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Assessment of Species diversity and Carbon stock potential in Weira-Amba and Bededo forests in Wollo, Ethiopia

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GRADUATE PROGRAM

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MSc Thesis

By

Derbie Wudu Sisay

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Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science (M.Sc.) in land resource management

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Bahir Dar

THESIS APPROVAL SHEET

As a member of the Board of Examiners of the Master of Sciences (M.Sc.) thesis open defense examination, we have read and evaluated this thesis prepared by **Mr. Derbie Wudu Sisay** entitled **Assessment of Carbon stock and species diversity in Weira-Amba and Bededo forests in Wollo, Ethiopia.** We hereby certify that, the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (M.Sc.) in **land resource management.**

Board of Examiners

Name of External Examiner	Signature	Date
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Name of Chairman	Signature	Date
___________________	________________	_____________

DECLARATION

This is to certify that this thesis entitled “**Assessment of Species diversity and Carbon stock potential in Weira-Amba and Bededo forests in Wollo, Ethiopia”** submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in “**Land resource management**” to the Graduate Program of College of Agriculture and Environmental Sciences, Bahir Dar University by Mr. **Derbie Wudu Sisay** (ID. No.PR 0906208) is an authentic work carried out by him under our guidance. The matter embodied in this project work has not been submitted earlier for award of any degree or diploma to the best of our knowledge and belief.

Name of the Student

____

Signature & date ___________________________

Name of the Supervisors

1) ___________________ (Major Supervisor) ____________Signature &date_________

2) __________________(Co-Supervisor)_________________Signature &date_____

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DEDICATION

“To My Family, for their inspiration, love and support throughout my life.”

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ABBREVIATIONS AND ACRONYMS

AGB	Above ground biomass
BGB	Below ground biomass
CDM	Clean development mechanism
COP	Conference of the parties
CSA	Central Statistical agency of Ethiopia
GHG	Greenhouse gas
GIS	Geographic information system
HBC	Herbaceous biomass carbon
IPCC	Intergovernmental Panel on Climate Change
NBP	Net biomass production
NEP	Net ecosystem production
NTFPs	Non-timber forest products
REDD	Reducing Emissions from Deforestation and Forest Degradation
RS	Remote sensing
SOC	Soil organic carbon
SSA	Science Society of America
UNFCCC	United Nations Framework Convention on Climate Change

ABSTRACT

Climate change is the most serious global problem due to the abundance of carbon dioxide in the atmosphere. This study was conducted in Weira-Amba and Bededo Forests, with the objectives of estimating of the carbon stock and its variation along the environmental gradients and species diversity. A systematic sampling method was used to conduct the vegetation sampling. In order to collect vegetation data a total of 30 sample plots were used, in each plot with the size of 50m x 50m nested plot design were used, with at an interval of 50 m between plots and were laid along the established transects at 100m apart. The Shannon-Wiener diversity index showed that both forests were natural regenerations and plantations. So, their evenness were almost equal, no difference between them. But according to diversity Weira-Amba forest was more diverse with (H′) 2.424 than Bededo forest. The major tree species for carbon stock sinkers at Weira-Amba forest was Acacia Senegal 35.986 %, *Eucalyptus camaldulensis* 20.471 % and *Olea europaea* 15.886 % whereas, at Bededo forest *Cupressus lusitanica* and *Eucalyptus globules* by accounted 66.344 and 32.288 % respectively. Related to Aspect at Weira-Amba forest higher mean values of above and below ground biomass have got on North-West aspects, whereas in Bededo forest higher mean values of above and below ground biomass were recorded on Southwest and South aspects. The highest total mean carbon stock density at Weira-Amba forest got from medium elevation and at the Bededo forest at upper elevations 184.15 and 226.47 tons of carbon ha^{-1} were recorded respectively. Mean carbon stocks of the aboveground and below ground carbon in the Weira-Amba forest was a statistically significant difference in elevation ($P < 0.05$) $p=0.043$ also in aspect gradient $p=0.015$. But in Bededo forest there was no significant difference between them. Generally the elevation difference, species type, and aspect gradient were factors that affect the different carbon pools of the forest. From the point of view of managing forests for climate change mitigation, the result suggested that the forest should be conserved and protected in a sustainable way for further carbon sinks.

Keywords: Aspect, carbon stock, elevation and species diversity

1. INTRODUCTION

Climate Change is the change in the planet's climate beyond its natural variability. It can be caused both by natural forces & human activities. But, very likely it is Human Activity in origin. Intergovernmental panel on climate change The Intergovernmental Panel on Climate Change (IPCC, 2007), indicates that, most of the observed increase in global average temperatures and changes in precipitation patterns since the mid-20th century is very likely due to observed increases in anthropogenic GHG concentrations.

(IPCC, 2007) Says it is 90-99 % sure that human activity is the cause of Climate Change. The mechanism is the creation of GHG, which increase the amount of heat trapped near the surface of the earth. Worldwide, net emissions of GHGs from human activities increased by 35% from 1990 to 2010. According to the United Nations Framework Convention on Climate Change (UNFCCC); climate change is a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere.

However, in spite of the fact that Africa contributes very little to the global greenhouse gas emissions, but the continent has been predicted to be the worst affected by climate change. Therefore, being explored to mitigate and adapt to the adverse effects of climate change, Reducing Emissions from Deforestation and Forest Degradation (REDD) has emerged as one of the most advanced concepts in international climate change mitigation efforts. Since the end of 2005, signed REDD+ progress has been evident within and outside of the UNFCCC process. Emissions of CO_2, which account for about 3/4 of total emissions, increased by 42% over this period.

The majority of the world's emissions result from: Electricity generation, transportation, Industries and other forms of energy production and use. Some Impacts that are comes from Climate Change: Sea Level Rise, Extreme Weather Events, Impact of temperature Rise on Crops and Ecosystems, Changing Disease Patterns and etc. At the eleventh session of the Conference of the Parties (COP) talks on; reducing emissions from deforestation in developing countries began, Parties recognized the importance of the issue in relation to addressing climate change, particularly in the light of the large contribution of deforestation activities in developing countries to global greenhouse gas emissions.

Climate change caused by human induced emissions of greenhouse gases is now recognized as one of the major medium and long term threats to human welfare and development. About 15% of greenhouse gas emissions result from deforestation and forest degradation. In response, a series of measures have been proposed to reduce these emissions global. Reduced Emissions from Deforestation and Forest Degradation-plus (REDD+) is a set of policies to prevent or slow down deforestation and forest degradation and to increase forest carbon stocks in developing countries. Integral to most models of REDD+ is the idea of an incentive mechanism through which rewards are provided to parties which take action to reduce emissions from forest lands.

According to REDD+, the forest sector in Ethiopia is responsible for the emission of 65 million tons of CO_2e, about 40% of the national GHG emissions. As a responsible member of the global community, Ethiopia has recognized the important role that it can play in global climate change mitigation. Forests represent a massive carbon reservoir on the planet storing over 4,500 G tons of carbon. GHGs emissions due to deforestation and forest degradation are the second-largest, representing about 15-17% of the global GHG emissions after industry sector.

Reducing deforestation would thus significantly reduce carbon emissions, and contribute to climate change mitigation cost effectively. Apart from its contribution to over a fifth of global mitigation, the REDD+ actions also provide a range of services (commonly referred to as co-benefits). The co-benefits (multiple benefits) among others include: Watershed management and water regulation; Development of over 1.2 billion of the world’s poorest or underserved communities; Sustainable forest as a source of fuel wood, food, medicines and shelter to local communities; Conservation of biodiversity; and Other ecosystem services on local to global scales.

Ethiopia has one of the largest forest resources in the horn of Africa. The highland terrain combined with its location in relation to the Atlantic and Indian Oceans has made Ethiopia to receive a higher moisture supply as compared to its neighbors’. Over 50% of Africa’s highlands are in Ethiopia makes it one of the significant water towers on the continent. The forest resource of the country is classified into natural, high forest, woodland, and shrub land (WBISPP, 2004). The high forests in Ethiopia cover about 4 million hectares or 3.56 percent of the area of the country. Some 95 percent of the high forest area is located in Oromia, SNNPR and Gambela Regions. In the context of REDD+, not only high forest, but also woodlands, and shrub lands are important forest ecosystems because together they represent about 80% of the carbon stocks in Ethiopia (Moges et al. 2010;Yohannes. et al., 2010).

The woodlands cover 29 million hectares (about 25%) and the shrub lands, Forest and other land cover and land use map of Ethiopia (WBISPP 2004), 2004), 26 million hectares (23%). Regions with the largest area of woodlands in order are Somali (45%), Oromia (34%), and Benshangul-Gumuz (8%). The largest area of shrub lands is found in Oromia Region (29%), Somali (20 %) and Amhara (16%). The WBISSPP also mapped 494,546 ha of lowland Bamboo, all of it in BeneshangulGumuz Region; although small patches mixed in with woodland trees occur in Amhara, Oromiya and Tigray Regions. The total area of plants, forests is estimated at 216,000 ha and comprises industrial, fuel wood and communal plantations (EEO 2007).

Ethiopia is endowed with different vegetation cover in dry land areas. *CombretumTerminalia* woodlands and *Acacia-Commiphora* woodlands are the two dominant vegetation types that cover large parts of the dry land areas in Ethiopia (Eshete et al., 2011). Forests provide a great variety of products and services to humankind. The major economic value of forests comes from the wood of trees, used or traded as lumber, plywood, fuel wood or charcoal. Other economic importance includes food, medicines, fodder for livestock, natural gums, etc. The latter collectively called non-timber forest products (NTFPs) (Ros-Tonen et al., 1995). The dry land, woodlands in Ethiopia possess diverse tree species that are known for their valuable Non-Timber Forest Products (NTFPs) of local, national and international significance. One of the well-known species in this regard is *Boswellia papyrifera*.

The species is a deciduous multipurpose tree with the potential for economic development and desertification control (Lemenih and Teketay 2003; 2004). This species is found in the *Combretum-Terminalia* (broad-leaved) deciduous woodland and wooded grassland, usually dominant on steep rocky slopes, lava flows or sandy valleys, within the altitudinal range of

950-1800 m.a.s.l. Altitude (Eshete et al. ,2005). In Ethiopia, Boswellia papyrifera provides the widely known and traded frankincense that accounts more than 80% of the export revenues that the country is earning from gum and resin resources (Eshete et al., 2012). Ethiopia is the leading producer and exporter of frankincense and with significant local and national economic benefits (Eshete et al., 2012). Boswellia papyrifera provides several goods and services such as poles, timber, fodder, nectar and gum, which is useful for traditional medicine, religious ritual and change mitigation and adaptation locally as well as globally. Globally, forest ecosystems account for approximately 90% of the annual carbon flux between the atmosphere and terrestrial ecosystems (Dixon et al. ,1994).

Carbon storage in forest ecosystems involves numerous components, including aboveground and below-ground biomass, deadwood, and litter and soil carbon. Forests are relevant to climate change mitigation through their potentials in mitigation GHGs, particularly carbon sequestration. Although there is no doubt growing trees function as an active carbon sink, large emissions from dead organic matter and soil would count as a reduction in the amount of sequestrated carbon (Takahashi et al., 2010).

However, dead organic matter and soil carbon stock are influenced by vegetation, site conditions and forest management practices. More biomass results in increased production of aboveground litter and belowground root activities. Some research undertaking also indicated that by adding trees in grassland or pasture systems, the SOC content can be increased considerably (Reyes-Reyes et al. 2002; Yelenik et al., 2004).

Therefore, managing the woodland ecosystems is a cost-effective carbon storing/sequestering effort towards absorbing carbon dioxide from the atmosphere (Smith et al. ,1993; Dixon et al. 1994; Lal 2005) and plays an important role in the global carbon cycle. Related to the effects of human activity in terrestrial ecosystems, land-use category is a key factor for determining the equilibrium level of carbon stock in the soil (Paul et al. ,2002). In Ethiopia, more than half of the country’s land area is located in such dry areas and associated tropical dry forest. The biomass carbon densities expressed as mass per unit area (Mg/ha) for different forest types where one of the important components for assessing the contribution of forestlands to the global carbon cycle (Haripriya ,2002).

According to the UNDP climate change country profiles, the average annual temperature in Ethiopia is projected to increase by 1.1°C to 3.1°C by the 2060s. All projections indicate substantial increases in the frequency of days and nights that are considered ‘hot’ in the current climate (Lyngbaek et al. 2001; Feyissa et al. ,2013). Climate model projections under some IPCC scenarios show warming in all four seasons across Ethiopia, which may cause a higher frequency of heat waves as well as higher rates of evaporation. Thus, current ‘hot’ days and nights will increasingly become the new normal for the Ethiopian climate.

Biodiversity is a common factor that links agriculture, forestry, fisheries and other sectors and provides the necessary materials for livelihood, sustenance, trade, medicines and industrial development. Ethiopia is endowed with plant diversity; the total number of vascular plants in Ethiopia is estimated to be about 6000 species (Hedberg et al. ,2009), out of which about 10% are endemic. The number of woody plants is said to be around 1000 and out of which about 300 are tree species (Berehan 1991; EFAP 1994; EPA 1997). According to (Kent and Cocker 1992), over large parts of the globe, human populations have modified plant communities extensively.

This is also true in Ethiopian condition. However, there is high deforestation and the annual rate of deforestation of the high forests in Ethiopia ranges from 150,000 to 200,000 ha (EFAP 1994; EPA 1997). The Ethiopian country report of the FAO, from the Global Forest Recourses Assessment (GFRA), also shows similar results of deforestation rate, which is 2 1.25% of forests (156,241.96 ha of forest per year) (FAO, 2015). From the same report the deforestation rate for woodlands is even more serious which amounts 1.8% per year, which is 731,363.13 ha of woodlands per year. Information on vegetation may be required to help reduce carbon emission.

In this respect, the local farmers or forest dependent communities should be eligible for payments for carbon credits/market for managing the woodland resources, and this will be strong additional incentive for promoting sustainable woodland development and management in dry lands of Ethiopia. In addition to the aforementioned benefits, the presence of woodlands in the dry lands of Ethiopia could serve as a sink for atmospheric CO_2 and have potential contributions to climate

1.2. Statement of the Problem

Weira-Amba and Bededo forests were the two study sites found in North and south wollo administrative zone in Amhara region. Despite the fact that these forests were not studied before with respect to carbon sequestration as well as species diversity. In comparison, some studies were conducted on Bededo forest, but did not provide holistic information, including: plant diversity and its potential for carbon sink and its contribution to climate change mitigation. Factors such as landscape change (changing forest to another type of land use), deforestation, agricultural expansion, climate change and others are affecting the forests. On the top of that, information leaks on the current plant diversity of the Weira-Amba and Bededo forests also, their contribution to climate change mitigation in general and their carbon sequestration potential, in particular and also the relationships of carbon stocks to environmental gradients not yet studied. Therefore, this paper was initiated to alleviate those problems.

1.3. Objective

1.3.1. General Objective

- To conduct plant diversity study and the contribution to climate change mitigation as carbon sinks in Weira-Amba and Bededo forests, in order to support the knowledge based plant diversity conservation planning effort of the country, to support the sustainable development of the two forests, as well as to supply current information of the two forests for the scientific community.

1.3.2. Specific Objective

- To estimate the total carbon stock density of the study areas
- To assess the tree species diversity in these selected enclosures watershed
- To investigate the impact of topography and time of forests for carbon sequestration

1.4. Research questions

1. What were the plant species compositions and vegetation types exist in the study areas and how they relate to each other?

2. What were the relationships between different environmental variables and plant communities and how they affect each other?

3. What variability exists in the structure of woody species?

4. What are the contributions of these forests as carbon sink and climate change mitigation?

1.5. Significance of the study

Currently, the importance of forest ecosystems are considered in the context of climate change mitigation because they can act as the sinks of CO_2 (Pearson et al., 2005). If the woodlands are to be used in carbon sequestration schemes such as the CDM/REDD, it is a better option in developing countries for the dual objective of reducing greenhouse gas emissions and contributing to sustainable woodland development and management (Roshetko et al.,2002). As a result, carbon determination may provide clear indications of the possibilities of promoting dry woodland development and management for climate change mitigation through soil and vegetation carbon sequestration and opportunities for economic benefit through carbon trading to farmers (Lal, 2009).

Vegetation cover and climate are interrelated as one affects the other, and the effect of one on the other is very important and decisive. Climate change has affected the environmental conditions to which forest trees are adapted and climate is also shaped and strongly influenced by vegetation cover.

Therefore, knowledge on the plant diversity of these forests, their potential as carbon sinks and overall ecosystem services were contributing a lot to the conservation and sustainable utilization of the resources and to have knowledge based conservation plan. Moreover, areas for *in situ* and *ex situ* conservation were identified and species which need conservation priority was identified for future conservation. Apart from these, the different ecosystem services of the forests were well known and alternative income generating options which can be accrued from the sustainable use of the forest was diversified.

2. LITERATURE REVIEW

2.1. Description of Major Vegetation Types in Ethiopia

The forest cover of Ethiopia has been diminishing continued from time to time. About 35–40% of Ethiopia’s land area was covered with high forests before 1950, and it was estimated to be 16% in the early 1950’s, 3.6% in 1980’s, 2.7% in 1989 and less than 2.3% in 1990 (EFAP, 1994). Reusing M.,1998), also reported that, since 1973, the Ethiopian forests have shown a tremendous decline. By analyzing satellite data the author reported that, around 24,543 km2 (2.14%) of the land area of Ethiopia had been deforested between 1973 and 1990.

The Ethiopian country report for the FAO, Global Forest Recourses Assessment (GFRA) shows that, the forest covers estimate of the country for the early 2000s is 12.3% (1,3701,014 ha) (FAO, 2015). This doesn’t mean that the forest cover of the country dramatically increased from less than three present to 12.3%, but the FAO definition considered the high woodland which were previously not included in this category (FAO, 2010). Thus, if we consider only the high forest, the cover is only 3.29% (3.65 million ha) (FAO, 2015).

Several authors have contributed to describe the vegetation types in Ethiopia, such as: (Breitenbach 1993; Beals 1998; Friis et al., 2010). The latest work of the potential vegetations of Ethiopia by Friis et al., 2010) identified twelve major types and twelve subtypes, which combined make up a total of 19 types and 7 subtypes Friis et al., 2010). Table 1 below shows the classification of potential vegetation types of Ethiopia.

Table 1: Classification of potential vegetation types of Ethiopia, according to different authors.

Zerihun Woldu (1999)	**Friis and Sebsebe Demissew (2001)**	**Friis *et al*., 2010**	
Semi-desert and desert open xerophilous woodland	Desert and semi desert scrubland	1. Desert and Semi-desert scrubland (DSS)	
Acacia-Commiphora woodland	*Acacia-Commiphora* Woodland	*2. Acacia-Commiphora*	*2a.Acacia Commiphora* woodland and bush land properly (ACB)

		Woodland and bush land (ACB)	*2b. Acacia* woodland of the Rift Valley (ACB/RV)
		3. Wooded grassland of the western Gambella region (WGG)	
Combretum-Terminalia (broadleaved deciduous) woodland	*Combretum-Terminalia* woodland	4. *Combretum-Terminalia* woodland and wooded grassland (CTW)	
Dry evergreen mountain forest	Dry evergreen mountain forest and Grassland complex	5. Dry evergreen Afromontane forest And grassland complex (DAF)	5a. Undifferentiated Afromontane forest (DAF/U)
			5b. Dry single-dominant Afromontane forest of the Ethiopian highlands (DAF/SD)
			5c. Afromontane woodland, wooded grassland and grassland (DAF/WG)
			5d. Transition between Afromontane vegetation and *Acacia- Commiphora* bush land on the eastern escarpment (DAF/TR)
Moist evergreen montane forest	Moist evergreen montane forest	6. Moist evergreen Afromontane forest (MAF)	6a. Primary or mature secondary moist evergreen Afromontane forest (MAF/P)
			6b. Edges of moist evergreen Afromontane forest, bush land, woodland and wooded grassland (MAF/BW)
Lowland dry evergreen Forest	Lowland semi-evergreen forest	7. Transitional rainforest (TRF)	
Afro alpine and	Afro alpine and	8. Afro alpine belt	

sub-Afro alpine	sub-Afro alpine	9. Ericaceous belt	
Wetlands	Aquatic /Wetland and Riparian vegetation	10. Riverine vegetation (RV)	
		11. Freshwater Lakes, Lake shores, marshes, Swamps and flood plains Vegetation (FLV)	11a. Freshwater lake vegetation [open water] (FLV/OW)
			11b. Freshwater marshes and swamps, floodplains and lake shore vegetation (FLV/MFS)
		12. Salt-water lakes, lake shores, salt marshes and pan vegetation (SLV)	12a. Salt-water lake vegetation [open Water] (SLV/OW)
			12b. Salt pans, saline/ brackish and Intermittent wetlands and salt-lake Shore vegetation (SLV/SSS)
Mountain, Evergreen thickets and scrub			

Source : (Breitenbach 1993; Beals 1998; Friis et al., 2010)

In addition to the classification of vegetation at a national scale there have been, vegetation studies conducted in different parts of the country on afro alpine/forest/ woodland vegetation by a number of authors including: the vegetation of the Erer Gota Plain, Harar (Beals, 1998), Menagesha State Forest, Shewa (Demissew, 1980), Grass-land Vegetation of Welmera (Woldu, 1980), Jemjem Forest, Sidamo (Sharew 1982)-, Harena Forest, Bale (Nigatu and Tadesse, 1989), Forest of the Central Plateau of Shewa (Bekele, 1993), Afro alpine Vegetation of Senati Plateau, Bale (Gashaw and Fetene, 1996), Ecological study of lowland vegetation, Key-Afer Shala-Luqua and Southwest of lake Chammo (Soromessa, 1996).

Vegetation of Gambella Region, Southwestern Ethiopia (Awas et al., 2001), Afromontane and Transitional Rainforest Vegetation of Southwestern Ethiopia (Yeshitila and Bekele, 2001), Vegetation of Denkoro Forest South Wollo (Ayalew, 2003), Vegetation of Dodolla Forest, Bale (Hudera, 2003), (Kelbessa and Demissew, 2014), and many others. Studies have shown that there is still a need for in-depth research to understand the extent of Ethiopia's plant resources and wildlife, and the issues that concern them (e.g., quality, quantity, distribution, and habitat requirements), (Ståhl and Wood, 1989; IUCN, 1992; SIDA, 1991; Ethiopian Government, 1992; Hillman, 1993; Jacobs and Schloeder, 2001).

2.2. Forests and Climate Change: The Source and Sink Scenario

Carbon pools are major components of an ecosystem that can either accumulate or release carbon. A carbon sink is a carbon pool from which more carbon flows in than out. On the other hand a carbon source is a carbon pool from which more carbon flows out than flows in. Therefore, forests can act as a carbon sink through the process of tree growth and resultant biological carbon sequestration as well as, can often represent a net source of carbon due to the processes of decay, combustion and respiration. the generalized carbon cycle of the territorial ecosystem as described in the (IPCC, 2006).

About 30% of the global land area is covered by forests, which provide a wide range of important products such as timber, fuel wood, paper, food and fodder as well as environmental and social services including the protection of soil and water resources, the conservation of biological diversity and the provision of livelihoods for an estimated 1.6 billion people (World Bank, 2004). Forests, like other ecosystems, are affected by climate change, but also influence climate and the climate change process. They absorb carbons in wood, leaves and soil, and release it into the atmosphere, for example, when burned or when forest land is cleared.

That means forests act both as a source and sink of carbon. At the global level, it is estimated that during the 1990s deforestation and forest degradation released around 1-2 Pg C/year (Pentagrams of carbon) (Houghton, 2005); which represents around 17% of total annual anthropogenic Green House Gas (GHG) emissions and the majority of deforestation and forest degradation takes place in developing countries (Gullison et al., 2007). (Le Quéré et al., 2009), also indicated that in the 1990's, humans added 8.0 x 1015 grams of carbon (1015grams of carbon = 1 Pg C) to the atmosphere each year, primarily by burning fossil fuels (6.4 Pg C/yr) and clearing land in the tropics (1.6 Pg C/yr). Among this amount carbon, the ocean took up 28%, and the land absorbed 32%. The remaining 40% stays in the atmosphere to cause global warming. (Le Quéré et al. (2009), also presented that, from 2000-2008 humans added 9.1 Pg C to the atmosphere each year, 7.7 Pg C/yr from fossil fuels and 1.4 Pg C/yr from land use change. A larger fraction of these recent emissions (45%) has remained in the atmosphere (Le Quéré et al., 2009).

Therefore, future global warming depends on both the CO_2 source from human emissions and the CO_2 sink from natural sinks in the ocean and the terrestrial biosphere which is mainly forests. In order to improve this situation (increase in the amount of CO_2 in the atmosphere) there are two alternatives: the first one is to reduce the emissions of greenhouse gases into the atmosphere; and the second is to remove these gases from the atmosphere once it is in place, in which forests play a significant role.

2.3. The Role of Forests in Climate Change Mitigation

The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere which is in addition to natural climate variability observed over comparable time periods (UNFCCC 1994). Climate includes the long term patterns of temperature, precipitation, humidity, wind and seasons. "Climate change" refers more than just a change in the weather; it refers to seasonal changes over a long period of time.

According to the (IPCC, 2001): climate change is defined as "a significant and long-lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. It may be a change in average weather conditions or in the distribution of weather around the average conditions (i.e., more or fewer extreme weather events) (IPCC 2001). These climate patterns play a fundamental role in shaping natural ecosystems, economies and the human cultures that depend on them. Because so many natural, economic and social systems are strongly related to climate, a change in climate can affect many related aspects of where and how people, plants and animals live, such as food production, availability and use of water, and health risks. For example, a change in the usual timing of rains or temperatures can affect when farmers sow their crops and the types of crops to grow, when plants bloom and set fruit, when insects hatch or when rivers and streams are their fullest. This can affect historically synchronized pollination of crops, food for migrating birds, water supplies for drinking and irrigation, forest health, and more.

Some short-term climate variation is normal, for example, recurrent drought is a common phenomenon in Ethiopia and it occurs usually almost every ten years in some parts of the country. A year or two of an extreme change in temperature or other condition doesn't mean a climate change. But longer-term trends globally as well as in the country now indicate a changing climate. Forest and climate are interrelated, one affects the other and the effect of one on the other is very important and decisive.

Climate change will affect the environmental conditions to which forest trees are adapted and expose them to new pests and diseases; thus create additional challenges for forest management and threats the biological diversity in forest ecosystems. In addition to soils, aspect and elevation; climate dictate what will grow when, where and how well.

Therefore, changes in temperature, precipitation and other climatic factors have the potential to dramatically affect forests at the national level and similarly worldwide. On the reverse, climate is also shaped and strongly influenced by forests. That means forests are shaped by climate and vice versa. IPCC, (2006), also described this relation as: "Forests and climate change are intrinsically linked, in ways that extend beyond carbon.

Climate change and global warming could change the forest landscape worldwide and vice versa. Changes in global climate through higher mean annual temperatures, altered precipitation patterns and more frequent and extreme weather events may have diverse effects on forests, including stress, compositional and functional changes, and changes in the capacity of forests to provide products and services.

These effects are as yet poorly understood."In recent years, climate change is becoming a hot issue and as well as a global number one agenda, since its effect is being clearly seen in different parts of the globe in different magnitudes. Human activities including industry, transportation and change in land uses are significant causes of climate change. So, mitigating climate change through the conservation and sequestration of carbon dioxide, which is the major GHGs, is important. Forest management, therefore will improve sequestration of the atmospheric carbon dioxide and increases forest carbon stocks which have many additional benefits including the improved capacity of forest lands to provide other ecosystem services, support biodiversity, and contribute to social welfare which is socially and environmentally acceptable, and economically cost-effective.

As described by (Canadell and Michael, 2008), forests currently absorb billions of tons of CO_2 globally every year, an economic subsidy worth hundreds of billions of dollars if an equivalent sink had to be created in other ways. According to (Rogner, 2007), reducing GHG emissions and stabilizing atmospheric concentrations at 350-450 parts per million CO_2-equivalent (ppm CO_2-e) is essential (CO_2-e is a universal standard of measurement against which the impacts of releasing or actively sequestering different greenhouse gases can be evaluated). The current GHG level is approximately 390 ppm CO_2-e. Scientists have estimated that lowering concentrations to 350 ppm may enable us to avert tipping points of ocean acidification and the melting of permafrost and arctic ice. Stabilization at 450 ppm is thought to be the threshold to avoid dangerous warming of more than 2 degrees Celsius, which would bring potentially catastrophic impacts for natural and human communities 15 alike. The solution for this is protection and sustainable management of natural ecosystems. Protecting the Earth's ecosystems can yield immediate, cost effective climate change solutions.

According to (FAO, 1997), detailed estimations of the biomass of all land cover types are necessary for carbon accounting, although reliable estimations of biomass in the literature are a few. Biomass and carbon content are generally higher in tropical forests, reflecting their influence on the global carbon cycle.

Tropical forests also have great potential for the mitigation of Co_2 release through appropriate conservation and management. On the contrary, poor management of forests will also contribute to an increment of GHG and climate change, since the accumulation of carbon by a forest is reversible, with carbon being returned to the atmosphere through dieback, decay and burning of wood if the forest stands are not maintained (Broadmeadow and Robert, 2003). For example, the burning and clearing of tropical forests is a major, even though, often unrecognized source of greenhouse gas emissions. It accounts for roughly 16 percent of the total global emissions, which is more than all of the world's cars, trucks, ships, trains and planes combined (Rogner, 2007). It is now generally recognized that it will be impossible to achieve equal or below any of the needed targets for mitigating climate change without significantly restricting the clearing and burning of tropical forests. In fact, reducing global deforestation by 50 percent by 2020, offers nearly one-third of the cost-effective, technologically available options to meet 450 ppm stabilization targets. Therefore, forests, especially tropical forests play a key role in the mitigation of the global climate change which is far beyond a case of carbon sinks.

2.4. Forest Management and Carbon Sequestration

The term '***carbon sequestration***' is the most commonly used term to talk about the removal of GHGs from the atmosphere in which forests play a significant role in fixing the atmospheric CO_2. To achieve climate change mitigation through forest management, it requires that forests to be managed in such a ways that, it fundamentally reduces carbon emissions due to forest degradation and deforestation in addition to the removal of CO_2 gas from the atmosphere (IPCC, 2007). To do so, several forest-related options are available, such as:

- Maintained or increased forest land area;
- Reduced deforestation and forest degradation;
- Increased afforestation and reforestation (by planting and natural regeneration approaches);
- Maintained or increased forest carbon density;
- Forest restoration and conservation;
- Wildfire management;
- Increased use of wood products from sustainably managed forests; and
- Increased long-term carbon storage in timber products.

In the year 2010 the World Food and Agriculture Organization of the United Nations (FAO) estimated the global forest cover to be over 4 billion hectares, which is 31% of total land area of the world (FAO, 2010).

As described by the (IPCC, 2007), tropical forests are the richest in carbon density per unit area as compared to other biomes and other terrestrial carbon stocks. Moreover, tropical forests support much of the Earth's biological diversity and contribute substantially to the global economy and to the local human welfare, in addition to the contribution to the global carbon budget.

Based on case studies from across the tropics, the Economics of Ecosystems and Biodiversity (Sukhudev, 2010) described that, if all the ecosystem services provided by tropical forests were paid for, they would generate about $11.1 trillion per year ($ 6,120 ha-1 *1807 million ha), nearly equivalent to the European Union's GDP in 2009. Unfortunately, the capacity of tropical forest to provide these services is reduced each year by deforestation as well as by forest degradation principally due to uncontrolled logging (Lambin et al., 2003; FAO, 2010). Concerning degradation, at least 392 million ha, or 20% of the total area of humid tropical forests, was logged during 2000–2005, and about 50% of standing humid tropical forests retained 50% or less cover as of 2005 (FAO, 2010). Therefore, forest management plays a significant role not only as a carbon sink, but also from the point of view as a source of carbon which can be generated due to a poor forest management.

2.5. Relationship between Environmental Variables and Forest Carbon Sequestration

Plant growth and carbon sequestration depend on a number of factors such as local climate, Nutrient availability and other soil factors, land use and management. As described by (Sheikh et al., 2009), elevation is one of the most important environmental gradients that affect biomass, stem size, stand density and spatial heterogeneity of stems. Altitude has a significant effect on climatic factors such as temperature and precipitation. It has a direct relation with precipitation and an inverse relation with temperature. This means, as altitude increases, temperature decreases and precipitation increases. So, as temperatures decline, usually the amount of biomass that can be produced also declines, due to shorter heat periods. Since temperatures typically decline with elevation, locations at higher elevations support less biomass than locations at lower elevations; however, the rate of decline probably varies between areas such that there is no single rate that can be used everywhere.

In contrary, the result of (Griffiths et al., 2009), showed that increased elevation significantly increased soil moisture, mean annual precipitation, soil organic matter, available C and mineralizable N, microbial activities, extractable ammonium, and de-nitrification potentials which are likely driven by a reduction in decomposition rates rather than an increase in primary productivity.

In general, altitude strongly affects species composition, productivity of vegetation and consequently affects the quantity and turnover of organic matter. As described by (Sheikh et al., 2009), as that of above ground biomass and carbon sequestration, altitude also influences the soil organic matter and carbon sequestration in the soil by controlling soil, water balance, soil erosion and deposition process and this further affects the quantity of the whole carbon stock of the forest. As that of altitude, slope gradient and aspect, climatic variables such as precipitation and temperature and other environmental variables such as soil also known to influence the amount of organic matter and carbon.

According to (Bayat, 2007), slope and aspect have a significant relationship with biomass in forest areas due to the interaction between solar radiation and soil properties such as soil moisture and nutrient. Thus, the south-facing slopes, which receive high solar radiation as compared to the north-facing slope, have typically hot soil surfaces, which can lead to high biomass accumulation. According to (Friis and Demissew, 2001), slope, aspect has a significant effect on aboveground biomass, below ground biomass, soil organic Carbon and total carbon density, in which east slope, aspect showed the highest, whereas south slope aspect showed the lowest total carbon stock. Similarly, different studies have shown that, the higher slope class showed a lower total carbon stock as compared to the low slope class, since increase in the slope will increase runoff and soil erosion (Maggi et al., 2005; Yohannes. et al. 2010; Güner et al., 2012; Feyissa et al., 2013)

2.6. Relationship between Plant Diversity and Carbon Sequestration

Trees and woody biomass play an important role in the global carbon cycle. Forest biomass accounts for over 45% of terrestrial carbon stocks, with approximately 70% and 30% contained within the above and belowground biomass, respectively (Cairns et al., 1997; Mokany et al., 2006). Carbon sequestration capacity and the amount of carbon sequestered not only related to the type of vegetation such as Forest, Woodland, Savanna etc., but also by the plant diversity and the type of species within it. The amount of carbon accumulated by a certain tree species is calculated from its biomass. Biomass in its turn is a function of wood density and it is obvious that different tree species have different wood densities which eventually lead to different carbon sequestration capacity.

According to Hicks et al., (2014), globally there is a generally positive relationship between carbon stocks and biodiversity; tropical moist forests are rich in both biodiversity and carbon stock. However, within intact tropical forests the patterns are more complex and there is no clear evidence for a correlation between spatial patterns of carbon stocks and biodiversity. Although, there is established, but incomplete evidence supporting the link between species richness and forest carbon sequestration, in tropical forests it is still uncertain, whether and to what degree biodiversity influences carbon stocks. However, (Hicks et al., 2014): generalized that, increased species richness has been shown to increase sequestration, both due to the increased chance of having highly productive species and due to the more efficient use of resources that results from the presence of multiple species with different requirements.

2.7. Carbon Stock Pools

2.7.1. Aboveground Biomass Carbon Stock

Carbon sequestration can be defined as the removal of CO_2 from the atmosphere and store into green plant biomass (sink) where it can be stored indefinitely through the process of photosynthesis (Watson et al., 2000). These sinks can be above ground biomass (trees), living biomass below the ground in the soil (roots and microorganisms) or in the deeper sub-surface environments (Nair et al., 2009), Forests are major contributors to terrestrial carbon sink, mitigating climate change and associated economic benefits (Watson et al., 2000; Sheikh et al., 2009).

As a leading tree based system, especially in the tropics, Agroforestry, afforestation and reforestation has been suggested as one of the most appropriate land management systems for mitigating the atmospheric carbon increase (Dixon et al., 1994; Albrecht and Kandji, 2003; Montagnini and Nair, 2004).

The estimation of the total global carbon sequestration potential for afforestation and reforestation activities for the period 1995-2050 was between 1.1-1.6 Gt carbon per year and of which 70% will be in the tropics (IPCC, 2000). Even though the climate protection role of forests is apparent, it is complex to determine how much of the forest carbon sink and reservoir can be managed to mitigate atmospheric CO_2 and in what way to build up. Four major strategies are available to mitigate carbon emissions through forestry activities: (I) increase forest land area through reforestation and afforestation, (ii) increase the carbon density of existing forests at both stand and landscape scales, (iii) expand the use of forest products that sustainably replace fossil-fuel and (iv) reduce emissions from deforestation and degradation (Canadell and Michael, 2008).

Deforestation and the burning of forests release CO_2 to the atmosphere. Indeed, land use and land cover change, especially deforestation is responsible for about 25% of all greenhouse emissions to the atmosphere (Watson et al., 2000). On the other hand, forest ecosystems could also help reduce greenhouse gas concentrations by absorbing carbon from the atmosphere through the process called photosynthesis. Of all the global forests, tropical forests have the greatest potential to sequester carbon primarily through reforestation, Agroforestry and conservation of existing forests (Brown and Lugo, 1992).

Forests are also producing renewable materials in order to substitute fossil fuel (Watson et al., 2000). Forests operate both as vehicles for capturing additional carbon and as carbon reservoirs. A young forest, when growing rapidly, can sequester relatively large volumes of additional carbon roughly proportional to the forest's growth in biomass. An old-growth forest acts as a reservoir, holding large volumes of carbon even if it is not experiencing net growth.

Thus, a young forest holds less carbon, but it is sequestering additional carbon over time. An old forest may not be capturing any new carbon but can continue to hold large volumes of carbon in its biomass over long periods of time. Managed forests offer the opportunity for influencing forest growth rates and providing for full stocking, both allow for more carbon sequestration. Forest management for carbon sequestration would have associated with it a relative increase in stock of carbon held captive in the forest ecosystem over what would have occurred in the absence of such focused management. Increases in the stock of carbon could be accomplished as the result of an increase in the forest biomass and as a result of an increase in forest soil carbon directly. Finally, if the stock of long-lived wood products increases, the carbon held captive in wood products stock would also increase (Sedjo, 2001).

2.7.2. Root Biomass Carbon Stock

Roots are an important part of the carbon balance, because they transfer large amounts of carbon into the soil. More than half of the carbon assimilated by the plant is eventually transported below-ground via root growth and turnover, root exudates (of organic substances) and litter deposition. Depending on rooting depth, a considerable amount of carbon is stored below the plow layer and better protected from disturbances, which leads to longer residence times in the soil. With some trees having rooting depths of greater than 60 m, root carbon inputs can be substantial, although the amount declines sharply with soil depth (Cairns et al. , 1997).

Root biomasses in ecosystems are often estimated from root-to shoot ratios. The ratio ranges from 0.18 to 0.30, with tropical forests in the lower range and the temperate and boreal forests in the higher range (Cairns et al., 1997). The roots make a significant contribution to SOC (Strand et al., 2008). About 50% of the carbon fixed in photosynthesis is transported below ground and partitioned among root growth, rhizosphere respiration, and assimilation to soil organic matter (Lynch, J.M., and Whipps, 1990); (Nguyen, 2003). Roots help in accumulation of the SOC by their decomposition and supply carbon to the soil through the process known as rhizoid position (Rees et al., 2005); (Weintraub et al., 2007). Increased production and turnover rates of roots lead to increased SOC accumulation following root decomposition (Matamala et al., 2003).

2.7.3. Dead Wood Biomass Carbon Stock

Dead organic matter is composed of litter and deadwood, generally divided into coarse and fine, with the breakpoint set at 10 cm diameter (Harmon and Sexton, 1996; Takahashi et al., 2010). Although logging dead wood, standing and lie down on the ground, is often a significant component of forest ecosystems, often accounting for 10-20% of the aboveground biomass in mature forests, but it tends to be ignored in many forest carbon budgets (Delaney et al., 1998).

The quantity of dead wood does not generally correlate with any index of stand structure (Harmon and Sexton, 1996). The primary method for assessing carbon stock in the dead wood pool is to sample and assess the wet-to-dry weight ratio, with the large pieces of dead wood measured volumetrically as cylinders and converted to biomass on the basis of wood density, and standing trees measured as live trees but adjusted for losses in branches (<20%) and leaves (<2 3%) (MacDicken, 1997).

Dead trees serve many key functions in the ecosystems (Franklin et al., 1987). Since dead trees may persist for centuries, they can influence ecosystems as long as living trees. Woody detritus reduces erosion, they are a major source of energy and nutrients, serves as a seedbed for plants and they are a major habitat for microbes, invertebrates and vertebrates (Harmon et al., 1986).

2.7.4. Litter Carbon Stock

Carbon is stored in trees (stem, branches, leaves and root), understory, and forest litter and forest soils. The mechanism of species driven carbon sequestration in soil is influenced by two major activities, aboveground litter decomposition and below ground root activity (Lemma et al., 2007). Litter decomposition is one of the major sources of SOC and the quality of litter is very important in this regard (Mafongoya et al., 1998; Lemma et al, 2007).

In the systems with high plant diversity, litters are present with different degrees of chemical resistance, creating the possibility of longer residence of carbon through slower decomposition of litters from some species. Lignin in litter is highly resistant to decomposition and therefore, litter with high lignin content would have slower decomposition rate (Mafongoya et al., 1998). In contrast, litter with low lignin, phenols, and high nitrogen content would have a faster rate of decomposition.

2.7.5. Soil Carbon Stock

The term ‘‘soil carbon sequestration’’ implies the removal of atmospheric CO_2 by plants and storage of fixed carbon as soil organic matter. The strategy is to increase SOC density in the soil, improve the depth distribution of SOC and stabilize SOC within stable micro aggregates, so that carbon is protected from microbial processes or as recalcitrant carbon with long turnover time. Soil carbon sequestration also increases soil organic carbon stocks through judicious land use and recommended management practices. The potential of soil carbon sink capacity in managed ecosystems is approximately equals to the cumulative historic carbon loss estimated. The attainable soil carbon sink capacity is only 50-66% to the potential capacity. The strategy of oil carbon sequestration is cost-effective and environmentally friendly (Lal, 2004). Soils are the largest carbon reservoirs of the terrestrial carbon cycle, 1500–1550 Gt, of organic soil carbon and soil inorganic carbon approximately 750 Gt both to 1 m depth. About three times more carbon is contained in soils than in the global vegetation (560 Gt) and soils hold double the amount of carbon that is present in the atmosphere (720 Gt) (Lal, 2004). Soils play a key role in the global carbon budget and greenhouse gas effect. Soils contain 3.5% of the earth's carbon reserves, compared with 1.7% in the atmosphere, 8.9% in fossil fuels, 1.0% in biota and84.9% in the oceans (Lal, 2004).

The Soil Science Society of America recognizes that carbon is sequestered in the soils directly and indirectly (SSSA, 2001): Direct soil carbon sequestration occurs by inorganic chemical reactions that convert CO2 into soil inorganic carbon compounds such as calcium and magnesium carbonates. Indirect plant carbon sequestration occurs as plants photosynthesize atmospheric CO_2 into plant biomass. Some of this plant biomass is indirectly sequestered as SOC during decomposition processes. The amount of carbon sequestered at a site reflects the long-term balance between carbon uptake and release mechanisms. Because those flux rates are large, changes such as shifts in land use and land cover practices that affect pools and fluxes of SOC have large implications for the carbon cycle and the earth’s climate system (Lal and Bruce, 1999; Lal, 2008).

Forest soils are one of the major carbon sinks on earth, because of their higher organic matter content. Soils can act as sinks or as a source for carbon in the atmosphere depending on the changes happening to soil organic matter. Equilibrium between the rate of decomposition and rate of supply of organic matter is disturbed when forests are cleared and land use and land cover is changed (Lal, 2004). Soil organic matter can also increase or decrease depending on numerous factors, including climate, vegetation type, and nutrient availability, disturbance, and land use and management practice. About 75% of the total terrestrial carbon is stored in the global soils and 40% of it resides in forest ecosystem (Dixon et al., 1994; Six and Jastrow, 2002; Baker, 2007).

3. MATERIALS AND METHODS

3.1. Description of the Study Areas

The study areas are Weira-Amba forest and Bededo forests, which are found in North wollo and south willow administrative zones of Amhara National Regional State (ANRS). Each of the forests is described separately as follows:

3.1.1. Weira-Amba forest

Weira-Amba Forest is one of the remnants dry evergreen Afromontane forests in northern Ethiopia and the forest is located between$11^0$45’00’’N latitude and $39^0$36’36’’E longitude also it has an altitude range from 1850-2154 m a.s.l. It is 16 k/m far from Woldia, which is the capital city of the North Wollo at Amhara National, Regional State and 508 Km northing to Addis Ababa on the way to Woldia, close to the Sirinka Agricultural Research Center. It is part of the chain of mountains of the northeast escarpment of northeastern Ethiopia. More than half of the area is undulating and covered with degraded hills.

The forest area was closed during around 1982 and the forest ownership was transferred to community ownership. According to the seed zone classification of Ethiopia and Eritrea (Aalbaec and Tiruneh, 1993), the vegetation type is part of the Wolo Dry *Juniperus*, *Juniperus-Olea* forest. The present vegetation cover is mostly localized around degraded hills and includes pioneer species like *Euclea racemosa* and *Dodonea Viscosa.* Plantations of exotic species like *Eucalyptus* and *A.decurrense* are also found in on some hills in the area. The area is located in one of the regions of the country that are most frequently affected by drought. It is characterized by erratic rainfall; the mean annual rainfall is estimated at 945mm, with mean maximum and mean minimum annual temperature of 26.34 $^O{}_C$ and 13.43 $^O{}_C$, respectively. According to the soil study conducted by the Sirinka Agricultural research center, the two dominant soil types are *vertisol* and *cambisol*.

3.1.2. Bededo forest

The study area was carried out near Haik around Bededo water spring, in the eastern margin of the North-Central Massif 20 km north east of the town of Desse, and about 415 km north east of Addis Ababa. Latitudinal location of the study area is around 11°149 North and 39°469 East; with average elevation range from 2118- 2440 m a. s. l. This site was one of the oldest restoration areas in South Wollo and was not a complete victim of the forest destruction during the change of the government in the early 90s. Today there are three kinds of ownership; these are community, bureau of agriculture, and government. Twenty year climate data from Haik and Desse stations within 10 km of the study area recorded shows the influence of both the southeast monsoon and the high-elevation westerlies upon rainfall seasonality. It has a double maxima rain fall. The highest rainfall (Kiremt) occurs from June – September and little rainfall (Belg) occurring from December –May. The least rainfall is erratic and unpredictable in distribution. The average annual precipitation was estimated to be 1030 mm, whereas the average monthly temperature was 21 degree Celsius. Within short distance from the study area is situated the highland lakes in Ethiopia: Haik and Hardibo.

The soils are derived from volcanic rocks, mainly basalts of Tertiary age. The major soil types are *Lithosols* and *Vertisols*. Due to excessive erosion, in large areas the soil is too shallow. Almost 80% of the area has a soil depth less than 20 cm leading to low soil productivity and low water holding capacity (Hurni, 1988). Generally speaking the vegetation around the site could be categorized under Dry Afromontane forest dominated by *Juniperus, Olea*, *Eucalyptus globules and Cupressus lusitanica exotic plantation.*

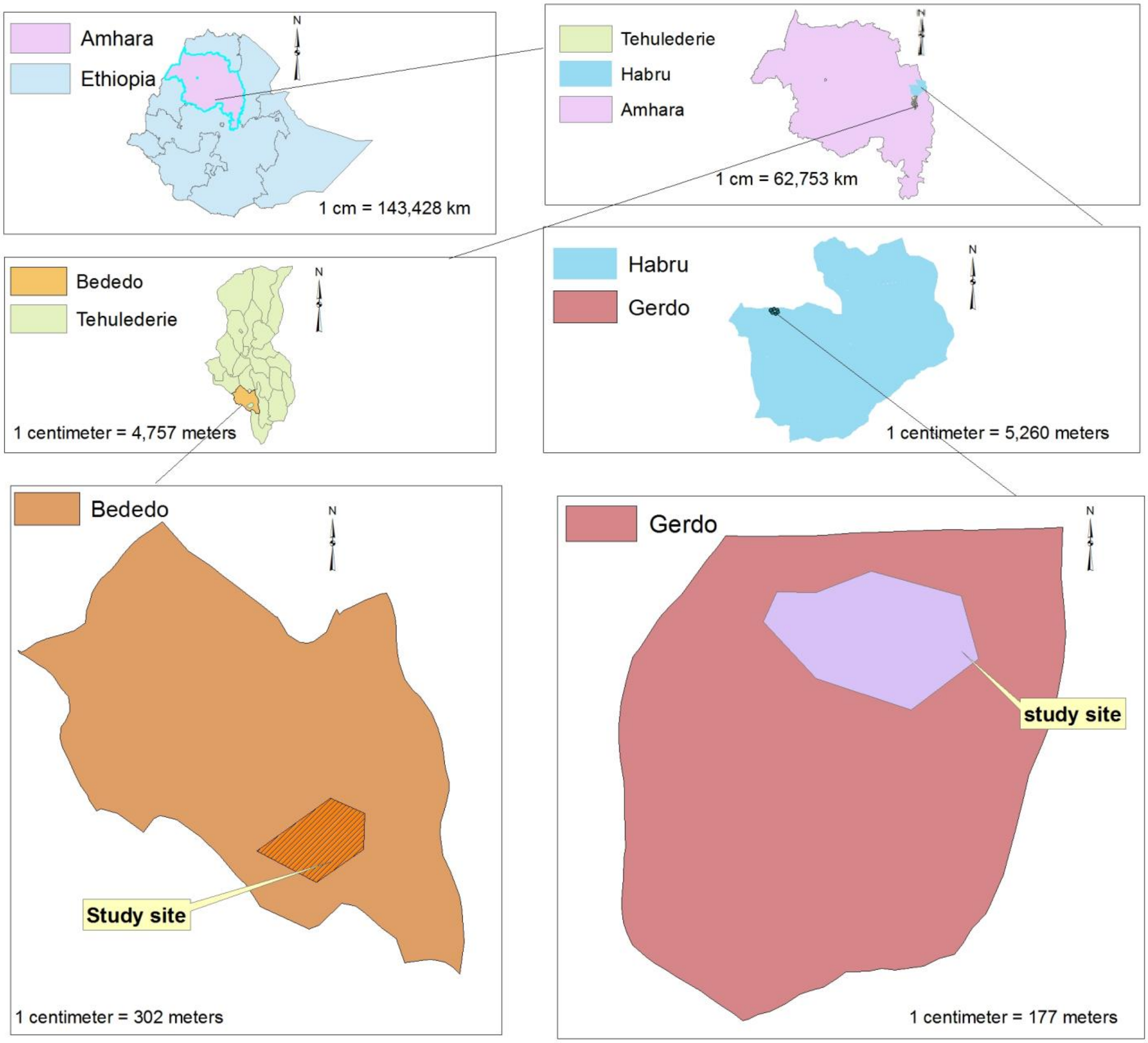


Figure 1: Maps of the study sites of Weira-Amba and Bededo forests

Figure 2: photograph of forests from Weira-Amba forest 2018

Figure 3: photograph of forests from Bededo forest 2018

3.2. Materials

The experiment was conducted by using, caliper, meter tape, Rope, clinometers, data collection sheet, pencil, vehicle, digital camera, auger, sample bags, Core sampler, oven dry and other soil laboratory chemicals' and materials (Sirinka Agriculture Research Center soil laboratory) were used.

3.3. Sampling and Data Collection Method

3.3.1. Study site selection

The reconnaissance survey was made across the forests in order to obtain an impression in site conditions and physiognomy of the vegetation, collect information on accessibility to identify sampling sites. Then, the elevation range and transect direction of the forest were determined and transects were laid from the lowest altitudinal elevation to the highest. The boundaries of the study forest area were delineated by taking geographic coordinates with GPS at each turning point to facilitate accurate measurement and accounting of the forest carbon stock. Stratification was done in the study forest in order to take accurate data from the field as well as to maintain the homogeneity of the area. Altitudes, Aspect were the major parameters to classify the study area. Therefore, based on latitudinal variation, the study site was stratified into three elevation zones listed as below table.

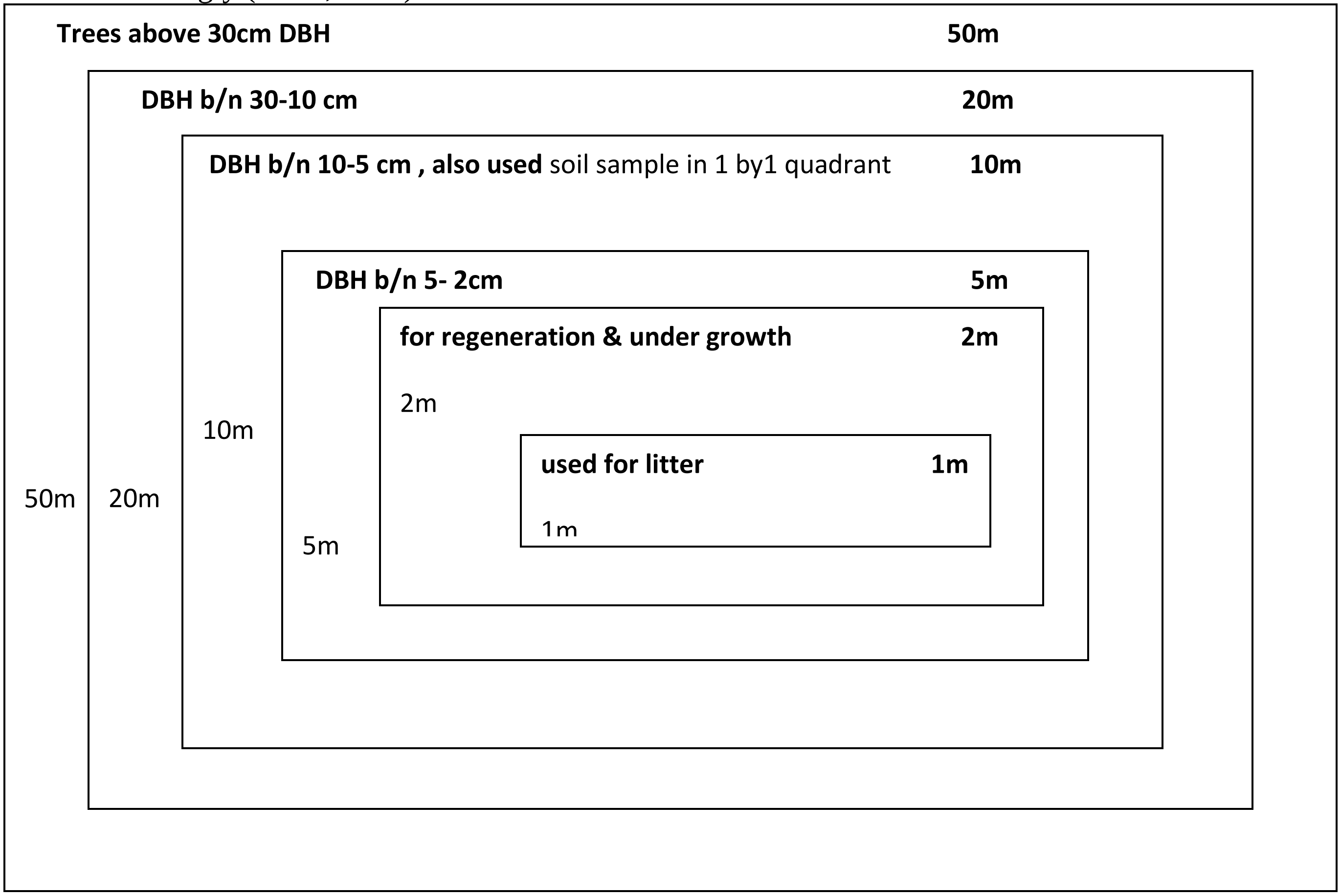
Table 2. Classification zones for both forests, according to elevation

Classification zones	**Weira-Amba forest**	**Bededo**
Lower elevation	From 1850- 1950m	2118-2218 m
Middle elevation	1951 -2051m	2219-1319 m
Upper elevation	2052-2152 m	2320-2420m

3.3.2. Sampling and Plot established technique

Three transect lines were laid for each sites systematically depend on perpendicular to the main slope, considering topographic variation, tree size and species composition. A plot size of 50 m by 50 m size was set up at 100 m elevation intervals. The total sample sizes were 15 plots for each site and totally 30 sample plots were used. In each plot, to be measured biometric parameters such as stem diameter (D) at breast height (1.3 m above the ground) and tree height (H) for individual living trees and snags (i.e., standing dead trees) using diameter tape and clinometers, respectively.

Nested plot designs were used, which is appropriate for inventories in natural forests where there is high variability in tree size, distribution and structure, were used (Pearson and Brown 2005). Forest carbon assessments in particular use nested plot designs that present variable size subplots for the different tree size classes and also for the different forest carbon pools. Accordingly (IPCC, 2007)



Soil samples were taken at four corners and at the centers of the 10m*10m subplots at a depth of 30cms, and one composite sample was taken for soil carbon determination All woody vascular plant species encountered in each sample plot were recorded also their height and Diameter were recorded in order to do analysis related to plant community types.

3.4. Data analysis

3.4.1. Species diversity and Composition

The structure and composition of woody species were determined through quantitative analysis. The collected quantitative data were analyzed by using different indexes. For the determination of species structure, parameters such as height, important value index (IVI), which includes relative frequency, relative density and relative dominance were calculated following (Woldemichael, 2010, and Newton AC, 2007). Basal area, frequency and density were also calculated. To the species composition, diversity indexes (Shannon diversity index, Simpson Reciprocal Index, and evenness) were computed as follows:

1. $Shannon - Wiener\ index\ (H') = -\sum_{i=1}^{s} pi * \ln pi$

Where: H'= Diversity of species, s = Number of species,

pi = the proportion of individuals abundance of the specie, ln = log base

2. Simpson's Reciprocal Index

$$SI(simpson) = 1/D$$

$(D = \sum_{i=1}^{s} \left(\frac{n}{N}\right) 2$; Where: SI = Simpson's index of species diversity, *n* = the total number of organisms of a particular species, *N* = the total number of organisms of all species.

3.$Evennes = H'/lnS$; Where H'=is the Shannon diversity index, *S*=is the number of species in a particular elevation contour.

3.4.2. Carbon Stock Estimation

The usual methods for determining of the aboveground biomass of forests are inventoried with allometric tree biomass regression models. This estimation of AGB in the forests is based on plot inventories by; Chave *et al.*, 2014, estimation methods that are: *AGB = 0.0673 * (ρ* (DBH)2 * H)^0.976*: Where: AGB = above ground biomass (in kg dry matter), *ρ* = wood density(g/cm3), DBH = diameter at breast height (in cm), H = total height of the tree (in m), then tree biomass will be converted to carbon stock by AGB * 0.5.

Apply a regression equation to stem diameter or some other measure of tree size in order to estimate root biomass. But, measurement of root biomass is time consuming and expensive. Thus, a simple root: shoot ratio was used. This ratio ranges from 20 to 45 % and the global average of 26% is commonly used; i.e. Belowground biomass = Aboveground biomass x 0.26 and then, the product is multiplied by 50% to calculate belowground biomass stock.

The biomasses of herbs were collected during the end of the rainy season, the peak growth period. All the herbaceous vegetation emerging within the quadrant areas (1m x 1m) was cut at the ground level/closed to the mineral soil, weighed, and a composite samples were obtained from each subplot for oven-dry mass determination in the laboratory. Dry Mass (kg) = Sub Sample Dry Mass (kg) / Sub Sample Fresh Mass (kg) * Field Mass (kg).

The soil samples were collected for the bulk density and soil carbon stock analysis. Soil samples were taken from quadrants (1 m2) allocated in the four directions (north, south, east and west) of the rectangular sample plots Soil samples for the determination of soil carbon density were collected from 30 cm soil depth after the herbs and litter samples were taken. Within 1 x 1 m quadrant four soil samples were taken by pressing an auger to a depth of 30 cm, and the four soil samples were composited

The total carbon stock density will be calculated by summing all the carbon pool stock densities using the following formula:

$C_{Density} = C_{AGTB} + C_{BGTB} + C_{DWB} + C_{HB} + C_{LB} + SOC$

Where, $C_{Density}$= Carbon Stock Density

C_{AGTB} = Carbon Stock in Above Ground Tree Biomass

C_{BGB} = Carbon Stock in Below Ground Tree Biomass

C^{DWB} = Carbon Stock in Dead Wood Biomass

C_{HB} = Carbon Stock in Herb Biomass

C_{LB} = Carbon Stock in Litter Biomass

SOC = Soil Organic Carbon

4. RESULTS AND DISCUSSIONS

4.1. Results

4.1.1. Vegetation Characteristics

The structure and composition of woody species were determined through quantitative analysis. The collected quantitative data were analyzed by using different indexes. For the determination of species structure, parameters such as height, important value index (IVI), which includes relative frequency, relative density, and relative dominance, was calculated following (Woldemichael, 2010, and Newton AC , 2007). Basal area, frequency and density were also calculated. To determine the species composition, diversity indexes (Shannon diversity index, Simpson Reciprocal Index, and evenness) was computed as follows:

Table 3 Plant Species found at Weira-Amba (Gerado) forest

No.	**Scientific Name**	**Amharic Name**	**Family**	**Life form**	**Origin**
1	*Euclea racemosa*	*Dedeho*	*Ebenaceae*	Shrub	Indigenous
2	*Olea europaea*	*Weira*	*Oleaceae*	Tree	Indigenous
3	*Euphorbia candelabrum*	*Kulkual*	*Euphoribiaceae*	Tree	Indigenous
4	*Carissa spinarum*	*Agam*	*Apocynaceae*	Shrub	Indigenous
5	*Clutia abyssinica*	*Fiyele feji*	*Euphoribiaceae*	Shrub	Indigenous
6	*Dodonaea viscosa*	*Kitkita*	*Sapindaceae*	Tree	Indigenous
7	*Acacia senegal*	*Sbansa-girar*	*Fabaceae*	Tree	Indigenous

8	*Celtis africana*	*Kawoot*	*Ulmaceae*	Tree	Indigenous
9	*Juniperus procera*	*Yehabesha-tid*	*Cupressaceae*	Tree	Indigenous
10	*Croton macrostachyus*	*Bisana*	*Euphoribiaceae*	Tree	Indigenous
11	*Cupressus lusitanica*	*Yeferenji-tid*	*Cupressaceae*	Tree	Mexico
12	*Eucalyptus camaldulensis*	*Key-bahir zaf*	*Myrtaceae*	Tree	Australia
13	*Strychnos innocua*	*Merenz*	*Loganiaceae*	Shrub	Indigenous
14	*Acacia decurrens*	*Yferenji-girar*	*Fabaceae*	Tree	Australia
15	*Ehretia cymosa*	*Ulaga*	*Boraginaceae*	Tree	Indigenous

At Gerado (wire-Amba) forest a total of 15 tree species was recorded. Of these 15 species, 11 species are trees and shrub species are four (4) within 11 families. Most plant species were indigenous types of species, except *Eucalyptus camaldulensis, Acacia decurrens* and *Cupressus lusitanica.*

Table 4 Plant species found in Bededo forest

Ser. No	**Scientific Name**	**Amharic Name**	**Family**	**Life form**	**Origin**
1	*Eucalyptus globules*	*Nech-bahir zaf*	*Myrtaceae*	Tree	Australia
2	*Olea europaea*	*Weira*	*Oleaceae*	Tree	Indigenous
3	*Clutia abyssinica*	*Fiyele feji*	*Euphoribiaceae*	Shrub	Indigenous
4	*Carissa spinarum*	*Agam*	*Apocynaceae*	Shrub	Indigenous
5	*Maytenus arbutifolia*	*Atat*	*Celastraceae*	Shrub	Indigenous
6	*Cupressus lusitanica*	*Yeferenji-tid*	*Cupressaceae*	Tree	Mexico
7	*Acacia abyssinica*	*Bazra-girar*	*Fabaceae*	Tree	Indigenous
8	*Bersama abyssinica*	*Azamir*	*Melianthaceae*	Shrub	Indigenous

From Bededo forest belongs to 8 species 4 trees and 4 species were shrubs within 8 families. In the two forest areas *Euphorbiaceae, Fabaceae and Cupressaceae* families were the most dominant families. Most plant species are indigenous origins' except *Eucalyptus globules* and *Cupressus lusitanica* which were plantation come from exotic.

4.1.2. Species diversity, richness and evenness

For the determination of species structure, parameters such as height, important value index (IVI), which includes relative frequency, relative density and relative dominance, was calculated. To determine the species composition, diversity indexes (Shannon diversity index) and evenness was computed.

Table 5: Species Basal area, frequency Density and IVI at upper elevation in Weira-Amba forest

Spp	Basal area	Relative basal area	Relative frequency	Density	Relative density	IVI
Acacia Senegal	1.38423	42.9732	16.129	1175	18.4314	77.5336
Ehretia cymosa	0.36909	11.4583	12.9032	400	6.27451	30.6361
Olea europaea	1.02746	31.8972	16.129	1175	18.4314	66.4576
Dodonaea viscose	0.21815	6.77255	16.129	2025	31.7647	54.6663
Cupressus lusitanica	0.07732	2.4003	6.45161	325	5.09804	13.95
Euclea racemosa	0.0258	0.8011	16.129	725	11.3726	28.3027
Eucalyptus camaldulensis	0.10259	3.18479	3.22581	175	2.7451	9.1557
Strychnos innocua	0.01651	0.51256	12.9032	375	5.88235	19.2981

Higher basal areas were occupied by *Acacia senegal, Dodonaea viscose and Celtis africana respectively. Dodonaea viscose, Celtis africana and Celtis africana* species had higher frequency but *Clutia abyssinica and Euphorbia candelabrum* species had less important value Indexes.

Table 6: Species Basal area, frequency, Density and IVI at medium elevation in Weira-Amba forest

Spp	Basal area	Relative basal area	Relative frequency	Density	Relative density	IVI
Carissa spinarum	0.003383	0.202733	9.52381	200	3.305785	13.03233
Euclea racemosa	0.104168	6.241563	4.761905	500	8.264463	19.26793
Clutia abyssinica	0.001127	0.067519	4.761905	75	1.239669	6.069093
Celtis Africana	0.292998	17.55591	14.28571	875	14.46281	46.30443
Dodonaea viscose	0.319082	19.11879	23.80952	2150	35.53719	78.4655
Euphorbia candelabrum	0.059717	3.578119	4.761905	175	2.892562	11.23259
Acacia Senegal	0.646659	38.74661	19.04762	1175	19.42149	77.21572
Olea europaea	0.108744	6.515732	9.52381	500	8.264463	24.304
Cupressus lusitanica	0.133065	7.973027	9.52381	400	6.61157	24.10841

Higher basal areas were occupied by *Acacia senegal, Olea europaea and Ehretia cymosa respectively. Dodonaea viscose, Olea europaea, Celtis africana and Acacia senegal* species had almost the same frequency. Instead of density *Dodonaea viscosa*, *Olea europaea* and *Acacia Senegal* species had highest densities, but *Eucalyptus camaldulensis and Cupressus lusitanica* species had less important value Indexes.

Table 7. Species diversity richness and evenness at lower elevation in Weira-Amba forest

Spp	Basal area	Relative basal area	Relative frequency	Density	Relative density	IVI
Acacia decurrens	0.60415	20.1118	11.1111	450	7.72532	38.9482
Eucalyptus camaldulensis	1.64968	54.9172	18.5185	2025	34.764	108.2
Ehretia cymosa	0.02576	0.85736	7.40741	175	3.00429	11.2691
Acacia Senegal	0.60159	20.0268	14.8148	650	11.1588	46.0004
Dodonaea viscose	0.0664	2.21048	18.5185	1325	22.7468	43.4758
Euclea racemosa	0.00643	0.21402	7.40741	175	3.00429	10.6257
Olea europaea	0.04363	1.45231	14.8148	700	12.0172	28.2843
Carissa spinarum	0.00631	0.21014	7.40741	325	5.5794	13.197

Higher basal areas were occupied by *Eucalyptus camaldulensis, Acacia decurrens and Acacia Senegal* respectively. *Dodonaea viscose and Eucalyptus camaldulensis and* species had higher frequency. Instead of density: *Eucalyptus camaldulensis* and *Dodonaea viscosa* species had highest densities, but *Ehretia cymosa and Euclea racemosa* species had less important value Indexes.

Table 8 . Species diversity and evenness at elevation difference in Weira-Amba forest

Elevation	Shannon (H')	Simpsons (D)	Evenness (E)
Upper	2.04228	6.784615	0.929482
Middle	1.993168	7.014599	0.958511
Lower	2.012894	7.07767	0.967997

As shown in the above tables Shannon-Wiener diversity indices, species evenness and richness were computed. Almost the same no difference between them. In Bededo forest for the determination of species structure, parameters such as height, important value index (IVI), which includes relative frequency, relative density, and relative dominance, was calculated. To determine the species composition, diversity indexes (Shannon diversity index) and evenness was computed.

Table 9. Species Basal area, frequency, Density and IVI at upper elevation in Bededo forest

Spp	Basal area	Relative basal area	Relative frequency	Density	Relative density	IVI
Carissa spinarum	0.000843	0.008007	11.53846	475	7.089552	18.63602
Bersama abyssinica	0.016177	0.153716	15.38462	500	7.462687	23.00102
Acacia abyssinica	1.776185	16.87773	15.38462	550	8.208955	40.4713
Clutia abyssinica	0.031381	0.298193	7.692308	200	2.985075	10.97558
Eucalyptus globules	3.303505	31.39068	15.38462	1475	22.01493	68.79022
Olea europaea	0.082772	0.786522	15.38462	500	7.462687	23.63382
Cupressus lusitanica	5.312975	50.48515	19.23077	3000	44.77612	114.492

Higher basal areas were occupied by *Cupressus lusitanica*, *Eucalyptus globules and Acacia abyssinica* respectively. *Cupressus lusitanica* species had higher frequency. Instead of density, *Cupressus lusitanica* and *Eucalyptus globules* species had highest densities, but *Clutia abyssinica* species has less important value Indexes.

Table 10. Species Basal area, frequency, Density and IVI at medium elevation in Bededo forest

Spp	Basal area	Relative basal area	Relative frequency	Density	Relative density	IVI
Carissa spinarum	0.023936	0.210037	11.11111	375	6.666667	17.98781
Bersama abyssinica	0.005854	0.051367	5.555556	125	2.222222	7.829145
Acacia abyssinica	1.063053	9.328394	16.66667	325	5.777778	31.77284
Eucalyptus globules	3.462165	30.38084	27.77778	1575	28	86.15861
Olea europaea	0.022719	0.19936	11.11111	250	4.444444	15.75492
Cupressus lusitanica	6.818159	59.83001	27.77778	2975	52.88889	140.4967

Higher basal areas, Frequency and densities were occupied by *Cupressus lusitanica and Eucalyptus globules* respectively. But *Bersama abyssinica* species has less important value Indexes.

Table 11. Species Basal area, frequency, Density and IVI at lower elevation in Bededo forest

Spp	Basal area	Relative basal area	Relative frequency	Density	Relative density	IVI
Carissa spinarum	0.009777	0.069377	11.11111	225	3.719008	14.8995
Bersama abyssinica	0.01071	0.076	11.11111	250	4.132231	15.31934
Acacia abyssinica	1.598569	11.34359	11.11111	375	6.198347	28.65305
Eucalyptus globules	3.485457	24.73312	27.77778	1425	23.55372	76.06461
Olea europaea	0.055736	0.395505	11.11111	275	4.545455	16.05207
Cupressus lusitanica	8.932021	63.38241	27.77778	3500	57.85124	149.0114

Higher basal areas, frequency and densities were occupied by *Cupressus lusitanica and Eucalyptus globules* respectively, trees which have higher density were *Cupressus lusitanica and Eucalyptus globules* But *Carissa spinarum, Bersama abyssinica and Olea europaea* species has less important value Indexes. So, those tree species have special care and protection if we need sustainability.

Table 12. Species diversity and evenness at elevation difference in Bededo forest

Elevation	Shannon (H')	Simpsons (D)	Evenness (E)
Upper	1.915403	6.627451	0.984322
Middle	1.659105	4.764706	0.925964
Lower	1.688174	4.909091	0.942188

As shown in the above tables Shannon-Wiener diversity indices, species evenness and richness were computed. Almost the same no difference between them.

Generally The Shannon-Wiener diversity index showed that both the site is mixed forests (natural regenerations and plantations of some tree species). So, their evenness is almost equal, no difference between them. But according to diversity *Weira-Amba forest is* more diverse with (H′) 2.424 than Bededo forest.

Table 13. IVI value of most dominant top five tree species in both forests

Weira-Amba Forest					
No	**Scientific name**	**Relative BA %**	**Relative density**	**Relative frequency**	**IVI**
1	*Acacia Senegal*	35.986	16.455	16.851	69.292
2	*Dodonaea viscose*	7.772	17.723	31.215	56.71
3	*Olea europaea*	15.886	13.924	14.365	44.175
4	*Eucalyptus camaldulensis*	20.471	7.594	11.878	39.943
5	*Euclea racemosa*	1.7563	10.126	7.7348	19.617
Bededo Forest					

1	*Cupressus lusitanica*	66.344	22.727	48.858	137.929
2	*Eucalyptus globules*	32.288	21.212	22.716	76.216
3	*Acacia abyssinica*	0.506	15.151	10.914	26.571
4	*Carissa spinarum*	0.1506	12.121	6.0914	18.363
5	*Olea europaea*	0.507	12.121	5.203	17.831

4.1.3. Frequency

Frequency is the number of sample plots in which a given species occurred in the study area, expressed in percentage of the total number of sample plots. The five most frequent tree species in Weira-Amba forests were: *Dodonaea viscose* which occurred in all plots and accounts 30.2% of the total tree species, *Acacia Senegal* which was occurred in13 sample plots and accounts about 16.8%, *Olea europaea* was occurred at 12 sample plots and accounts 14.9%, *Euclea racemosa* occurred in 10 sample plots and *Eucalyptus camaldulensis* which was occurred at lower altitude near homestead areas in 6 ample plots and accounts 11.5% of the total tree population. But *Carissa spinarum, Euphorbia candelabrum and Juniperus procera* types of tree species were only found at higher elevation and have less frequency than other tree species. In case of Bededo forest: *Cupressus lusitanica* and *Eucalyptus globules* were the most dominated tree species which were occurring at15 & 14 sample plots and also 51.6%24.3% 0f the total tree population respectively. *Carissa spinarum* tree species were the last frequency and occurred only at upper elevations.

4.1.4. Regeneration

At Weira-Amba forest total of 15 tree species with only 4 tree species have sapling and seedlings, the rest haven't seedlings or saplings. At Weira-Amba forest the highest saplings and seedling density was recorded at middle elevation of the watershed, i.e. *Dodonaea viscose and Euclea racemosa* which have 2145 and 418 individuals per ha respectively. At upper elevations also *Dodonaea viscose* 1681, *Carissa spinarum* and *Olea europaea* 75 individuals per hectare were recorded. Even though, the density of seedlings decreases at lower elevation, there were recorded *Dodonaea viscose and Euclea racemosa* 853 and 111 seedlings per hectare respectively. As the result shows that in the future at Weira-Amba forest *Dodonaea viscose* and *Euclea racemosa* tree species will be a dominate species in the forest.

At Bededo only 1 tree species have seedlings out of 7 tree species, and one tree species was at seedling stage only recorded. At higher elevation *Maytenus arbutifolia* 1110 and *Carissa spinarum745* seedlings and also at middle elevation of the watershed *Maytenus arbutifolia* 813 and *Carissa spinarum 645* seedlings per hectare were recorded. At lower elevation there were no any seedlings or samplings. These results show in the future, at the Bededo forest without *Carissa spinarum* they do not have an ancestors if some measures have not done. In Bededo forest the maximum above ground carbon was recorded at lower elevation, from 2118-2218 m was recorded 172.85 ton ha^{-} and the minimum was recorded at higher elevation 2320-2420 m was recorded 153.97 ton ha^{-} .

4.2. Role of plant diversity in forest carbon sequestration

Carbon sequestration capacity and the amount of carbon sequestered not only related to the type of vegetation such as Forest, Woodland, Savanna etc., but also related to the plant diversity and the type of species within it. The result of carbon stock density in Weira-Amba and Bededo forests have showed that, plant community types in different elevation and species diversity remarkably exhibited a high total carbon stock density (Table 7and 8). Hicks et al. (2014), also describes that, globally there is a generally positive relationship between carbon stocks and biodiversity.

Apart from that, having diverse species may also have a complimentary effect to use different resources as they have different requirements and can generate more biomass by using the same resources as described by Hicks et al. (2014). Moreover, in the present study the amount of biomass and carbon density per species were significantly different between species (table 7&8). In Weira-Amba forest Species such as *Acacia Senegal, Olea europapea and Eucalyptus camaldulensis* with 45.07, 16.62 and 14.25 tons of carbon per hectare respective, while many other tree species contributed less than eight ton Carbon per /species/ha. This shows that, the contribution and role of plant diversity is different for forest carbon sequestration.

4.2.1. Carbon Stocks in above ground Biomass

Among the five carbon pools, the above ground carbon stock includes three of them namely:

- ✓ The above ground woody biomass calculated from DBH of the trees using alomertic equations;
- ✓ The above ground herbaceous biomass calculated by direct harvesting of the herbaceous biomass; and
- ✓ The Litter biomass, which are calculated by direct harvesting of the litter.
- ✓ While the below ground carbon pool includes the live underground ground root biomass and the soil organic carbon.

The above ground biomass and carbon stock of forest was calculated by adding all values obtained from 30 plots of Weira-Amba and Bededo forests, and converted into carbon. The mean above ground carbon stock of Weira-Amba and Bededo forest were 98.95 and 163.19 tons of Carbon ha^{-} respectively. At Weira-Amba forest the maximum above ground carbon was recorded at middle elevation, i.e. From 1951-2051m was recorded 129.18 ton ha^{-} and the minimum was recorded at lower elevation from 1850-1950m recorded 64.59 ton ha^{-}

Table 14: In Weira-Amba forest above and below ground Carbon pool according to tree Species

Scientific Name	**AGB**	**AGC**	**BGC**	**A&B GC**
Euclea racemosa	3.917928	1.958964	0.509331	2.468295
Olea europaea	33.25194	16.62597	4.322752	20.94872
Euphorbia candelabrum	0.355748	0.177874	0.046247	0.224121
Carissa spinarum	0.053977	0.026988	0.007017	0.034005
Clutia abyssinica	0.008514	0.004257	0.001107	0.005364
Dodonaea viscose	8.429321	4.21466	1.095812	5.310472
Acacia senegal	90.15488	45.07744	11.72013	56.79757
Celtis africana	11.82241	5.911205	1.536913	7.448118
Juniperus procera	6.048544	3.024272	0.786311	3.810583
Croton macrostachyus	8.115776	4.057888	1.055051	5.112939
Cupressus lusitanica	0.119315	0.059658	0.015511	0.075169

Eucalyptus camaldulensis	28.50791	14.25396	3.706028	17.95999
Strychnos innocua	0.152444	0.076222	0.019818	0.09604
Acacia decurrens	6.867015	3.433508	0.892712	4.32622
Ehretia cymosa	0.167616	0.083808	0.02179	0.105598

According to the above table 14: at Weira-Amba forest the main contributors of above ground carbon sinkers' of tree species were *Acacia Senegal, Olea europaea and Eucalyptus camaldulensis* with 45.07, 16.62 and 14.25 tons of carbon per hectare respectively

Table 15. In Bededo forest above and below Ground Carbon (tone per hectare) according to Species

Scientific Name	AGB	AGC	BGC	A&BGC
Carissa spinarum	0.29157	0.14579	0.0379	0.18369
Bersama abyssinica	4.72917	2.36459	0.61479	2.979377
Acacia abyssinica	38.878	19.439	5.05414	24.49314
Clutia abyssinica	10.5139	5.25697	1.36681	6.623782
Eucalyptus globules	139.827	69.9133	18.1775	88.09078
Olea europaea	1.17454	0.58727	0.15269	0.739961
Cupressus lusitanica	130.966	65.4831	17.0256	82.50867

As shown the above table 15; in the Bededo forest the main contributions of carbon sequestration on its above ground carbon stocks were *Eucalyptus globules, Cupressus lusitanica and Acacia abyssinica* with 69.91, 65.48 and 19.44 tons 0f carbon per hectare respectively.

4.2.2. Below ground carbon stock

As that of the above ground biomass, below ground biomass also showed similar trend in terms of species and elevation. Similarly, the maximum below ground carbon within species were recorded from the Weira-Amba forest: Acacia *Senegal, Olea europaea and Eucalyptus camaldulensis with* 11.72, 4.32 and 3.7 tons of carbon per hectare were recorded respectively. Whereas at Bededo forest: *Eucalyptus globules, Cupressus lusitanica and Acacia abyssinica* with 69.91, 65.48 and 19.44 tons of carbon per hectare were recorded respectively.

In Weira-Amba forest the mean below ground carbon was 25.73 tons per hectare recorded. But in terms of elevational difference: 26.8, 33.59 and 16.8 tons of carbon recorded within upper, middle and lower elevation of the forest respectively. Whereas at Bededo forest the mean below ground carbon was 42.43 tons per hectare and within elevation difference the upper 40.04, the middle 42.33 and 42.43 tons of carbon were recorded.

4.2.3. Carbon Stock in Litter

The result showed that the mean litter carbon density of Weira-Amba forest 0.47 ton per hectare was recorded. But instead of its elevation difference: 0.48, 0.63 and 0.59 tons of Carbon per hectare were recorded at upper, middle and lower elevation of the area respectively. Whereas, at Bededo forest: the mean litter carbon was 0.57 tons per hectare, and within its elevation divides: 0.91, 0.54 and 0.78 tons of carbon per hectare at upper, middle and lower elevation of the area respectively.

4.2.4. Carbon Stock in the Soil

The result of soil laboratory analysis of the percentage of soil organic carbon showed That, the mean soil organic carbon of Weira-Amba forest was which ranged from 7.64 % at upper elevation to the lowest 3.96% at lower elevation, and also at middle elevation 6.435% were recorded. While at Bededo forest at upper 5.99, at middle 3.68 and the lower elevation also 6.54 % of organic carbon.

The mean organic carbon in Bededo forest was 5.4% recorded. The soil bulk density, which is also an important factor for the soil carbon density calculation was analyzed and at Weira-Amba forest bulk density ranged from 0.62g cm-3 for to 0.91 g cm-3 and also in Bededo forest was ranged from 0. 38 to 0.98 g cm^{-3}.

The result showed that at Weira-Amba forest soil carbon stock density was at upper elevation 26.98, medium elevation 20.3 and at lower elevation also 36.168 tons of carbon ha^{-1}, while at Bededo forest soil carbon stock density was: at upper 30.264, middle 22.745 and at lower elevation 33.38 tons of carbon ha^{-1} were recorded.

4.2.5. Total Carbon stock density

The total forest was calculated by adding all the above carbon stock densities calculated for each carbon pool; which is the above ground biomass, litter, belowground biomass (roots) and soil organic carbon.

At Weira-Amba forest the highest carbon stock was recorded from at medium elevation, which was 184.15 tons of carbon ha^{-1}, and also at upper elevation and lower elevation were 158.172 and 118.9 tons of carbon ha^{-1}, respectively. While in Bededo forest the total carbon stock was recorded at upper elevation 226.47, also in the middle 229.31 and the lower elevation with 252.77 tons of carbon ha^{-1}.

4.2.6. . Variability of Carbon Stock along Elevation Gradient

Elevation is recognized to have a major effect on the biomass and carbon stock in the forest ecosystems. In the present study area: At Weira-Amba forest the medium elevation showed an increasing carbon stock's potential and followed by the upper elevation and decreased when we go into downward of the mountain.

There was highly significant variation in carbon stock in above and below ground carbon pools between medium and lower elevation, and also significant variation in upper elevation along with an elevational gradient. This condition suggests that the lower parts of the forest have scattered type of plant arrangement and displayed a lack of large trees as compared with the middle and upper elevation of the mountain and due to suitable environmental condition, more species of plant habit in the middle part and result in high biomass and carbon stock values.

Table 16. Weira-Amba forest carbon pool according to elevation difference

Elevation	**AGB**	**AGC**	**BGC**	**SC**	**LC**	**TC**
Upper	206.14	103.07	26.7982	26.984	1.32	158.1722
Medium	258.6	129.3	33.618	20.3	0.93	184.148
Lower	129.18	64.59	16.7934	36.168	1.35	118.9014

In Bededo forest there is no significance difference between elevation differences, these conditions showed more about plantation forests have a higher carbon sink than indigenous trees. Consequently, plantations have similar ages, diameters and heights between trees. Even though there was no significantly different among elevation gradients the lower elevation of the mountain has higher above and below ground biomass than medium and higher elevation differences.

Table 17 . Bededo Carbon pool according to elevations

Elevation (m)	AGB	AGC	BGC	SC	LC	TC
Higher	307.94	153.97	40.0322	30.264	2.206	226.4722
Medium	325.56	162.78	42.3228	22.7448	1.467	229.3146
Lower	345.64	172.82	44.9332	33.388	1.628	252.7692

4.2.7. Variability of Carbon Stock in the Aspects (Slope Facings)

Aspect is one of the environmental factors that can affect the carbon stock of forests in different carbon pools and thus, it can be used as a useful variable to forecast the forest carbon stock in different carbon pools. According to an aspect has a significant relationship with biomass carbon in forest areas due to the interaction between solar radiation and soil properties. The result of the present study revealed that: At Weira-Amba forest higher mean values of above and below ground biomass and carbon stock on North-West aspect compared to the other aspects, whereas the lowest mean value was recorded on the West aspect of the mountain. This result is similar to Hicks *et al*., (2014) works, in the carbon stock study of Egdu Forest, higher mean values of above and below ground biomass carbon stocks were found on Northern aspect.

Table 18. Weira-Amba forest carbon pool according to Aspect

NO.	Aspects	AGB (t/h)	AGC	BGC	SC	LC	TC
1	N	178.8605	89.43026	23.25187	28.973	12.321	332.837
2	NW	225.4263	112.7132	29.30542	30.008	8.987	406.4399
3	SW	159.3272	79.66358	20.71253	26.123	5.678	291.5046
4	W	30.06596	15.03298	3.908575	15.01	1.987	66.00452

In general, at Weira-Amba forest in the North-Western aspects has higher values above and below ground biomass and carbon stocks as compared to other aspects. This can be attributed to the occurrence of moister and favorable environment such as the type and fertility of the soil on the Northern aspects of Weira-Amba Forest as pointed out by Hicks *et al.*, (2014) that soil properties are influenced by aspect. This is because the North and south facing slopes receive an unequal amount of solar radiation.

The South facing slopes receive high solar radiation compared to the North facing which receive less sunlight (Bayat, 2011). Thus, the South facing slopes are warmer and drier, whereas the North facing slopes are relatively cooler and form better-growing conditions on the Northern aspects than the Southern aspects. On the other hand, the least above and below carbon stock was found in the Western aspect which was in agreement with result found by "un-published" (Kidanemariam Kassahun, 2014) The reason might be the availability of less fertile soil and moisture in the western part. In addition, the higher and lower values of soil organic carbon in the North West and West aspects respectively have been reported in the present study. The reason might be due to the presence of moist climate and high decomposition rate on the North West aspect which had maximum SOC value and the reverse is true for West aspect.

Table 19. Bededo Carbon pool according to Aspects

No.	Aspects	AGB	AGC	BGC	Sc	LC	TC
1	SW	332.3812	166.1906	43.20955	29.758	6.26	245.4182
2	W	155.3429	77.67147	20.19458	28.00333	3.076	128.9454
3	NW	141.593	70.79649	18.40709	22.707	5.32	117.2306
4	S	304.5799	152.29	39.59539	34.9175	2.765	229.5679
5	N	45.24297	22.62149	5.881586	25.23	8.431	62.16408

At Bededo forest higher mean values of above and below ground biomass and carbon stock were recorded on South-West and South aspects and the lowest mean value was recorded on the North aspect of the mountain. This result is similarly (Brown et al., 1989), at" Brazilian

Amazon forest" works. As indicated by (Bayat, 2011), aspect has the significant relationship with biomass in forest areas due to the interaction between soil radiation and soil properties such as soil moisture and nutrients. Moreover, litter pool enhanced the maximum and minimum carbon stock on Northeast and Southwest aspects, respectively. This difference might be due to the difference in litter-fall amount and its decomposition rate. The absence of high decomposition rate of a litter on North East aspect of the forest growing on the North-East aspect are generally exposed to various natural disturbances such as, windfall cause the litter pool enhances the highest biomass and carbon stock in North East aspect than other aspects of the study area, whereas the reverse is true to the South West direction of the site. Overall, the present study pointed out that the carbon stock density of all carbon pools did show a significant difference along aspects.

Table 20. Summary of values of significance for one-way ANOVA between environmental for different pools carbon stock at Weira-Amba forest

Environmental Variables	Carbon pools	F-value	P-value
Elevation	AGC	5.876	**0.043**
	BGC	5.876	**0.043**
	LC	0.231	0.795
	SOC	0.446	0.813
Aspect	AGC	4.743	**0.015**
	BGC	4.743	**0.015**
	LC	0.371	0.865
	SOC	0.441	0.647

Significant at the $p < 0.05$ level

At Weira-Amba forest elevation difference has significance difference in AGC and BGC, but at aspect facing have a highly significant difference in AGC and BGC.

Table 21. Summary of values of significance for one-way ANOVA between environmental for different pools carbon stock at Bededo forest

Environmental Variables	Carbon pools	F-value	P-value
Elevation	AGC	0.966	0.391
	BGC	0.966	0.391
	LC	0.708	0.487
	SOC	0.342	0.67
Aspect	AGC	1.768	0.146
	BGC	1.768	0.146
	LC	0.935	0.471
	SOC	0.371	0.865

Significant at the $p < 0.05$ level

In Bededo forest have no significance difference for all parameters.

4.3. DISCUSSIONS

4.3.1. Composition, Diversity and Structure of Forests

The floristic diversity of Weira-Amba forest was higher than Bededo forest, at Weira-Amba forest there were a total of 15 tree species were recorded, from these species, 11 species were trees and shrub species were four (4) within 11 families. Most plant species were indigenous origins' except *Eucalyptus camaldulensis*, *Acacia decurrens* and *Cupressus lusitanica* which were plantations come from exotic

The Shannon-Wiener diversity index showed that both the site is mixed forests (natural regenerations and plantations of some tree species). So, their evenness is almost equal, no difference between them 0.918 and 0.919 respectively. According to diversity Weira-Amba forest is more diverse with (H′) 2.424 than Bededo forest 0.92. The H′ value usually falls between 1.5 and 3.5 and only rarely exceeds 4.5 (Magurran, 1988; Krebs, 1989). But when to compared to within its elevational difference of both forests have no difference between them. The structure of wood land forest is consistent with other studies on dry forests. For example, the observed range of basal area (BA) is comparable with the ranges (3.84-10.36 m 2 ha-1) reported by Singh and Singh, (1991) and 6.58-23.21 m2 ha-1 for several dry tropical communities in India. Similarly, the overall population structure of woodlands can help understand the status of the forest stand (Tesfaye et al. 2010;Worku et al., 2012). Despite indications of hampered regeneration, most of the species had a considerable number of individuals in the middle diameter classes that could be managed sustainably to improve their regeneration and produce quality wood products, in addition, the potential of carbon sequestration would enhance.

Frequency is the number of sample plots in which a given species occurred in the study area, expressed in percentage of the total number of sample plots. The five most frequent tree species in Weira-Amba forest were: *Dodonaea viscose* which occurred in all plots and accounts 30.2% of the total tree species, *Acacia Senegal* which was occurred in13 sample plots and accounts about 16.8%, *Olea europaea* was occurred at 12 sample plots and accounts 14.9%, *Euclea racemosa* occurred in 10 sample plots and *Eucalyptus camaldulensis* which was occurred at lower altitude near homestead areas in 6 ample plots and accounts 11.5% of the total tree population. But *Carissa spinarum, Euphorbia candelabrum and Juniperus procera* types of tree species were only found at higher elevations and have less frequency than other tree species.

In case of Bededo forest: *Cupressus lusitanica* and *Eucalyptus globules* were the most dominated tree species which were occurring at 15 & 14 sample plots and also 51.6%24.3% of the total tree population respectively. *Carissa spinarum* tree species were the least frequent and occurred only at upper elevations. The highest contributors of tree species for carbon sinker at Weira-Amba forest were: *Acacia Senegal* 35.986 %., *Eucalyptus camaldulensis* 20.471 % and *Olea europaea* 15.886 %. At Bededo forest *Cupressus lusitanica* and *Eucalyptus globules* were the main dominated tree species and recorded by 66.344 and 32.288 % respectively.

At Weira-Amba forest total of 15 tree species with only 4 tree species have sapling and seedlings, the rest haven’t seedlings or saplings. At Weira-Amba forest the highest saplings and seedling density were recorded from at middle elevation of the watershed, i.e. *Dodonaea viscose and Euclea racemosa* which have 2145 and 418 individuals of seedlings per ha respectively. At upper elevations also *Dodonaea viscose* 1681, *Carissa spinarum* and *Olea europaea* 75 individuals per hectare were recorded. Even though, the density of seedlings decreases at lower elevation, there were recorded *Dodonaea viscose and Euclea racemosa* 853 and 111 seedlings per hectare respectively. As the result shows that in the future at Weira-Amba forest *Dodonaea viscose* and *Euclea racemosa* tree species will be a dominate species in the forest.

At Bededo only 1 tree species have seedlings out of 7 tree species, and one tree species was at seedling stage only recorded. At higher elevation *Maytenus arbutifolia* 1110 and *Carissa spinarum 745* seedlings and also at middle elevation of the watershed *Maytenus arbutifolia* 813 and *Carissa spinarum 645* seedlings per hectare were recorded. At lower elevation there was no any a seedling or samplings. These results shows in the future, at the Bededo forest without *Carissa spinarum* they do not have an ancestors.

Comparison of the ranges of tree diameters with respect to the above ground biomass accumulation revealed that tree species with lower range of diameter possess more density but accumulated less biomass. On the other hand, trees having bigger diameters were few in number but accumulated more biomass. Therefore, an inverse relationship was seen between tree density and DBH whereas a direct relationship was observed between the above ground biomass and DBH. In this regard, the findings from (Terakunpisut et al., 2007; Juwarkar et al., 2011), indicate similar results with the current study. Trees during their initial stages of growth i.e. when their DBH is smaller could sequester less carbon but gradually increases in DBH and would accumulate more carbon. Moreover, it has been observed the younger trees grow much faster as compared to older ones. Thomas ,(1996), suggested that fast growing tree species are expected to have higher growth rates, and may accumulate large amounts of carbon in the first stage of their lifespan while the high specific gravity of slower-growing species allows them to accumulate more carbon in the long-term

4.3.2. Carbon Stocks in Different Carbon Pools

Carbon sequestration capacity and the amount of carbon sequestered not only related to the type of vegetation such as Forest, Woodland, Savanna etc, but also related to the plant diversity and the type of species within it. The result of carbon stock density in Weira-Amba and Bededo forests have showed that, plant community types in different elevation and species diversity remarkably exhibited a high total carbon stock density (Table 7and 8). Hicks et al., (2014), also describes that, globally there is a generally positive relationship between carbon stocks and biodiversity. Apart from that, having diverse species may also have a complimentary effect to use different resources as they have different requirements and can generate more biomass by using the same resources as described by Hicks et al., (2014).

Moreover, in the present study the amount of biomass and carbon density per species was significantly different between species. In Weira-Amba forest Species such as *Acacia Senegal, Olea europaea and Eucalyptus camaldulensis* with 45.07, 16.62 and 14.25 tons of carbon per hectare respectively, while many other tree species contributed less than eight ton Carbon per /species/ha. This shows that, the contribution and role of plant diversity is different for forest carbon sequestration.

The mean above ground carbon stock of Weira-Amba and Bededo forest were 98.95 and 163.19 tons of Carbon ha^{-} respectively. At Weira-Amba forest the maximum above ground carbon was recorded at middle elevation, i.e. From 1951-2051m was recorded 129.18 ton ha^{-} and minimum was recorded at lower elevation from 1850-1950m recorded 64.59 ton ha^{-}. At Bededo forest the maximum above ground carbon was recorded at lower elevation, from 2118-2218 m was recorded 172.85 ton ha^{-} and the minimum was recorded at higher elevation 2320-2420 m was recorded 153.97 ton ha^{-}). The sites were agreement with the reported result (97.66-143.22 ton ha-1) in Chen et al., (2004) in tropical deciduous forests.

In addition, the overall range of the aboveground carbon was within the range of 114-123 Mg ha-1 (Murphy and Lugo, 1986). The aboveground biomass of the current study sites was estimated by the allometry correlation with DBH. Consequently, the most of the finding are in agreement with other studies. Moreover, the variation of carbon stock in aboveground dependent on many factors such as the stand structure and composition, topography, altitude, disturbance, forest fire and fuel wood collection, micro climate.

As that of the above ground biomass, below ground biomass also showed similar trend in terms of species and elevation. Similarly, the maximum below ground carbon within species were recorded from the Weira-Amba forest: Acacia *Senegal, Olea europaea and Eucalyptus* *camaldulensis with* 11.72, 4.32 and 3.7 tons of carbon per hectare were recorded respectively. Whereas at Bededo forest: *Eucalyptus globules, Cupressus lusitanica and Acacia abyssinica* with 69.91, 65.48 and 19.44 tons of carbon per hectare were recorded respectively. At Weira-Amba forest the mean below ground carbon was 25.73 tons per hector recorded. But in terms of elevational difference: 26.8, 33.59 and 16.8 tons of carbon within upper, middle and lower elevation of the forest respectively.

Whereas at Bededo forest the mean below ground carbon was 42.43 ton per hectare .with elevation difference the upper 40.04, the middle 42.33 and 42.43 ton of carbon were recorded. This was because, trees have much more potential to produce larger quantities of belowground biomass compared to shrubs or herbs. As revealed by (Lemma et al., 2007), more biomass production increased the aboveground litter and the belowground root activity and these make trees are an important factor for SOC. Therefore, roots are a key component of the belowground system, and they are a main source of SOM, which are influencing the soil microbial activity and decomposition processes (Cheng, 1993; Janssens et al., 2002).

On a mass basis, coarse roots contribute more to the total ecosystem biomass than the fine roots. And when establishing carbon budgets and carbon allocation at an ecosystem level, coarse root biomass and production data should be collected (Vogt et al. 1998). However, coarse roots account for only a small portion of annual root production. In contrast, fine roots have a high turnover rate despite the fact that they account for only a small fraction of total root biomass (Chen et al., 2004). Due to their high metabolic activity, fine root production and turnover plays a critical role in forest carbon dynamics. Further, fine roots are an important structural and functional component of forested ecosystems, representing an important carbon input to the soil and can equal or exceed aboveground detritus production in some systems (Vogt 1991). A large proportion of forest production is allocated to fine roots, resulting in a large carbon flux into the belowground system (Kurz et al., 1996).

The result showed that the mean litter carbon density of Weira-Amba forest was 0.47 ton per hectare. But instead of its elevation: 0.48, 0.63 and 0.59 tons of Carbon per hectare were recorded at upper, middle and lower elevation of the area respectively, whereas, at Bededo forest the mean litter carbon were 0.57 tons per hectare and within its elevational differences

0.91, 0.54 and 0.78 tons of carbon per hectare ere recorded at upper, middle and lower elevation of the area respectively.

The overall result of the herbaceous biomass carbon stocks of the present study were in line with the study by (Roshetko et al., 2002), which ranges between 0.78 and 1.4 ton ha-1. Herbaceous plants contribute to the soil carbon sequestration. However, they are shorter lived than tree which can survive as high as 100 years or more.

Hence, the results indicated that low quantity carbon stocks when compared to the reported carbon by (Hirai et al., 2006) that was undertaken in the widely planted coniferous species litter biomass carbon stocks. The other study conducted by (Roshetko et al., 2002), in the home garden system of Indonesia reported the mean litter biomass carbon stock was 2.1 ton ha-^{1}, which is greater than the findings of the current study because the litter fall of the home garden system was utilized for soil fertility management. In most parts of Ethiopia tree litter layers are cleared for fuel wood; and this may explain the relatively lower carbon stock observed in the site.

This litter decomposition is one of the major sources of soil organic carbon and the decomposition process was dependent on the quality of the litter fall (Mafongoya et al., 1998) and the plant species (Lemma et al., 2007). Litter decomposition rates are also frequently considered to be regulated by soil organisms, environmental conditions and chemical nature of the litter (Gallardo and Merino, 1993).

The physical environment, especially soil moisture, temperature and relative humidity are important in litter decomposing as these regulate the biological activity in soil (Sayer, 2006). The climatic condition in the study areas is very hot and humid during the rainy season; and this might have been causing high rate of litter decomposition leading to relatively low litter accumulation at the ground surface beneath the tree canopy.

The Soil laboratory analysis for the percentage of soil organic carbon showed that, the mean soil organic carbon of Weira-Amba forest was which ranged from 7.64 % at upper elevation to the lowest 3.96% at lower elevation, and also at middle elevation 6.435% were recorded. While at Bededo forest at upper 5.99, at middle 3.68 and the lower elevation also 6.54 % of organic carbon. The mean organic carbon in Bededo forest was 5.4% recorded. The soil bulk density, which is also an important factor for the soil carbon density calculation was analyzed and at Weira-Amba forest bulk density ranged from 0.62g cm-^{3} for to 0.91 g cm-^{3} and also in Bededo forest was ranged from0.38 to 0.98 g cm-^{3}. This variation was due to the disturbance in the woodlands such as a free grazing and this results poor soil organic matter formation due to removal of the litter fall (Tschakert, 2004).

The result showed that at Weira-Amba forest soil carbon stock density was at upper elevation 26.98, medium elevation 20.3 and at lower elevation also 36.168 tons of carbon ha^{-1}, while at Bededo forest soil carbon stock density was: at upper 30.264, middle 22.745 and at lower elevation 33.38 tons of carbon ha^{-1} were recorded. These results are more or less similar with the study reported by (Mekuria et al., 2009). And the above argument was supported by the significant positive correlation between the soil carbon and the aboveground biomass and cover of carbon stock.

On the other hand, other related studies were reported the increment of soil carbon stocks in the ecosystem as the number of plant species and aboveground biomass increases (Solomon et al. 2002; Lemenih and Itanna 2004; Lemenih et al., 2005). Therefore, trees having more aboveground and belowground biomass contribute more to the soil carbon sequestration compared to shrubs or herbs. The accumulation of soil organic carbon also depends on the quantity of litter (Lemma et al., 2007) and root activity such as rhizo deposition and decomposition (Rees et al., 2005).

In addition, Solomon et al., (2002) was revealed that land use and land cover change could affect the amount and composition of soil organic matter through their influence on decomposition and humification processes. Moreover, the present findings agree with (Lal ,2001), who was reported the increasing soil organic carbon pool with the addition of biomass to soils when the pool has been depleted as a consequence of land use and land cover change. Proper forest management could increase the aboveground vegetation carbon density and this possibility to enhance the carbon storage in the soil. Degraded soils on the restoration practices could have the potential to provide terrestrial carbon sinks and reduce the rate of enrichment of atmospheric CO_2 (Marks et al., 2009). In addition, Solomon et al., (2002) was revealed that land use and land cover change could affect the amount and composition of soil organic matter through their influence on decomposition and humification processes.

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Plants capture CO_2 from the atmosphere through the process of photosynthesis. And the standing vegetation, most of which is eventually added to the soil as plant organic litter and then to the soil as SOC by microbial activity. Therefore, the estimation of carbon stock both in the aboveground and in soil becomes imperative to assess the carbon sequestration potential (Ramachandran et al., 2007). The total forest was calculated by adding all the above carbon stock densities calculated for each carbon pool; which is the above ground biomass, litter, belowground biomass (roots) and soil organic carbon.

At Weira-Amba forest the highest carbon stock was recorded from at medium elevation. Which is 184.15 tons of carbon ha^{-1}, at upper elevation and lower elevation were 158.172 and 118.9 tons of carbon ha^{-1}, respectively; while in Bededo forest the total carbon stock was recorded at upper elevation 226.47, also 229.31 in the middle and the lower elevation with 252.77 tons of carbon ha^{-1} were recorded. Statically, the estimated mean carbon stocks of the aboveground and belowground carbon in the Weira-Amba forest was significantly difference in elevation ($P < 0.05$) which is $p=0.043$ and also in aspect gradient significantly in above and below ground carbon $p=0.015$. But, in Bededo forest there no significant difference between them. SOC is higher than that of the biomass carbon 2.5 to 3 times of biomass carbon as recorded in well-managed terrestrial ecosystems (Singh and Singh, 1991). However, in the tropical forest, the carbon in the soil is roughly equivalent or lesser than the above ground biomass due to soil and vegetation degradation (Walkley, A. and Black, 1934).

In turn degradation is occurred because of the land use and land cover changes over time with the need-based forestry practices such as fuel wood, shifting cultivation, overgrazing and overall anthropogenic disturbances. Therefore, these mining practices cause the reduction of tree densities and carbon-storing capacity (Vishwanathan et al., 1999).

Aspect is one of the environmental factors that can affect the carbon stock of forests in different carbon pools and thus, it can be used as a useful variable to forecast the forest carbon stock in different carbon pools. According to aspect has a significant relationship with biomass carbon in forest areas due to the interaction between solar radiation and soil properties. The result of the present study revealed that in Weira-Amba forest, higher mean values of above and below ground biomass and carbon stock on Northwest aspect compared to the other aspects, whereas the lowest mean value was recorded on the West aspect of the mountain. This result is similarly to Hicks et al., (2014), works , in the carbon stock study of Egdu Forest, higher mean values of above and below ground biomass carbon stocks were found on Northern aspect.

In general, at Weira-Amba forest in the Northwestern aspects has higher values of above and below ground biomass and carbon stocks as compared to other aspects. This can be attributed to the occurrence of moister and favorable environment such as the type and fertility of the soil on the Northern aspects of Weira-Amba Forest as pointed out by Hicks et al., (2014), that soil properties are influenced by aspect. This is because the North and south facing slopes receive an unequal amount of solar radiation.

The South facing slopes receive high solar radiation compared to the North facing which receive less sunlight (Bayat, 2011). Thus, the South facing slopes are warmer and drier, whereas the North facing slopes are relatively cooler and form better-growing conditions on the Northern aspects than the Southern aspects. On the other hand, the least above and below carbon stock was found in the Western aspect which was in agreement with result found by “un-published” (Kidanemariam Kassahun, 2014), The reason might be the availability of less fertile soil and moisture in the western part. In addition, the higher and lower values of soil organic carbon in the North West and West aspects respectively have been reported in the present study. The reason might be due to the presence of moist climate and high decomposition rate on the Northwest aspect which had maximum SOC value and the reverse is true for West aspect.

At Bededo forest higher mean values of above and below ground biomass and carbon stock were recorded on Southwest and South aspects and the lowest mean value was recorded on the North aspect of the mountain. This result is similarly (Brown and Lugo, 1992) at

“Brazilian Amazon forest” works. As indicated by (Bayat, 2011), aspect has the significant relationship with biomass in forest areas due to the interaction between soil radiation and soil properties such as soil moisture and soil nutrients. Moreover, litter pool enhanced the maximum and minimum carbon stock on North East and South West aspects, respectively. he absence of high decomposition rate of a litter on Northeast aspect of the forest growing on the Northeast aspect are generally exposed to various natural disturbances such as, windfall cause the litter pool enhances the highest biomass and carbon stock in Northeast aspect than other aspects of the study area, whereas the reverse is true to the Southwest direction of the site. Overall, the present study pointed out that carbon stock density of all carbon pools did show significant difference along aspects.

5. CONCLUSION AND RECOMMENDATIONS

5.2. Conclusion

Both Weira-Amba and Bededo forests represents the same dry evergreen Afromontane type of forests. Also, they harbor a number of indigenous and exotic plant species. The high numbers of plant species diversity were recorded form were-Amba forest than Bededo forests, but their evenness were almost equal, no difference between them. At Bededo forest, mostly dominated by exotic plant species than indigenous, this show that why less regeneration was registered than Weira-Amba forest. The average carbon stocks in the Weira-Amba forest was relatively less than Bededo forest, but not least.

The result is comparable to some study results of forests in Ethiopia and other tropical countries. This indicates the contribution of the forest for carbon sequestration and hence mitigation of climate changes. Analysis of variance of carbon stock in different carbon pools of the forest area showed differences along different environmental gradients. In Weira-Amba forest the medium parts of elevation were high in above ground and below ground carbon stocks while the upper and lower parts of elevations had low to moderate carbon stock in both carbon pools due to the fact that there was a dense vegetation cover in the middle than others range. However, litter carbon and SOC showed the upper and lower elevations had better carbon stock than the middle elevation. Whereas at Bededo almost similar carbon stock among its elevation difference were recorded, these may as a result of most dominated species were exotic plantation species, for the reason that plantation species have the same age, diameter class and pattern.

According to Aspects at Weira-Amba forest the total carbon stock was found to be higher in the Northwest and Northern sides of the forest and very little in the West direction. Whereas, at Bededo higher carbon stock were found in the south and south west direction than other aspects Overall, the present study result revealed that because of different factors affecting forest carbon stocks, these carbon stocks of different forest ecosystem components showed different patterns along environmental gradients and thus these variables can play different roles in carbon sequestration.

5.3. Recommendations

- ✓ The carbon sequestration of the forest should be studied integrated with Reduced Emission from Deforestation and Degradation (REDD+) and Clean Development Mechanism (CDM) carbon trading system of the Kyoto Protocol to get the monetary benefit of carbon dioxide mitigation which can help in conservation and further enhancement of the forests.
- ✓ Special consideration should be given to the remnant Forest found in few pocket places like where-Amba and Bededo and other forest found in the country and conserve threatened species like, *Olea europaea*, *Juniperus procera* and others, to establish an in situ conservation sites and the community should protected to illegal encroachment and clearing of forests for farmland expansion.
- ✓ Also, it is important, to conduct further studies should be investigated on these forests instead to select better management options, which can contribute to sequester the highest amount of carbon in the forest land and to secure safe environment.

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7. APPENDIX

Appendix 1: Tree Species found in Weira-Amba forest

Ser. No	**Scientific Name**	**Amharic Name**	**Family**	**Life form**	**Origin**
1	*Euclea racemosa*	*Dedeho*	*Ebenaceae*	Shrub	Indigenous
2	*Olea europaea*	*Weira*	*Oleaceae*	Tree	Indigenous
3	*Euphorbia candelabrum*	*Kulkual*	*Euphoribiaceae*	Tree	Indigenous
4	*Carissa spinarum*	*Agam*	*Apocynaceae*	Shrub	Indigenous
5	*Clutia abyssinica*	*Fiyele feji*	*Euphoribiaceae*	Shrub	Indigenous
6	*Dodonaea viscose*	*Kitkita*	*Sapindaceae*	Tree	Indigenous
7	*Acacia Senegal*	*Sbansa-girar*	*Fabaceae*	Tree	Indigenous
8	*Celtis Africana*	*Kawoot*	*Ulmaceae*	Tree	Indigenous
9	*Juniperus procera*	*Yehabesha-tid*	*Cupressaceae*	Tree	Indigenous
10	*Croton macrostachyus*	*Bisana*	*Euphoribiaceae*	Tree	Indigenous

11	*Cupressus lusitanica*	*Yeferenji-tid*	*Cupressaceae*	Tree	Mexico
12	*Eucalyptus camaldulensis*	*Key-bahir zaf*	*Myrtaceae*	Tree	Australia
13	*Strychnos innocua*	*Merenz*	*Loganiaceae*	Shrub	Indigenous
14	*Acacia decurrens*	*Yferenji-girar*	*Fabaceae*	Tree	Australia
15	*Ehretia cymosa*	*Ulaga*	*Boraginaceae*	Tree	Indigenous

Appendix 2: Tree Species found in Bededo forest

No.	**Scientific Name**	**Amharic Name**	**Family**	**Life form**	**Origin**
1	*Eucalyptus globules*	*Nech-bahir zaf*	*Myrtaceae*	Tree	Australia
2	*Olea europaea*	*Weira*	*Oleaceae*	Tree	Indigenous
3	*Clutia abyssinica*	*Fiyele feji*	*Euphoribiaceae*	Shrub	Indigenous
4	*Carissa spinarum*	*Agam*	*Apocynaceae*	Shrub	Indigenous
5	*Maytenus arbutifolia*	*Atat*	*Celastraceae*	Shrub	Indigenous
6	*Cupressus lusitanica*	*Yeferenji-tid*	*Cupressaceae*	Tree	Mexico
7	*Acacia abyssinica*	*Bazra-girar*	*Fabaceae*	Tree	Indigenous
8	*Bersama abyssinica*	*Azamir*	*Melianthaceae*	Shrub	Indigenous

Appendix 3: Soil analysis in Weira-Amba forests

			WEIRA AMBA						
Elev.	Plot	PH	OC%	OM%	Clay%	Silt%	Sand%	BD	SC
1	1	6.25	1.313426	2.264347	10	27.5	62.5	0.71	2797.597
1	2	6.17	1.445145	2.491431	5	30	65	0.69	2991.45
1	3	6.23	1.41692	2.44277	35	17.5	47.5	0.7	2975.532
1	4	6.16	1.273911	2.196222	10	20	70	0.72	2751.648
1	5	6.12	0.986011	1.699882	15	17.5	67.5	0.8	2366.426
Aver.		**6.19**	**6.435413**		**15**	**22.5**	**62.5**	**3.62**	**13882.65**
2	1	6.07	1.06316	1.832888	7.5	22.5	70	0.81	2583.479
2	2	6.18	0.504296	0.869405	5	15	80	0.92	1391.857
2	3	6.26	0.549456	0.947263	10	7.5	82.5	0.91	1500.015
2	4	6.37	0.976602	1.683662	15	20	65	0.82	2402.441
2	5	6.23	0.871227	1.501995	12.5	15	72.5	0.87	2273.902
Aver.		**6.22**	**3.964741**		**10**	**16**	**74**	**4.33**	**10151.69**
3	1	5.99	2.459381	4.239974	22.5	35	42.5	0.62	4574.449
3	2	6.12	1.902398	3.279735	22.5	32.5	45	0.64	3652.604
3	3	6.16	1.90428	3.282979	10	32.5	57.5	0.65	3713.346
3	4	6.02	1.375522	2.371401	12.5	32.5	55	0.7	2888.596
Aver.		**6.07**	**7.641581**		**16.88**	**33.13**	**50**	**2.61**	14829

Appendix 4: Soil analysis in Bededo forest

			BEDEDO						
Block	Plot	PH	OC	OM	Clay	Silt	Sand	BD	Sc
1	1	6.44	1.136547	1.959406	30	27.5	42.5	0.78	2659.52
1	2	6.26	1.586273	2.734734	25	27.5	47.5	0.68	3235.997
1	3	6.03	1.176062	2.027531	12.5	22.5	65	0.75	2646.14
1	4	6.38	2.086805	3.597652	10	20	70	0.65	4069.27
		6.28	**5.985687**		**19.38**	**24.38**	**56.25**		**12610.93**
2	1	6.3	0.856173	1.476043	12.5	25	62.5	0.93	2388.723
2	2	6.58	0.970957	1.67393	10	32.5	57.5	0.84	2446.812
2	3	6.33	1.102676	1.901013	15	35	50	0.74	2447.941
2	4	6.3	0.747035	1.287888	20	32.5	47.5	0.98	2196.283
		6.38	**3.676841**		**14.38**	**31.25**	**54.38**		**9479.758**
3	1	6.1	1.663423	2.86774	7.5	25	67.5	0.66	3293.578
3	2	6.13	1.623907	2.799615	7.5	22.5	70	0.68	3312.77
3	3	6.46	1.147837	1.978871	10	27.5	62.5	0.79	2720.374
3	4	6.39	2.107504	3.633336	17.5	37.5	45	0.38	2402.555
		6.27	**6.542671**		**10.63**	**28.13**	**61.25**		**11729.28**

Appendix 5: Species diversity, Basal area relative frequency and IVI upper elevation in Weira-Amba forest

Spp	BA	Relative BA	frequency	Relative frequency	Pi
Carissa spinarum	0.003383	0.202733	2	9.52381	0.095238
Euclea racemosa	0.104168	6.241563	1	4.761905	0.047619
Clutia abyssinica	0.001127	0.067519	1	4.761905	0.047619
Celtis africana	0.292998	17.55591	3	14.28571	0.142857
Dodonaea viscosa	0.319082	19.11879	5	23.80952	0.238095
Euphorbia candelabrum	0.059717	3.578119	1	4.761905	0.047619
Acacia senegal	0.646659	38.74661	4	19.04762	0.190476
Olea europaea	0.108744	6.515732	2	9.52381	0.095238
Juniperus procera	0.133065	7.973027	2	9.52381	0.095238
	1.668943		21		

ln pi	pi*lnpi	pi^2	n rep	no tree/plot	Density	rel.Density	IVI
2.35138	-0.22394	0.00907	25	8	200	3.305785	13.03233
3.04452	-0.14498	0.002268	25	20	500	8.264463	19.26793
3.04452	-0.14498	0.002268	25	3	75	1.239669	6.069093
1.94591	-0.27799	0.020408	25	35	875	14.46281	46.30443
1.43508	-0.34169	0.056689	25	86	2150	35.53719	78.4655
3.04452	-0.14498	0.002268	25	7	175	2.892562	11.23259
1.65823	-0.31585	0.036281	25	47	1175	19.42149	77.21572
2.35138	-0.22394	0.00907	25	20	500	8.264463	24.304
2.35138	-0.22394	0.00907	25	16	400	6.61157	24.10841
	-2.04228	0.147392			6050		
H'	2.04228						
D(simpison	6.784615						
j(evennes)	0.929482						

Appendix 6: .Species diversity, Basal area relative frequency and IVI medium elevation in Weira-Amba forest

	BA	relativ BA	frequancy	rel. frequa	pi	ln pi
Acacia senegal	1.384231	42.97322	5	16.12903	0.16129	1.82455
Croton macrostachyus	0.36909	11.45832	4	12.90323	0.129032	2.04769
Olea europaea	1.027455	31.89715	5	16.12903	0.16129	1.82455
Dodonaea viscosa	0.218154	6.772553	5	16.12903	0.16129	1.82455
Cupressus lusitanica	0.077317	2.400298	2	6.451613	0.064516	2.74084
Euclea racemosa	0.025804	0.801095	5	16.12903	0.16129	1.82455
Eucalyptus camaldulensis	0.102587	3.184794	1	3.225806	0.032258	3.43399
Strychnos innocua	0.01651	0.512564	4	12.90323	0.129032	-.04769
	3.221148		31			

pi*lnpi	pi^2	n rep	no tree/plot	Density	rel.Density	IVI
0.29428	0.026015	25	47	1175	18.43137	77.53362
0.26422	0.016649	25	16	400	6.27451	30.63606
0.29428	0.026015	25	47	1175	18.43137	66.45756
0.29428	0.026015	25	81	2025	31.76471	54.66629
0.17683	0.004162	25	13	325	5.098039	13.94995
0.29428	0.026015	25	29	725	11.37255	28.30268
0.11077	0.001041	25	7	175	2.745098	9.155699
0.26422	0.016649	25	15	375	5.882353	19.29814
1.99317	0.14256			6375		
		H'	1.993168			
		D(simpison	7.014599			
		j(evennes)	0.958511			

Appendix 7: Species diversity, Basal area relative frequency and IVI lower elevation in Weira-Amba forest

Spp	BA	relativ BA	frequancy	rel. frequa	pi	ln pi
Acacia decurrens	0.604146	20.11176	3	11.11111	0.111111	2.19722
Eucalyptus camaldulensis	1.64968	54.91715	5	18.51852	0.185185	1.6864
Ehretia cymosa	0.025755	0.857359	2	7.407407	0.074074	2.60269
Acacia senegal	0.601593	20.02678	4	14.81481	0.148148	1.90954
Dodonaea viscosa	0.066402	2.210483	5	18.51852	0.185185	1.6864
Euclea racemosa	0.006429	0.214021	2	7.407407	0.074074	2.60269
Olea europaea	0.043627	1.452308	4	14.81481	0.148148	1.90954
Carissa spinarum	0.006312	0.210138	2	7.407407	0.074074	2.60269
	3.003944		27			
pi*lnpi	pi^2	n rep	no tree/plot	Density	rel.Density	IVI
-0.24414	0.012346	25	18	450	7.725322	38.94819
-0.3123	0.034294	25	81	2025	34.76395	108.1996
-0.19279	0.005487	25	7	175	3.004292	11.26906
-0.2829	0.021948	25	26	650	11.1588	46.0004
-0.3123	0.034294	25	53	1325	22.74678	43.47578
-0.19279	0.005487	25	7	175	3.004292	10.62572
-0.2829	0.021948	25	28	700	12.01717	28.28429
-0.19279	0.005487	25	13	325	5.579399	13.19695
-2.01289	0.141289			5825		
		H'	2.012894			
		D(simpison	7.07767			
		j(evennes)	0.967997			

Appendix 8: Species diversity, Basal area relative frequency and IVI Upper elevation in Bededo forest

	BA	relativ BA	frequancy	rel. frequa	pi	ln pi
Carissa spinarum	0.000843	0.008007	3	11.53846	0.115385	-2.15948
Bersama abyssinica	0.016177	0.153716	4	15.38462	0.153846	-1.8718
Acacia abyssinica	1.776185	16.87773	4	15.38462	0.153846	-1.8718
Clutia abyssinica	0.031381	0.298193	2	7.692308	0.076923	-2.56495
Eucalyptus globules	3.303505	31.39068	4	15.38462	0.153846	-1.8718
Olea europaea	0.082772	0.786522	4	15.38462	0.153846	-1.8718
Cupressus lusitanica	5.312975	50.48515	5	19.23077	0.192308	-1.64866
	10.52384		26			
pi*lnpi	pi^2	n rep	no tree/plot	Density	rel.Density	IVI
-0.24917	0.013314	25	19	475	7.089552	18.63602
-0.28797	0.023669	25	20	500	7.462687	23.00102
-0.28797	0.023669	25	22	550	8.208955	40.4713
-0.1973	0.005917	25	8	200	2.985075	10.97558
-0.28797	0.023669	25	59	1475	22.01493	68.79022
-0.28797	0.023669	25	20	500	7.462687	23.63382
-0.31705	0.036982	25	120	3000	44.77612	114.492
-1.9154	0.150888		268	6700		
		H'	1.915403			
		D(simpison	6.627451			
		j(evennes)	0.984322			

Appendix 9: Species diversity, Basal area relative frequency and IVI medium elevation in Bededo forest

	BA	relativ BA	frequancy	rel. frequa	pi	ln pi
Carissa spinarum	0.023936	0.210037	2	11.11111	0.111111	-2.19722
Bersama abyssinica	0.005854	0.051367	1	5.555556	0.055556	-2.89037
Acacia abyssinica	1.063053	9.328394	3	16.66667	0.166667	-1.79176
Eucalyptus globules	3.462165	30.38084	5	27.77778	0.277778	-1.28093
Olea europaea	0.022719	0.19936	2	11.11111	0.111111	-2.19722
Cupressus lusitanica	6.818159	59.83001	5	27.77778	0.277778	-1.28093
	11.39589		18			
pi*lnpi	pi^2	n rep	no tree/plot	Density	rel.Density	IVI
-0.24414	0.012346	25	15	375	6.666667	17.98781
-0.16058	0.003086	25	5	125	2.222222	7.829145
-0.29863	0.027778	25	13	325	5.777778	31.77284
-0.35581	0.07716	25	63	1575	28	86.15861
-0.24414	0.012346	25	10	250	4.444444	15.75492
-0.35581	0.07716	25	119	2975	52.88889	140.4967
-1.6591	0.209877			5625		
			H'	1.659105		
			D(simpison	4.764706		
			j(evennes)	0.925964		

Appendix 10: Species diversity, Basal area relative frequency and IVI lower elevation in Bededo forest

	BA	relativ BA	frequancy	rel. frequa	pi	ln pi
Carissa spinarum	0.009777	0.069377	2	11.11111	0.111111	2.19722
Bersama abyssinica	0.01071	0.076	2	11.11111	0.111111	2.19722
Acacia abyssinica	1.598569	11.34359	2	11.11111	0.111111	2.19722
Eucalyptus globules	3.485457	24.73312	5	27.77778	0.277778	1.28093
Olea europaea	0.055736	0.395505	2	11.11111	0.111111	2.19722
Cupressus lusitanica	8.932021	63.38241	5	27.77778	0.277778	1.28093
	14.09227		18			
pi*lnpi	pi^2	n rep	no tree/plot	Density	rel.Density	IVI
-0.24414	0.012346	25	9	225	3.719008	14.8995
-0.24414	0.012346	25	10	250	4.132231	15.31934
-0.24414	0.012346	25	15	375	6.198347	28.65305
-0.35581	0.07716	25	57	1425	23.55372	76.06461
-0.24414	0.012346	25	11	275	4.545455	16.05207
-0.35581	0.07716	25	140	3500	57.85124	149.0114
-1.68817	0.203704			6050		
		H'	1.688174			
		D(simpison	4.909091			
		j(evennes)	0.942188			

Appendix 11: Species diversity, Basal area relative frequency and IVI in totally Weira-Amba forest

Spp	BA	Rela. BA	Freq.	rel. freq.	pi	ln pi	pi*lnpi
Euclea racemosa	0.10417	50.14566	20	42.55319	0.425532	0.85442	0.36358
Olea europaea	0.03944	18.98379	11	23.40426	0.234043	1.45225	0.33989
Euphorbia candelabrum	0.05972	28.74714	7	14.89362	0.148936	1.90424	0.28361
Carissa spinarum	0.00109	0.525064	3	6.382979	0.06383	2.75154	0.17563
Clutia abyssinica	0.00113	0.542456	3	6.382979	0.06383	2.75154	0.17563
Dodonaea viscosa	0.00219	1.05589	3	6.382979	0.06383	2.75154	0.17563
	0.20773		47				1.51397

pi*lnpi	pi^2	n rep	no tree/plot	Density	rel.Density	IVI
0.36358	0.18108	4	20	80	42.55319	135.252
0.33989	0.05478	4	11	44	23.40426	65.7923
0.28361	0.02218	4	7	28	14.89362	58.5344
0.17563	0.00408	4	3	12	6.382979	13.2910
0.17563	0.00408	4	3	12	6.382979	13.3084
0.17563	0.00408	4	3	12	6.382979	13.8219
1.51397	0.27026			188		
		H'(shannon)	1.513969			
		evennes(J=H'/ln	0.844962			
		simpison (D=1/sum pi^2)		3.7002		

Appendix 12: Species diversity, Basal area relative frequency and IVI in totally Bededo forest

Spp	BA	Rel. BA	Freq.	Rel. Freq	pi	ln pi
Acacia abyssinica	0.725059	24.80972	9	16.36364	0.163636	1.81011
Cupressus lusitanica	1.250537	42.79025	18	32.72727	0.327273	1.11696
Eucalyptus globules	0.90935	31.11567	15	27.27273	0.272727	1.29928
Olea europaea	0.03064	1.048409	6	10.90909	0.109091	2.21557
Bersama abyssinica	0.004991	0.170787	4	7.272727	0.072727	2.62104
Carissa spinarum	0.001904	0.065164	3	5.454545	0.054545	2.90872
	2.922481	100	55			
pi*lnpi	pi^2					
0.2962	0.026777	4	9	36	16.36364	57.53699
0.36555	0.107107	4	18	72	32.72727	108.2448
0.35435	0.07438	4	15	60	27.27273	85.66112
0.2417	0.011901	4	6	24	10.90909	22.86659
0.19062	0.005289	4	4	16	7.272727	14.71624
0.15866	0.002975	4	3	12	5.454545	10.97425
1.60708	0.22843		55	220		
		Shannon(H')	1.607078			
		evennes(E=H'/ln(s))	0.896927			
		simpison (D=1/sum pi^2)	4.377713			

Appendix 13: Aspects of Weira-Amba forest

Aspect								
N	27.97	25.87	27.51	24.02	22.73	45.74	173.84	28.97333
NW	29.91	13.91	36.52	37.13	32.57		150.04	30.008
SW	23.66	25.83	28.88				78.37	26.12333
W	15.01						15.01	15.01

Appendix 14: Aspects of Bededo forest

Aspect BEDEDO				
SW	W	NW	South	N
26.59	32.35	26.46	32.93	**25.23**
23.88	24.46	18.954	40.69	
24.47	27.2	45.414	32.93	
40.45	84.01	**22.707**	33.12	
33.4	**28.00333**		139.67	
148.79			**34.9175**	
29.758				

Appendix 15: Summary of values of significance for one-way ANOVA between environmental for different pools carbon stock at Weira-Amba forest

Environmental Variables	Carbon pools	F-value	P-value
Elevation	AGC	5.876	0.043
	BGC	5.876	0.043
	LC	0.231	0.795
	SOC	0.446	0.813
Aspect	AGC	4.743	0.015
	BGC	4.743	0.015
	LC	0.371	0.865
	SOC	0.441	0.647
	significant at the p < 0.05 level		

Appendix 16: Summary of values of significance for one-way ANOVA between environmental for different pools carbon stock at Bdedo forest

Environmental Variables	Carbon pools	F-value	P-value
Elevation	AGC	0.966	0.391
	BGC	0.966	0.391
	LC	0.708	0.487
	SOC	0.342	0.67
Aspect	AGC	1.768	0.146
	BGC	1.768	0.146
	LC	0.935	0.471
	SOC	0.371	0.865
	Significant at the p < 0.05 level		

Biographical sketch

Derbie Wudu Sisay was born in woldia north wollo, Ethiopia in 1984. He completed his elementary and secondary education at woldia in July 2002. He attended a B.Sc. degree in Natural Resource Management at Bahir Dar University, College of Agriculture and Environmental science from October, 2009 - June, 2011. After graduation, he was employed as research assistance and a researcher of forestry and agro forestry at Sirinka Agriculture Research Center in Amhara Agricultural Research Institute (ARARI) from July 2011 up to now (2018). In 2016, he joined again Bahr Dar University, College of Agriculture and Environmental Science and for his study of M.Sc. degree in land Resource Management.