	971736	1832
4	311899	971486	1767
5	312149	971486	1680
6	312399	971486	1772
7	312649	971486	1831
8	311899	971236	1794
9	312149	971236	1788
10	312399	971236	1803

11	312649	971236	1740
12	311899	970986	1815
13	312149	970986	1763
14	312399	970986	1735
15	312649	970986	1752
16	310899	970736	1829
17	311149	970736	1794
18	311399	970736	1801
19	311649	970736	1824
20	311899	970736	1740
21	312149	970736	1710
22	312399	970736	1703
23	310899	970486	1807
24	311149	970486	1798
25	311399	970486	1644
26	311649	970486	1670
27	311899	970486	1706
28	312149	970486	1739
29	310649	970236	1822
30	310899	970236	1817
31	311149	970236	1781
32	311399	970236	1905

Higher altitude forest stratum x-coordinates and y-coordinates of plots in the study area

Plot No.	**X-coordinate in meter**	**Y-coordinate in meter**	**Altitude in meter**
1	311649	970236	1982
2	311899	970236	1974
3	312149	970236	1978
4	310899	969986	1951
5	311149	969986	1882

6	311399	969986	1960
7	311649	969986	2018
8	311899	969986	1975
9	312149	969986	1871
10	311399	969736	2021
11	311649	969736	1882
12	311899	969736	1944
13	312149	969736	1867
14	312399	969736	1918
15	311399	969486	1965
16	311649	969486	1982
17	311899	969486	2012
18	312149	969486	1878
19	312399	969486	1871
20	312649	969486	1871
21	311899	969236	1910
22	312149	969236	1866
23	312399	969236	1963
24	312649	969236	1974
25	312899	969236	1959
26	311899	968986	1951
27	312649	968986	1911
28	312899	968986	1892

Appendix 7 LHG biomass carbon (ton ha^{-1}) in lower and higher altitude gradient

No.	Plot	Average Field Wt. (g)	Sub-sample Wt. (dry)	Sub-sample Wt. (fresh)	% of C Fraction	Biomass Carbon (t ha^{-1})	
						B (t c ha^{-1})	LHG (t c ha^{-1})
1	1	711	84.2	100	0.37	5.99	2.22
2	2	923	85.6	100	0.37	7.90	2.92
3	8	440	83.9	100	0.37	3.69	1.37
4	9	471	84.4	100	0.37	3.98	1.47
5	10	457	82.9	100	0.37	3.79	1.40
6	11	665	90.3	100	0.37	6.00	2.22
7	12	485	84.4	100	0.37	4.09	1.51
8	17	525	83.3	100	0.37	4.37	1.62
9	19	670	88.3	100	0.37	5.92	2.19
10	20	546	84.3	100	0.37	4.60	1.70
11	21	125	84.3	100	0.37	1.05	0.39
12	22	274	88.6	100	0.37	2.43	0.90
13	23	328	83.7	100	0.37	2.75	1.02
14	24	453	55	100	0.37	2.49	0.92
15	25	405	89.7	100	0.37	3.63	1.34
16	26	516	88.2	100	0.37	4.55	1.68
17	27	346	88	100	0.37	3.04	1.13
18	28	219	86	100	0.37	1.88	0.70
19	29	469	85.7	100	0.37	4.02	1.49
20	30	638	87.9	100	0.37	5.61	2.07
21	31	571	85.9	100	0.37	4.90	1.81
22	32	426	90.9	100	0.37	3.87	1.43
23	35	321	86.2	100	0.37	2.77	1.02
24	36	620	75.8	100	0.37	4.70	1.74
25	37	441	78.5	100	0.37	3.46	1.28

26	44	568	70.5	100	0.37	4.00	1.48
27	45	323	89.9	100	0.37	2.90	1.07
28	46	353	81.7	100	0.37	2.88	1.07
29	47	352	78.7	100	0.37	2.77	1.02
30	48	318	87.2	100	0.37	2.77	1.03
31	59	420	89.7	100	0.37	3.77	1.39
32	60	159	98.6	100	0.37	1.57	0.58
	Ave	454.31	84.45	100	0.37	3.84	1.42

LHG biomass carbon (ton ha^{-1}) in higher altitude gradient

No.	Plot	Average Field Wt. (g)	Sub-sample Wt. (dry)	Sub-sample Wt. (fresh)	% of C Fraction	Biomass Carbon (t/ha^{-1})	
						B (t c ha^{-1})	
1	3	851	84.3	100	0.37	5.74	2.12
2	4	893	82.3	100	0.37	5.88	2.18
3	5	527	83.3	100	0.37	3.51	1.30
4	6	328	82.9	100	0.37	2.18	0.80
5	7	633	91.9	100	0.37	4.65	1.72
6	13	408	83.8	100	0.37	2.74	1.01
7	14	370	89	100	0.37	2.63	0.97
8	15	1070	87.3	100	0.37	7.47	2.76
9	16	868	86.1	100	0.37	5.98	2.21
10	18	541	86.4	100	0.37	3.74	1.38
11	33	416	82.6	100	0.37	2.75	1.02
12	34	410	81.9	100	0.37	2.69	0.99
13	38	253	86.4	100	0.37	1.75	0.65
14	39	420	84.1	100	0.37	2.83	1.05
15	40	296	78.9	100	0.37	1.87	0.69
16	41	256	91.8	100	0.37	1.88	0.70

17	42	500	74.1	100	0.37	2.96	1.10
18	43	204	83.1	100	0.37	1.36	0.50
19	49	380	88.2	100	0.37	2.68	0.99
20	50	217	88	100	0.37	1.53	0.57
21	51	477	41.2	100	0.37	1.57	0.58
22	52	690	76.1	100	0.37	4.20	1.55
23	53	640	70.8	100	0.37	3.62	1.34
24	54	390	65.2	100	0.37	2.03	0.75
25	55	324	76	100	0.37	1.97	0.73
26	56	217	58	100	0.37	1.01	0.37
27	57	272	64.9	100	0.37	1.41	0.52
28	58	275	90.7	100	0.37	2.00	0.74
	Ave	468.786	79.975	100	0.37	3.00	1.12