Madda Walabu Univerrsity

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Department of Biodivresity Conservation and Ecotourism

Diversity and Above ground Carbon Storage of Woody Species species in agricultural landscape, Goro District, Bale, Zone, South Eastern Oromia, Ethiopia.

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A Thesis Submitted to Department of Biodivresity Conservation and Ecotourism, College of Agriculture and Natural Resources, Madda Walabu Univerrsity in partial Fulfillment for the Requirements of Masters of Science Degree in Ecosystem and Biodiversity Conservation

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Approval Sheet 1

This is to certify that the thesis entitled "Diversity and Carbon Storage of live Woody species in an Agricultural Landscape of Goro District, Bale, Zone South Eastern, Oromia, Ethiopia" submitted in partial fulfillment of the requirements for the degree of Master's with specialization in **Ecosystem and Biodiversity Conservation ,** the Graduate Program of the Collage of Agriculture And Natural Resource, Madda Walabu University, has been carried out by Mohammed Ibrahim under my supervision and no part of the thesis have been submitted for any other degree or diploma. Therefore, I recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

Dr. Habte Telila	________________	____________
Name of Major Advisor	Signature	Date

Submitted by:	Signature	Date
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Approval Sheet 2

We, the undersigned, members of the Board of examiners of the final open defense by Mohammed Ibrahim have read and evaluated his thesis entitled Diversity and Carbon Storage of live Woody species in an Agricultural Landscape of Goro District, Bale, Zone South Eastern, Oromia, Ethiopia and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science.

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Acronomy

AGB	Aboveground Biomass
AGC	Aboveground Carbon
AGCO2	Aboveground Carbon dioxide
CCAFS	Climate Change, Agriculture and Food Security
IPCC	Intergovernmental Panel for Climate Change
NBP	Net Biome Production
REDD	Reduced Emwassion from Deforestation and Degradation
UNFCCC	United Nations Framework Convention on Climate Change

Abstract

Woody plant species in agricultural landscape play a vital role in ecosystem services including food security that supports human livelihood. They can further offer synergy between adaptation and mitigation in addressing climate change impact. Aboveground woody biomass provide opportunities for better management of the carbon pools. Hence the aim of the study was to assess the diversity and carbon storage of woody species in agricultural landscape of Goro district of Bale Zone. Plant data were collected using systematic sampling by laying plots of size (100 m × *50 m and a total 71 plots were used in the study) Woody plant species encountered were counted and recorded and common characteristic dimension of species such as Diameter at breast height and height were also measured and recorded.Data on species diversity were calculated using the Shannon diversity index formula, variations in species diversity and impacts of altitude,* slope *and aspect were analyzed using ANOVA and MANOVA and Multiple linear regressions respectively. For the purpose of woody biomass estimation, allometric equations developed for a similar area were used. A total of 54 woody plant species were recorded, and* The most frequent species was *Croton macrostachyus followed by Erythrina brucei,* the most abundant specie was *Embelia schimperi* followed by *Croton macrostachyus.* The common families were Fabaceae and Asteraceae. The species diversity and richness were impacted by altitude. *The average above ground carbon storage of woody species was 19 Tone Carbon per hectare and the average aboveground carbon pool per plot was* 1209 Tone carbon per ha*. Albizia schimperiana and Flacourtia indica had the highest carbon storage Altitude, slope and aspect did not significantly affected the carbon storage and carbon pool though there was the above ground carbon storage showed significant difference with the characteristic dimension of woody species. Eventually woody species in on farmscape hold a high potential of carbon storage which may greatly contribute to the climate resilience green economy strategy and their conservation should be promoted.*

Keywords: Aboveground carbon stock, carbon pool, Goro, species diversity, woody species

1. INTRODUCTION

1.1 Background of the Study

Climate change and biodiversity loss were the two major global crisis, each affect both individual as well as synergistic risks to human well-being and restraining humanity’s future options (MEA, 2005; Metz et al. , 2007). Forest patches and trees in agricultural land scapes were an important resource for many small holding farmers in tropical regions (Chazdon 2003: Fischer et al 2008). Apart from providing food, fodder, and fiber, the trees, woodlots, and forest patches also provide many other ecosystem services such as water and soil fertility regulation, carbon sequestration, amelioration of local microclimate, and shade (Ernoult et al. ,2005). Moreover, such forest patches and trees can contribute to biodiversity conservation because they connect forest fragments, serve as habitats, and ease pressure on protected forest areas (Manning et al. 2006, Bhagwat et al. 2008, Perfecto and Vandermeer 2008, Pulido-Santacruz and Renjifo 2011). In many agricultural land scapes particularly to understand what factors regulate the distribution of trees and their carbon storage is very crucial. The most important driver is the management by the farmers (Theilade et al., 2007; Ango et al., 2014(Esquel et al., 2008).

Even if trees on farm land were not primarily designed to sequester carbon, it is a unique opportunity to increase carbon stocks in the terrestrial biosphere (Albrecht and Kandji2003). Tree on farmland contains less carbon than primary or managed forests but they contain significantly higher carbon stocks than annual crops (Henry et al. 2009 Newaj et al. 2016). However, the potential of trees on farmlands to sequester carbon depends upon the tree species composition, types of land uses, ecoregion, agroecological conditions (climate, altitude, and wind), management regimes, and soil characteristics (Bunker et al. 2005; Henry et al. 2009; Newaj et al. 2016).

Tropical agricultural landscapes has received little attention especially in Bale zone regarding how trees and associated biodiversity were distributed and their role in carbon sequestration, perhaps due to a focus contiguous forest such as Harenna forest and protected areas such as Bale Mountains National Park. In Ethiopia, much focus has been on forest decline (Reusing, 2000; Hylander et al., 2013) and how the forest composition is affected by various forms of disturbances (Gashaw et al., 2014; Cheng et al., 1988).

Despite considerable efforts to protect biodiversity in reserves and parks and REDD+ referring to forest restoration, on farm trees were under constant pressure from human induced factors such as deforestation due to climate change and unsustainable land management practices. This imposes pressure on smallholders' sustainability a surviving abilities in confronting the adverse impacts of climate change (Bhattarai et al., 2016). Land degradation leads to reduction in vegetation cover that would be resulted in soil erosion, depleting soil nutrients. Thus, the low standing biomass of degraded land is associated with low soil carbon and reduced productive properties, weakening the whole farming system and the livelihood of the people making their living from these systems.

Farmers in developing countries were one of the world's largest and most efficient producers of sequestered carbon. However, measuring, monitoring and verifying how much carbon trees in farmer were removing from the atmosphere has remained a great challenge in developing nations. Devising a reliable way for measuring carbon associated with trees in agricultural landscapes is essential for helping smallholder farmers benefit from emerging carbon markets. Furthermore, Long-lasting conservation would require alliances among conservation biologists, farmers, and land managers to actively plan the future Ethiopian landscapes. In Ethiopia, most of the studies on carbon sequestration potential were focused on forest ecosystem (Adugna et al., 2013; Mohammed et al., 2014; Gebrehiwot et al., 2018; Sisay et al.,2017; Solomon et al., 2018).

For example, Bale Eco-Region REDD project covers 700,000 hectweres of forest over fourteen districts (BERSMP, 2010). However the projects did not include a single tree in a farmscapes and provide smallholder farmers with access to carbon markets.The study is mainly steered by the lack of information on farmer's preferences fortree functions and the priority plant species for these functions in Ethiopia. Understanding which species were most important for local people and the reason they were important for the farmers is crucial for developing participatory projects that prioritize the needs of smallholder farmers and climate change issues (Simons, et al 2004; Faye et al 2010).

1.2. Objectives

1.2.1. General Objective

The overall objective of the study is to investigate the diversity, and carbon storage of Woody species in Goro District of Bale Zone, South Eastern Oromia, Ethiopia.

1.2.2. Specific Objectives

The specific objectives of the study were to:

- Assess the species diversity, species composition, tree density in farm scape of Goro district of Bale zone
- Estimate the above ground carbon storage of tree species in the study area

1.3. Significance of the study

The result of the proposed study may i) help in finding positive synergies between goals for conservation and economic development in which the farming community plays a prominent role; (ii)data could be used to develop agroforestry design criteria for all regions and practices that optimize C sequestration, environmental benefits and economic returns; (iii) Investigation of tree diversity and carbon stock data is important in itself for feeding in to massiveglobal datasets such as those of the IPCC (Intergovernmental Panel on Climate Change) and for other planning and developmental purposes; (iv) Helps to demonstrate the multiple developmental and environmental benefits that result from a high value biocarbon approach to climate change and variability in large landscapes; (v) Understanding which species were the most essential for the farmers and the reason they were important to them is vital in designing participatory projects for sustainable management andcultivation of the species that local people were likely to conserve; (vi) The empirical data on the potential of farmers' preferred tree species to store carbon, increasing the adoption of agroforestry and other carbon-enriching farm practices that meet beneficiaries' priority needs and address climate change issues; and (vii) It helps in developing design criteria for appropriate configuration, species selection, and planting density for various agroforestry practices to optimize C sequestration.

2. REVIEW OF LITERATURE

2.1 The Importance of Trees in Agricultural Landscapes

Agriculture is the most prevalent of the human environment interaction and consumes more natural resources than any other human activity (FAO 2007). This has raised concerns about natural resource management trajectories as they relate to planetary boundaries and land degradation tipping points (Rockström et al .2009).

Conventional agriculture in the last century led to a dramatic increase in crop yields largely as a result of the introduction of new highyielding crop varieties, the use of mineral fertilizers, chemical pesticides, mechanization and the expansion of irrigation infrastructure (Foley et al. 2005). Therefore, in recent years, increasing attention on productive agricultural systems that were resource-use efficient has placed biodiversity at the centerstage of discussions on agricultural intensification (Brussaard et al. 2010; Snapp et al. 2010; Barrios et al. 2015; Prabhu et al. 2015).

The valuable contribution of trees to more ecological forms of agricultural intensification has been increasingly highlighted in the literature (Schroth et al. 2004; Pretty et al. 2006; Tscharntke et al. 2012a). Ecological intensification can be defined as generating more output from the same area of land while reducing the negative environmental impacts by decreasing the reliance on anthropogenic inputs through the management of regulating and supporting ecosystem services in agricultural practices (Bommarco et al. 2013).for light, water and nutrients (Beer et al. 1998; Ong et al. 2004; Steffan-Dewenter et al. 2007; Kuyah et al. 2016).

Nonetheless, if we consider tree cover on agricultural land greater than 10% as agroforestry, this land use would represent over 1 billion ha of land inhabited by 900 million people (Zomer et al. 2016) and hence of significant importance to the agriculture sector. Recent concern, however, has been raised about the global decline in shade tree cover particularly in coffee agro ecosystems and the potential implications for biodiversity, ecosystem services and Livelihoods (Jha et al. 2014). Biodiversity responsible for key ecological functions that provide benefits to society (i.e.ecosystem services) is a key component of agricultural sustainsability strategies (Kremen 2005; Balvanera et al. 2006; Barrios 2007).

Biodiversity in agricultural landscapes can be broadly separated into the better studied, visible aboveground biodiversity, which may be directly or indirectly managed by farmers like plants (e.g., shade trees) and insects with bio-control and pollination functions (e.g. parasitoid wasps, bees), and the less-studied, largely invisible and mostly unmanaged soil biodiversity contributing to soil health (Swift et al. 2004; Wall et al. 2010). Soil health is considered here as an integrative property that expresses the capacity of soil to respond to agricultural management where both agricultural production and the provwasion of other soilmediated ecosystem services were maintained (Kibblewhite et al. 2008).

Trees in agricultural landscapes can provide more favorable habitats for soil biodiversity, through microclimate buffering and continuous supply of organic matter inputs, thus fostering ‘hot spots’ of biological activity responsible for many ecological functions underpinning soil health (Pauli et al. 2010; Ushio et al. 2010; Diedhiou-Sall et al. 2013; Kamau et al. 2017). Increased tree cover often, but not always, also reduces pest pressures and improves pollination services (Ricketts et al. 2004; Pumariño et al. 2015). Agricultural landscapes, where agroforestry cover is significant, represent intermediate levels of complexity presumably most effective for the conservation of biodiversity and ecosystem services, yet also contributing to more resilient rural livelihoods (Tscharntke et al. 2012b; Prabhu et al. 2015; Balvanera et al. 2016).

2.2. Woody Species and the Preferences of Farmers’

Assessments of the available wood resources on farmers’ holdings were reflections of their preferences. Humans have long had a profound influence on forest ecosystems and their tree cover, and continue to do so (Schroth & Sinclair, 2003). Some activities have led to minor effects, while other have led to profound changes in the woody vegetation, or to permanent loss of tree cover (Longman & Jenik, 1987). Not all these modifications have been deleterious, but problems have been sufficiently frequent and serious to have resulted in the pace and extent of deforestation today. Deforestation of the world's tropical region, which attained the status of a ‘hot topic’ on the agenda of almost all environment related discussions at all levels during the 1980s, is a major environmental issue (Nair, 1993).

Although the rise in human populations has caused pronounced reductions in forest and tree cover, trees remain an important element of most human-dominated agricultural landscapes throughout the tropics. Diverse perennial vegetation (trees and shrubs) in agricultural landscapes has greater significance in nutrient cycling as compwered to annual crops (Sharma, 1997), and in addition, trees provide a wide range of important products and service functions (Young, 1997; Schroth & Sinclair, 2003; Tesfaye, 2005). The pattern of distribution of various vegetation structures and the mixture with diverse tree-based farming were interesting features with regard to floristic and eco-diversity at a landscape level (Backes, 2001). Thus, woody species diversity can contribute to ecosystem productivity and sustainability under conditions of heterogeneity in species traits and environmental characteristics in agricultural landscapes (Kindt et al., 2004).

Decisions by farmers to plant trees or maintain the existing trees as an agroforestry practice (AFP), is understood as a process which in the course of time is influenced by a number of agroecological, socio-economic, cultural, institutional and personal factors (Tesfaye, 1996; Solomon ,2009). Land-tenure systems that do not guarantee continued ownership and control of land were not likely to be conducive to the adoption of longer-term strategies (as also relatively short-term practices that include benefits which would only be realized in the long run) such as agroforestry (Nair, 1993).

Forestry extension programs were also responsible for promoting the management of agroforestry (AF) by providing technical advice and inputs such as improved seedlings and extension activities (Salam et al., 2000). Higher dependence on income from off-farm results in less labour being available to the farm to plant or manage, hence farm-level species diversity may be low (Shaxson & Tauer, 1992; Muktar, 2006).

A study in Malawi by Shaxson & Tauer (1992) noted that increased access to natural resources (i.e . forests) is associated with decreased species diversity on farmland, since farmers can obtain some of their requirements, such as wood, medicinal plants, fruits, utensils, etc. , from the forest. Findings from southern Ethiopian home garden agro forestry (AF) showed that smaller farm sizes and enhanced access to road networks decreased native and other multipurpose species (Tesfaye, 2005).

Women may prefer fruit and fodder trees close to homesteads or men may prefer timber or woodlots away from the homestead; wealthy households may prefer monocultures or poor households may prefer multi- strata gardens, to maintain diversity. Farmers with little access to resources, particularly land, may focus on the production of few staple food crops, depending on their individual comparative advantage. In addition, farm size plays a role in the choice of tree species, arrangement and density, as well as overall management practices of the system (Zebene, 2003). Inappropriate land-use practices and tenure, coupled with poor market access and absence of local institutions for farm resource management brought about a rapid decline in tree cover and loss of biological diversity. Other factors such as, exposure to information and extension input and biophysical environment conditions, were also known to affect tree species diversity management. The objectives of study were to inventory woody species diversity on farmers' landholding and assess farmers' woody species preferences.

2.3. Agroforestry and carbon storage

The anthropogenic global climate change has negative impacts on various sectors and communities who particularly rely on rain-fed agriculture. The most prominent factor driving this climate change is increased atmospheric concentrations of greenhouse gases (GHGs) (WMO., 2007). As it is widely documented, the current global climate change is caused by the increase in the average temperature of the Earth's near-surface air and oceans in recent decades and its projected continuation (Asako, 2007).

A key mitigation strategy is to reduce the atmospheric concentrations of GHGs, particularly carbon dioxide (CO2), through the process of carbon sequestration (Nair, 2011), besides reducing emission at source. Carbon sequestration can be done in terrestrial ecosystems such as in forests and agro forests, woodland scrubland and etc. Agro forestry is the practice of growing trees and crops or pasture in interacting combinations (Nair et al., 2010). It is a tree-based farming system that has been practiced for a long period of time in many countries including Ethiopia. During the past four decades, agroforestry has been known as an integrated approach to sustainable land use because of its production and environmental benefits. Its recent recognition as global climate change mitigation strategy under the Kyoto Protocol has given it an added attention (Nair et al., 2009).

Agroforestry has various systems and practices. Among others, the practices include parklands. Parklands were generally understood as landscapes in which mature trees occur scattered in cultivated or recently fallowed elds (Abdelkadir and Bwashaw, 2003); or it is the coexistence of woody plants and grasses in subtropical and tropical savanna ecosystem (Bayala et al., 2006). The practice involves the growth of individual trees and shrubs in wide spaces in the farmland, while eld crops were grown in the understory. Some of these trees were left when the natural forest is converted to other land uses; others regenerated after the land is clewered by farmers; and still others were deliberately retained or planted on the farmland (ICRAF., 2006) to provide multiple products and services such as soil structure improvement, moderate local climate, reduce erosion hazards and carbon sequestration.Carbon sequestration refers to the removal of C from the atmosphere and deposition or storage in a reservoir such as oceans, vegetation or soil (Jose, 2009).

Carbon sequestration in terrestrial ecosystems such as agroforestry systems and practices involves primarily the uptake of atmospheric CO2 through photosynthesis and transfer of the carbon into biomass, detritus, and soil pools for storage (Nair, 2011). The pools were categorized into above-ground and below-ground biomass, litter and soils. The above-ground biomass includes the carbon stored in live stems and leaves of trees and herbaceous plants and in standing and downed dead wood, below-ground biomass contains roots where as litter/detritus and soils include the carbon stored in dead plant and animal parts, defecates, and the carbon stored in various soil horizons.The mean carbon stock in soil and above-ground parts were estimated to hold major portions, roughly 60 and 30%, respectively, in tree-based land-use systems (Pan et al., 2011; Jose S., 2012). The estimates of carbon stored in agroforestry systems (AFSs) range from 0.29 to 15.21 Tone ha^{-1} $yr.^{-1}$ above-ground and 30 to 300 Tone C ha^{-1} up to 1 m depth in the soil. Recent studies under various AFSs in diverse ecological conditions showed that tree-based agricultural systems, compered to treeless systems, stored more carbon in deeper soil layers near the tree than away from the tree; higher soil organic carbon content is associated with higher species richness and tree density (Nair et al., 2010).

Most of the carbon in trees and shrubs were accumulated in above-ground biomass (AGB) and 50% of the total biomass is taken as carbon stock (Aklilu et al., 2015). Above-ground carbon stock is the amount of carbon that is assumed to be 50% of the total vegetation biomass (ICRAF., 2006; Lal. 2005). The below- ground biomass of vegetation is considered as a fraction that takes about 25–30% of above-ground biomass depending on the nature of the plant, its root system, and ecological conditions (ICRAF., 2006; Lal., 2005). Total biomass carbon is the sum of above and below ground carbon in vegetation (Kumar BM., 2011).

Agroforestry systems improve the resilience of smallholder farmers through more efficient water utilization, improved microclimate, enhanced soil productivity and nutrient cycling, control of pests and diseases, improved farm productivity, and diversied and increased farm income while at the same time sequestering carbon (Lasco et al., 2014). Understanding above-ground tree biomass and soil organic carbon stocks provide opportunities for better management of the carbon pools. However, more rigorous research results were required for agroforestry systems to be used in global agendas of carbon sequestration (Nair et al., 2010).

Agroforestry systems and practices contribute to combat different economic and ecological problems. Studies on agroforestry systems have so far mainly focused on their spatial design, food production, soil fertility management, and system interactions, and little attention has been given to their ecosystem services, such as biodiversity conservation and carbon sequestration (Negash, 2013).

In Goro District, like many parts of Ethiopia, there is a remarkable experience of traditional agroforestry practices mainly with parkland agroforestry practice on cultivated land. The carbon storage of parklands is different in sites due to variation in agro-climatic factors, in tree species, density and structure of tree species, management applied to parkland trees, agricultural land management (fertilization, fallowing, cropping of legumes, etc.), topographic factors (aspect, slope, and altitude), soil types, land-use history, etc. The presence of these large sources of variations and confounding factors highlighted that site- specic data is required to estimate its carbon storage s. On top of that, the potential of the parkland agroforestry in for climate change mitigation is not investigated. Understanding the context specific carbon stock of the parkland agroforestry would help land managers for better management of the carbon pools that were biomass and SOC. As a result, thise is study intended to carry out thise is study on parkland agroforestry practices at Goro District.Thise is study would be contributed to knowledge to the conservation of these unique agroforestry systems and to the recognition of the ecosystems services they provide to the local communities (food production, and income, soil and water protection, maintenance of soil fertility) and beyond (carbon sequestration and climate change mitigation, and conservation of biodiversity) (Negash, 2013).

2.4. Above ground Biomass and allometric equations for tress

In agricultural landscapes raw data were screened for outliers in scatter plots that assisted also in visually assessing the relationships between dependent variables and independent variables. Aboveground biomass and the biomass of components (leaves, branches and stem) were regressed on DBH alone, and DBH in combination with height, wood density and/or crown area to obtain allometric coefficients for estimating biomass. A generalized linear model with gamma distribution and log link function is used to avoid the problem of back transformation (Ketterings et al., 2001). All regression analyses were done in Genstat 12th Edition (VSN International Ltd) while graphs were prepered in SigmaPlot version 11. Allometric power function equations,y = axb and their linear equivalents, ln(y) = a + b×ln(x) where y is the dependent variable, x is the independent variable, and athe intercept coefficient, b the scaling exponent, were used to predict biomass from independent variables. The following allometric relationships were tested.

$$\ln(y)=a+b\times\ln(DBH) \quad (1)$$

$$\ln(y)=a+b\times\ln(DBH)+c\times\ln(H) \quad (2)$$

$$\ln(y)=a+b\times\ln(DBH)+c\times\ln(p) \quad (3)$$

$$\ln(y)=a+b\times\ln(DBH)+c\times\ln(ca) \quad (4)$$

$$\ln(y)=a+b\times\ln(DBH)+c\times\ln(p) +d\times\ln(ca) \quad (5)$$

$$\ln(y)=a+b\times\ln(DBH)+c\times\ln(H)+d\times\ln(p) \quad (6)$$

$$\ln(y)=a+b\times\ln(DBH)+c\times\ln(H)+d\times\ln(ca) \quad (7)$$

$$\ln(y)=a+b\times\ln(DBH)+c\times\ln(H)+d\times\ln(p)+e\times\ln(ca) \quad (8)$$

where DBH is the diameter at breast height, H is the height, p is the wood density and ca the crown area.The equations were fitted by including ln(DBH), ln(H), ln(p)and ln(ca) as separate predictors, so that they each can be attributed their own scaling parameter. Thise is because the identical scaling rule inhibited a detailed assessment of the effect of additional explanatory variables for equations fitted with compound derivatives of DBH, height, wood density and crown area; for example $\ln(y) = a + b \times \ln(DBH^2 \times H)$ or $\ln(y) = a + b\times\ln(DBH^2 \times H\times p)$ _). Equations were developed using a sample size of 66 trees (training set) and additional 6 trees for validation. One tree is randomly selected from each of the six diameter classes for the validation set, while the remaining trees were used to develop the equation.The process is repeated 12 times with different selections such that each tree in the sample is used once also for validation. Thise approach is adopted because the holdout sample of six trees is considered too small for validation to adequately allow assessment of bias and prediction error per class.

2.5. REED+ concepts and farmscapes

What's REDD+

R- Reducing, E- Emission, D Reducing emisions from deforestation requires new programmes, policies, or actions to slow or stop deforestation in high-risk areas where forest clearing occurs or is likely, D Reducing emissions from forest degradation incorporates actions that minimize negative effects on forest carbon storage in trees or shrubs within a forest, such as through logging or harvesting standards. “+” Forest conservation implies permanently protecting forests in zones not immediately threatened by deforestation, but which may be at risk in the future for economic or social reasons, “+” Sustainable management of forests ensures that forests being used for economic gain were managed sustainably and can continue to be used, thus lowering the emissions associated with their use, “+” Enhancement of forest carbon stocks denotes adding forest carbon, such as through tree planting. REDD+ (Reducing Emissions from Deforestation and Forest Degradation) is an incentive mechanism where rewards were provided to parties which take progressive actions to reduce emissions from forest lands. REDD+ has the potential to deliver social and environmental benefits that go beyond the reduction of greenhouse gas emissions. It may also entail potential risks to people and the environment.

REDD+ (Reduced Emissions from Deforestation and Forest Degradation) is a process that plays a vital role in mitigating problems associated with climate change and improving the livelihoods of forest-dependent communities. Its likelihood of success would be greatest where the local resource tenure situation is clear and conflicts were minimal. The term grievance refers to “an issue, concern, problem, or claim (perceived or actual) that an individual, a community or any other party that has stakes to be addressed and resolved”. Grievances were valuable sources of information that allow decision makers improve the functioning of a policies or programs. A grievance mechanism for claims related to REDD+ activities would help in improving outcomes not only for forests and the climate related issues but also for the lives and livelihoods of communities that depend on forests

2.6. Carbon financing and Smallholder farmers

There is growing interest globally in the development of agricultural carbon projects that can sequester large amounts of carbon dioxide from the atmosphere to mitigate climate change, while contributing to sustainable agriculture and land management for smallholder farmers. However, these projects face numerous challenges, especially in their inherent complexity, high costs of project development, and challenges of risk management and securing benefits for smallholder farmers (Shames et al. 2011).

The project-level institutions of these agricultural carbon initiatives have received little attention, and yet were critical to the success and replication of these highly complicated projects. They involved numerous actors, including large numbers of farmers as well as professionals in law, technology, monitoring, and finance, whose services consumed a large share of the financial benefits of carbon that could other wise have gone to farmers. The costs of aggregating, consulting with, and disseminating benefits to large numbers of smallholders also reduced the cash benefits received by farmers. Significant financing is needed for up-front investment, yet carbon revenues were usually received only after carbon is demonstrated to have been sequestered. Poorer farmers and women were often excluded from decision- making and benefits in these projects. Globally, the number and scale of these projects have been small in both regulated and voluntary carbon markets. An inventory of African agricultural carbon projects identified 81 project initiation efforts in 24 countries. In roughly one-third of these projects' money had exchanged hands, and the rest were in development (Shames and Scherr 2010).

But even in cases where projects have been established, their size is miniscule compared to the potential for climate change mitigation and farmer participation. Despite limited experiences globally and within Africa, lessons on the development and management of projects for the benefit of the climate, project developers, and farmers have been drawn from the last decade of community forest carbon projects (Bracer et al. 2007) and the last few years of agricultural carbon projects (Shames and Scherr 2010).

However, much more needs to be learned about these projects for the sake of current project managers, future managers and developers, as well as policy makers working to create more supportive enabling environments for future projects. There is paper summarizes the findings of a research initiative led by international NGO Eco Agriculture Partners with the support of the Climate Change, Agriculture and Food Security (CCAFS) Research Program and in partnership with managers of six African projects. It is designed to generate insights useful to each of these audiences by conducting an in-depth analyis of the structure and institutional innovations of these projects. The objective of there is initiative is to better understand mechanisms that can improve projects' viability and impacts on the rural poor, and thereby generate lessons for project developers, managers and policymakers. We review project organization and management, the structure and role of community groups within the projects, costs and benefits for managers and farmers, strategies to manage risks to farmers, and efforts to support women's participation. The final section presents conclusions and plans for future action research. The following section introduces the intellectual foundation upon which this study is built and presents the research methodology.

2.7. Carbon storage estimation and carbon financing in Ethiopia.

Ethiopia has experienced strong economic growth in recent years, but the country has historically been plagued by weather extremes (particularly droughts), resulting in large income swings; such shocks were expected to become more pronounced and frequent in the future (Robinson et al., 2013). Climate change model predictions for Ethiopia indicate not only a substantial rise in mean temperatures and an increase in rainfall variability but also a higher frequency of extreme events such as flooding and droughts.

The country is already experiencing more frequent droughts than in the past, causing water scarcity and degradation of range resources, which have a negative impact on food production. According to the National Meteorological Services Agency (2007), agriculture, water and range resources, biodiversity and human health were directly vulnerable to climate variability and change, with potentially huge social and economic impacts. There is also growing evidence of a link between climate related disasters, conflict and security, with pressure on resources often leading to increased mobility and the probability of conflict (Chibber and Laajaj, 2008).

At least five major droughts have occurred since the early 1970s, along with many more localized droughts. Studies indicate that the frequency and magnitude of such droughts has increased, especially in the lowlands (Amsalu and Alabāčaw; Lautze et al. 2003). A recurrent cycle of droughts creates poverty traps for many households, constantly thwarting efforts to build up assets and increase income that would enable households to absorb future economic shocks. The limited economic, institutional and logistical capacity to adapt to climate change exacerbates the vulnerability of many people and communities. Ethiopia would also likely face increased climate change linked disease burdens such as the spread of malaria, rift valley fever, meningitis andmalnutrition. Such an alarming trend requires the development of appropriate strategies to reduce vulnerabilities and disaster risks though the provision of timely early warnings about and responses to such disasters. Despite these challenges, Ethiopia has begun to take serious steps in terms of a national policy response and the design of strategies to deal with current as well as future impacts of climate change. The formulation of the Climate Resilient Green Economy (CRGE) Strategy in 2011 is considered a major step forward in terms of the country's commitment towards building a green economy that is also resilient to climate change. This low-carbon development strategy would require additional financial support from development partners and international organizations. (Robinson et al. 2013) estimate that adaptation costs may be as high as USD 0.8–2.8 billion annually

3. METHODOLOGY

3.1. Description of the Study area

3.1.1. Geographical Location

The study area was conducted in Goro district, Bale zone, Oromia regional state, South east Ethiopia. Goro district is bordered by the following district in North direction sinana district, south Dawe Qachen, in east direction Berbera and Guradhamole and in Western direction Gindhir district. Goro district is located at the Eastern part of the administrative town Robe at a distance of 60 km and it is far from Addis Abeba to the south Eastern direction at 490km. It is geographically located between 65°00′00″ - 64°20′00″ N latitude and 76°80′00″ - 76°20′00″ E longitude (Figure 1).

The average Altitude of the study site is between 1871-2035m above sea level. According to the meteorological records the mean annual temperature of the study area is 20c^{o} and mean annual rain fall distribution of 827.59mm.

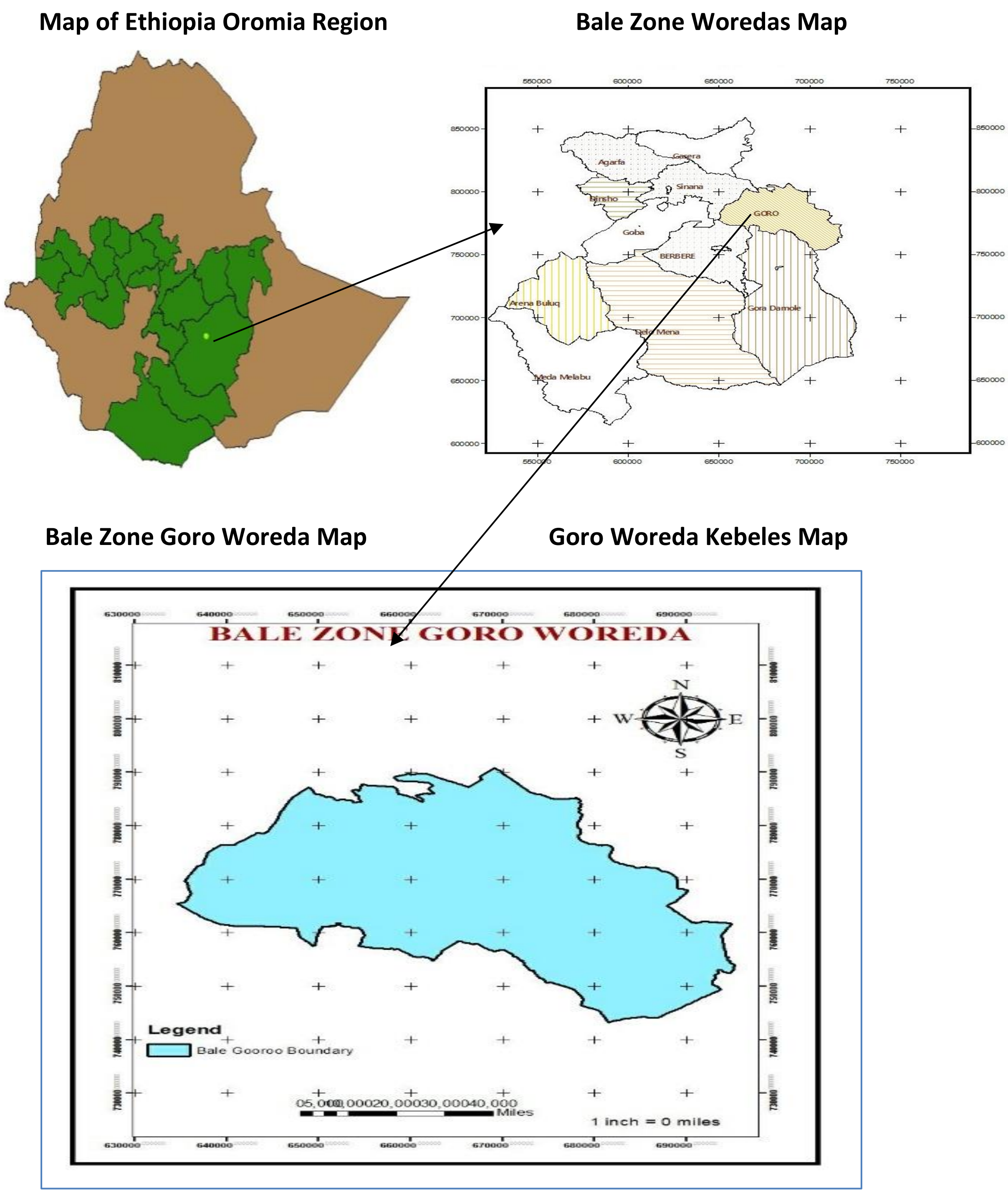

Figure 1. Map of the study Area

3.1.2 Climate

The temperature and rainfall data for this study were collected from Nation Meteorological Agency, Bale Robe branch, which is 60km from theGoro district. The data were collected from 2010-2019 by National MeteorologicalAgency (NMA,2020). According to the NationalMeteorological records the mean annual temperature is 20.11c^{o} and mean maximum T^{0} of 27.37c^{0} where as the mean minimum T^{0}of 12.41c^{0}.The mean annual rain fall is 827.59mm.In the area there is bimodal rainfall distribution.The first rainy season with long duration refers as kiremt which starts at the beginning of march and extend around the last month of May.The second season is short spring (Belge season) which start at the beginning of September and end around the last month of November.The most productive season of the district was kiremt.This is due to better access of the rainfall distribution in the district.Refer it on (Figure 2).

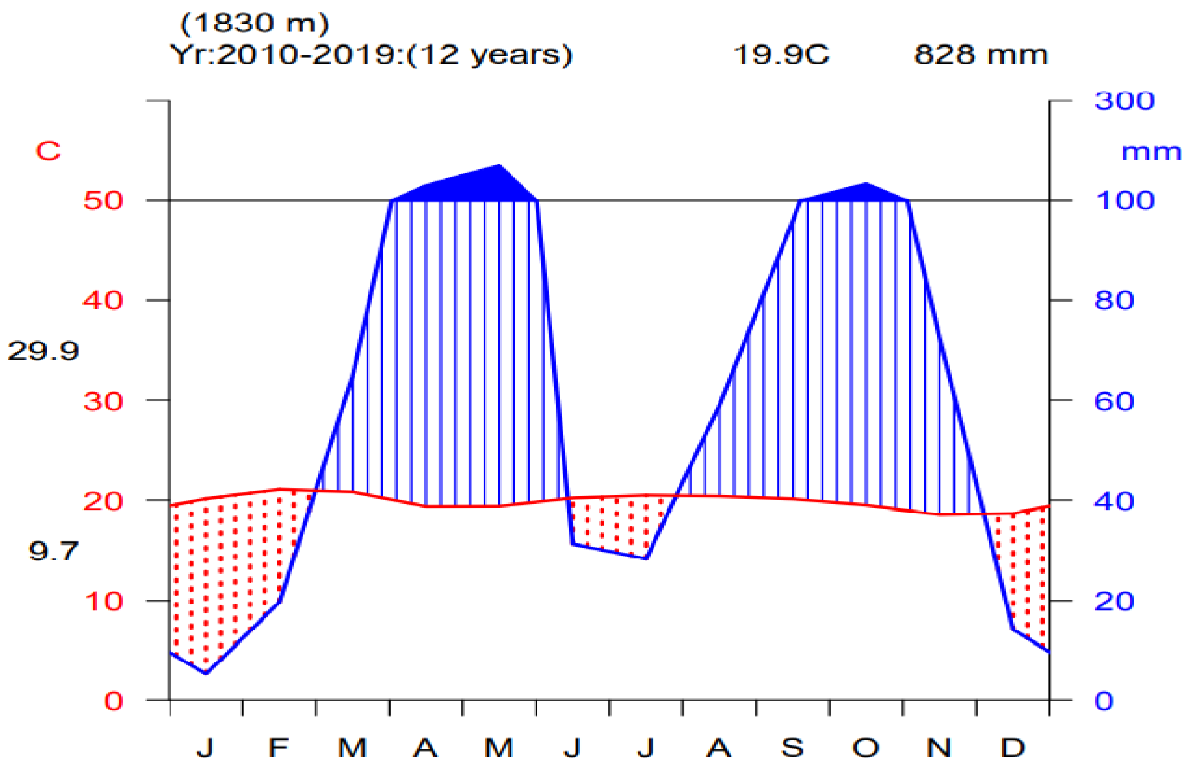

Figure 2. Climatic diagram of Goro twon (Nationalmeteorological agency Robe branch, 2020)

3.1.2 Vegetation

The vegetation of Goro district was entirely encompassed within moist montane rain forests with respect to its altitudinal range. The most common species of the study area *Embelia schimperi, Carissa spinarum, Croton macrostachyus, Vepirs dainellii, Acacia Albida Del., Teclea nobilis, Celtis Africana, Ficus sur, Clausena anisata, Albizia schimperiana. Where as, Allophylus abyssinicus, Rhamnus prinoides, Rhus glutinosa and Pouteria adolfi-friederici* (Firis and Demessew, 2010).

3.2. Methods

3.2.1. Sampling and Data Collection

Data collection of the study area was conducted between January 15, 2021 ─ Apr 20, 2021. Seventy-one plots, each 100 m x 50 m, (5000 m^2) were used for trees and shrubs DBH and height measurement. Nine transect lines 5000 m far apart from each other were used systematically following uphill to ensure a uniform assessment throughout all the plots and each plot were laid on the transect line belt 100 m far apart. Depending on the length of transect line belts, 495m (the shortest) to 1860m (the longest), the number of plots laid on each transect belt vary from 3 (the least) to 14 (the highest). altitude, slope and aspect of each plot were recorded using hand held GPS. All the woody plant species encountered in the plots counted and recorded. Trees and shrubs of DBH ≥ 5cm were measured using clinometers and height.

Trees and shrubs with multiple stems at 1.3 m height were treated as a single individual and DBH of the largest stem was taken. All encountered tree species were identify using vernacular names and Flora of Ethiopia and Eritrea and those difficult to identify their voucher specimens were brought.

3.2.2. Data analyses

3.2.2.1. Above Ground Carbon Stock Estimation (AGC) and carbon pool

Biomass carbon stocks for each plot (Tone C ha^{-1}) was be calculated as the product of dry matter biomass and carbon content. Trees and shrub biomass was calculated using the plot inventory data and allometric biomass functions. The allometric equation developed by (Kuyah et al., 2012) was be used to estimate the aboveground biomass (stem plus bark, branches, and foliage) of the trees and/or shrubs. This equation was selected as it was appropriate to estimate a wide range of parameters ranging from DBH or height to aboveground biomass (Kuyah et al., 2012) with the lowest prediction error value. Moreover, this equation was developed for trees grown in agroforestry and DBH greater than 2.5 cm.

$AGB=0.0905*DBH^{2.4718}$

Where, AGB is the aboveground biomass (dry mass per tree in kg) and DBH is diameter at a breast height (cm). The carbon pool of the study area was calculated by multiplying the number of individuals of each species in each plot by Average AGC storage of each species in the study area.

3.2.2.2 The importance value index (IVI)

That indicates the importance of species in an ecosystem and calculated as follows (Kent and Coker, 1992):

$$\text{Relative density} = \frac{\text{Number of individuals of species}}{\text{Total number of individuals}} * 100$$

$$\text{Relative dominance} = \frac{\text{Dominance of species}}{\text{Total dominance of all species}} * 100$$

$$\text{Relative Frequency} = \frac{\text{Frequency of species}}{\text{Frequency of all species}} * 100$$

Dominance is defined as the mean basal area per tree times the number of species and the importance value index for each woody species was the sum of its relative abundance, relative dominance and relative frequency.

3.2.2.3 Species diversity

Diversity: 'H' = - $\sum_{i=1}^{s} Pi ln Pi$

Where 'H' = the Shannon and Wiener diversity index, 'Pi' = the proportions of individuals abundance of the i^{th} species, and 'ln' = the natural logarism to base e (log) e Equitability(evenness): J = H/Hmax

Where "J" is the species evenness "H" Shannon and Wiener diversity index and "Hmax" is lnS, where S is the number of species.

3.2.2.4 Population structure

The DBH of each of the individuals of woody species were classified in to 7 classes (5-10 cm, 10-15 cm, 16-20cm, 21-25 cm, 26-30 cm, 31-35 cm, 36-40 cm) and height in to 6 classes (≤5 m, 6-10 m, 11-15 m, 16-20 m, 20-25 m, and 26-30 m,) (Lemenih et al., 2007). The results of the analyses were presented in bar graphs.

3.2.2.5 Inferntial statistics

Variation in species diversity indices in relation to altitude, slope and aspect: above Ground Carbon storage of woody species in relation to characteristic dimension of woody species, altitude, slope and aspect were tested using MANOVA. Moreover, the impact of altitude, slope, and aspect on species diversity indices, AGC storage Above gropund carbon pool were analyased using multiple linear regression model at $p<0.05$. All statistical computations were made using free R statistical Software.

4. RESULTS

4.1. Woody species

4.1.2. Species Composition

A total of 54 woody plant species categorized in 36 families were recorded in an agricultural landscape of Goro district. A total dencity of 44516 numbers of trees and shrubs and 1129 woody stems/ ha were recorded. The most frequent species was *Croton macrostachyus,* where as the least frequent species was *Embelia schimperi*, the most abundant specie was *Croton macrostachyus*. The common families were Fabaceae and Asteraceae (Table 3: Appendix 1).

4.2 Diversity of the woody species

The average number of species per plot in Goro district agricultural landscspe was 6 and the low average of species diversity index (i.e. 1.50). Plot number 35 was found to be with the highest species diversity followed by plot number 50. The plot 59 was with high number of individuals followed by plot number one. The woody species showed high even distribution (75%) in the study sites and the dominance by a few species was low (27 %) (Table 1).

Table 1. Diversity indices, species numbers and individuals' dominance and eveness. The abudance data were used in the analysis.

Plots	Taxa_S	Individuals	Dominance_D	Shannon_H	Evenness_e^H/S
1	5	94	0.46	1.11	0.61
2	5	84	0.30	1.35	0.77
3	7	76	0.42	1.22	0.48
4	7	70	0.24	1.62	0.72
5	6	87	0.28	1.48	0.73
6	5	60	0.26	1.45	0.86
7	5	84	0.47	1.04	0.57
8	6	71	0.29	1.43	0.69
9	7	74	0.29	1.48	0.63
10	6	55	0.27	1.50	0.74

11	7	80	0.26	1.52	0.65
12	7	75	0.25	1.61	0.71
13	6	48	0.26	1.53	0.77
14	4	42	0.30	1.29	0.91
15	6	73	0.31	1.41	0.68
16	7	91	0.20	1.73	0.81
17	6	53	0.24	1.59	0.81
18	6	45	0.26	1.52	0.76
19	5	86	0.35	1.23	0.69
20	6	59	0.24	1.58	0.81
21	8	76	0.17	1.88	0.82
22	7	68	0.22	1.67	0.76
23	7	68	0.24	1.64	0.73
24	6	64	0.23	1.57	0.80
25	7	68	0.23	1.63	0.73
26	6	81	0.24	1.51	0.75
27	7	66	0.18	1.80	0.86
28	6	57	0.20	1.71	0.92
29	7	70	0.21	1.71	0.79
30	6	67	0.30	1.42	0.69
31	5	25	0.22	1.57	0.96
32	6	72	0.23	1.56	0.80
33	4	44	0.42	1.08	0.73
34	6	47	0.29	1.45	0.71
35	10	92	0.14	2.12	0.83
36	7	72	0.23	1.63	0.73
37	6	55	0.25	1.53	0.77
38	7	49	0.23	1.67	0.76
39	7	69	0.24	1.66	0.75
40	6	32	0.22	1.65	0.86
41	6	70	0.26	1.48	0.73
42	6	63	0.36	1.30	0.61
43	6	50	0.26	1.54	0.78
44	5	76	0.39	1.22	0.68

45	7	73	0.20	1.74	0.82
46	5	74	0.40	1.23	0.69
47	6	53	0.25	1.50	0.75
48	6	48	0.22	1.61	0.84
49	5	32	0.27	1.44	0.84
50	8	64	0.17	1.91	0.85
51	7	53	0.18	1.80	0.86
52	7	65	0.18	1.80	0.87
53	7	59	0.25	1.63	0.73
54	6	51	0.27	1.52	0.76
55	7	55	0.25	1.59	0.70
56	5	42	0.22	1.56	0.95
57	7	68	0.20	1.75	0.83
58	6	92	0.51	1.05	0.47
59	6	108	0.46	1.13	0.52
60	3	65	0.51	0.82	0.76
61	5	31	0.33	1.33	0.75
62	7	52	0.27	1.56	0.68
63	6	64	0.26	1.54	0.78
64	4	38	0.30	1.28	0.90
65	6	93	0.28	1.43	0.70
66	6	45	0.26	1.51	0.75
67	6	75	0.42	1.19	0.55
68	6	48	0.21	1.67	0.89
69	6	49	0.22	1.59	0.82
70	6	47	0.25	1.56	0.79
71	6	64	0.29	1.43	0.70

4.2.1 Ecological importance

The most ecologically important woody species in the study area was *Croton macrostachyus*, *Albizia schimperiana and Erythrina brucei* where as the least important species were *Rhamnus prinoide and Bersama abyssinica. (*Table 3).

Table 2. List of woody plant species, and their relative frequency (RF, relative density (Rdens), and relative dominance (Rdo.), their Importance value index (IVI) and their respective ranks (Rank) on vegetation

Item	F	Dom.	Den	RF (%)	Rdo (%)	Rdens.	IVI(%)	Rank
Eucalyptus globulus	15	0	30	3.4	2.9	2.7	9	10
Teclea nobilis	17	0	45.5	3.9	1.4	4	9.3	9
Flacourtia indica	9	0.1	3.8	2.1	7.2	0.3	9.6	8
Carissa spinarum	10	0	82.8	2.3	0.2	7.3	9.8	7
Apodytes dimidiata	15	0.1	36.8	3.4	3.8	3.3	10.5	6
Embelia schimperi	11	0	94.5	2.5	0.2	8.4	11.1	5
Vepirs dainellii	17	0	64.3	3.9	1.8	5.7	11.4	4
Erythrina brucei	20	0.1	21.3	4.6	5.6	1.9	12.1	3
Albizia schimperiana	19	0.1	16	4.4	7.7	1.4	13.5	2
Croton macrostachyus	38	0.1	93.8	8.7	3.5	8.3	20.5	1

4.2.2. Population structure

The population of the woody species in agricultural landscape showed an inverted J shape in diameter at breast height i.e majority of the individual trees and shrubs were found in the lower size where asthe speciesshowed irregular type of arrangement (Fig.2).

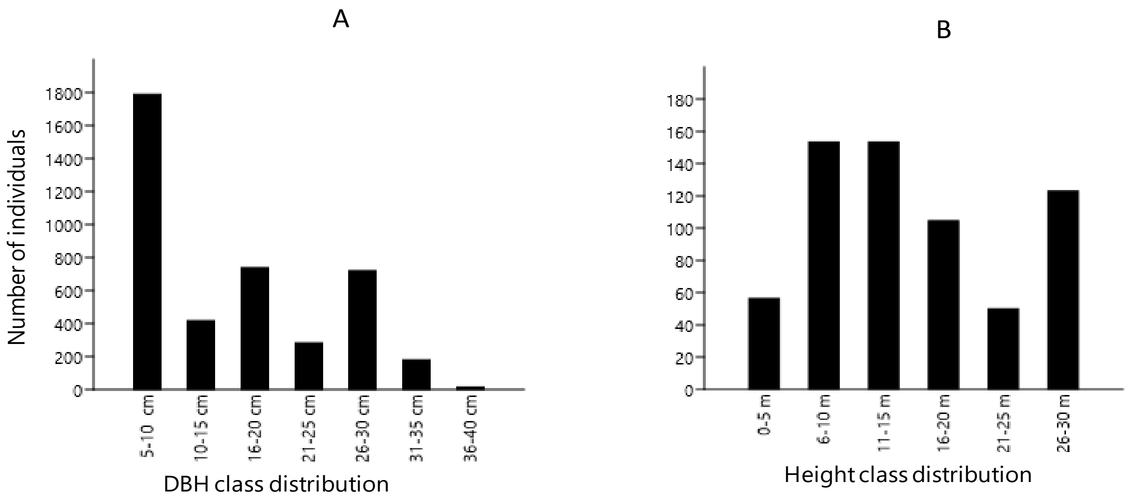

Figure 3. Bar graph showing population structure of the woody species based on (A) DBH class, and height class (B) in Goro district ageiculturallandscape, Bale Zone.

4.2.3. Size structure of six selected woody species

The selected woody species showed different structures. For instance, *A. abyssinica* and *C. africana* showed good regeneration status having high number of individuals in lower class whereas plant species such as *E. brucei*, *P.falcatus* and *J.procera* showed poor regeneration status. The tree species *A. abyssinica* had low DBH class in the medium class size, high in lower and high class size (Fig.4) .

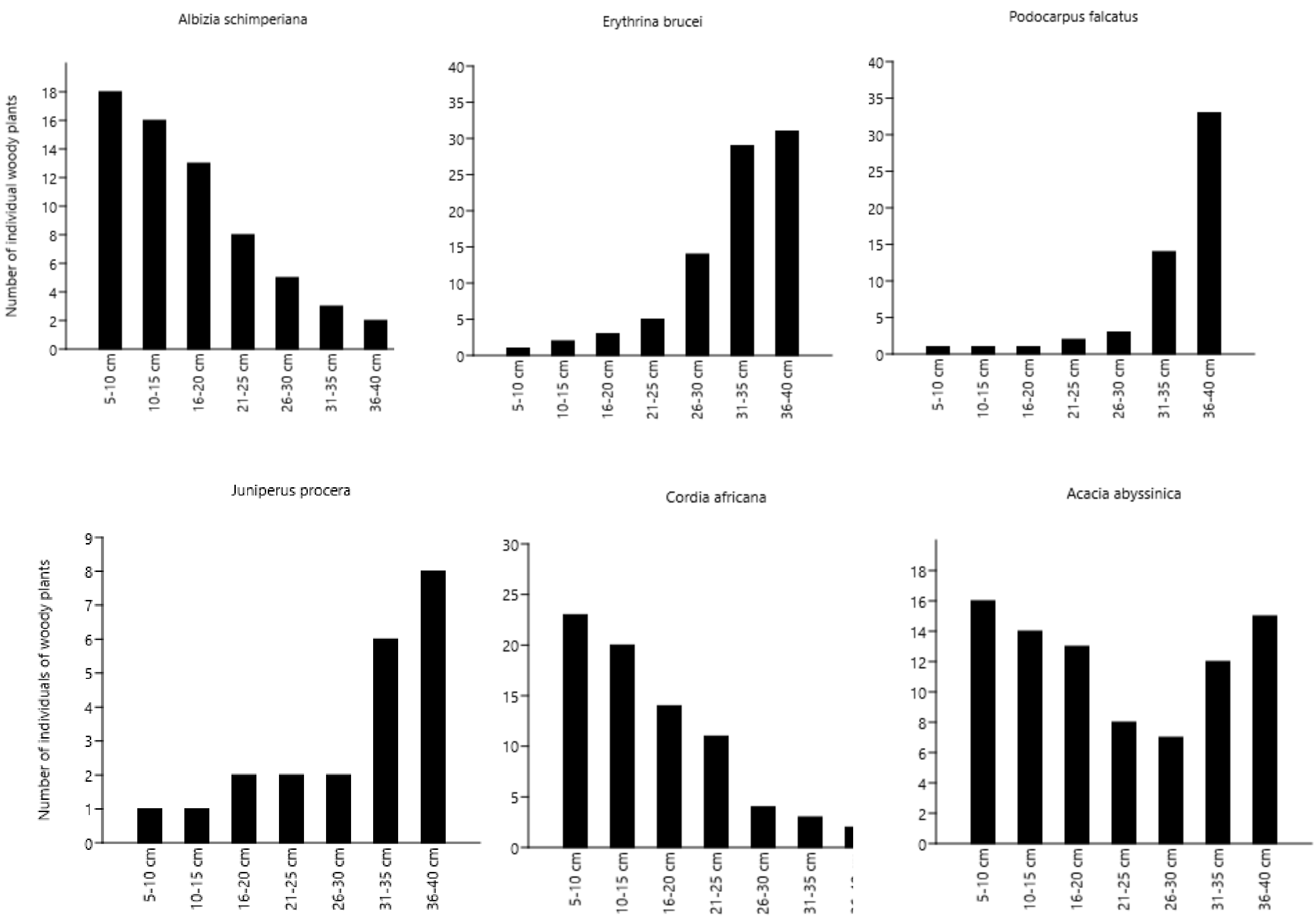

Figure 4. Bar graph showing the size structure of woody plant species in the study area

4.3. Above ground carbon estimate

4.3.1 Above ground Carbon storage of woody species

The woody species in the study area showed above ground carbon storage of an average 19 Tone of carbon/ ha, a minimum of 5.5 ToneC/ha. a maximum of 43.85 Tone C/ha and a total of 1007 Tone of carbon/ ha. The woody species that had the highest AGC was *Albizia schimperiana, Flacourtia indica, Erythrina brucei, Schefflera volkensii, Podocarpus falcatus,* and *Juniperus procera* where as *Justicia schimperina, Bersama abyssinica, Carissa spinarum* had the lowest AGC (Table 4).

Table 3. List of woody species and calculayed Above Ground Carbon AGC) storage per hectare (ha) in Goro district agricultural landscape, Bale Zone

Species	AGC (Tone C/ha)
Acacia abyssinica	29
Acacia Albida Del.	7
Acacia etbaica	13
Albizia schimperiana	44
Allophylus abyssincus	17
Apodytes dimidiata	31
Argomuellera macrophylla	6
Aspilia mossambicensis	7
Bersama abyssinica	6
Brucea antidysenterica	6
Buddleja polystachya	18
Carissa spinarum	7
Cassipouea malosana	30
Caulpurnia aurea	6
Celtis africana	23
Clausena anisata	10
Cordia africana	31
Croton macrostachyus	30
Dombeya schimperiana	19
Dombeya torrida	21
Dracaena steudneri	21
Ekebergia capensis	25
Embelia schimperi	7
Erythrina brucei	38
Eucalyptus globulus	27
Flacourtia indica	42
Gnidia glauca	6

Grevillea robusta	17
Celtis Africana	7
Hypericum quartinianum	9
Juniperus procera	33
Justicia schimperina	6
Lepido trichilia	8
Macaranga capensis	20
Maesa lanceolata	14
Maytenus addat	14
Maytenus gracilipes	8
Millettia ferruginea	26
Nuxia congesta	33
Oncoba spinosa	8
Pittosporum viridiflorum	16
Podocarpus falcatus	35
Pouteria adolfifriderici	30
Rhamnus prinoide	7
Rhus glutinosa	18
Rytigynia neglecta	9
Schefflera volkensii	37
Solanecio gigas	21
Syzygium guineense	28
Teclea nobilis	19
Vepirs dainellii	21
Vernonia adoensis	10
Vernonia amygdalina	17
Vernonia rueppellii.	13
Average	19
Minimum	6
Maximum	44
Total	1007

4.3.2 The Above ground carbon pool

The estimated amount of the AGC pool per plots of the study area was an average of 1209 Tone carbon/ha, minimum of 475 Tone carbon//ha, maximum of 2052 Tone carbon/ha and a total of 85, 804 Tone carbon /ha. (Appendix 3).

4.3.3 above ground carbon storage

4.3.3.1 Characteristics dimension of woody species

The above ground carbon storage of the woody species showed significant variations with DBH, density per hectare, Species richness and diversity (*F=, 237.4 P< 0.001*). Hence, the above ground carbon potential of the woody species significantly increased with DBH (Z=1.07, p=0’001), height (Z=1.71, p=<0.002), IVI (1.69, p<0.001) and Basal area (317.13, p<0.001) (Fig.5). However, the AGC potential of the woody species in the study area were not impacted by slope (Z=0.19, p-0.67).

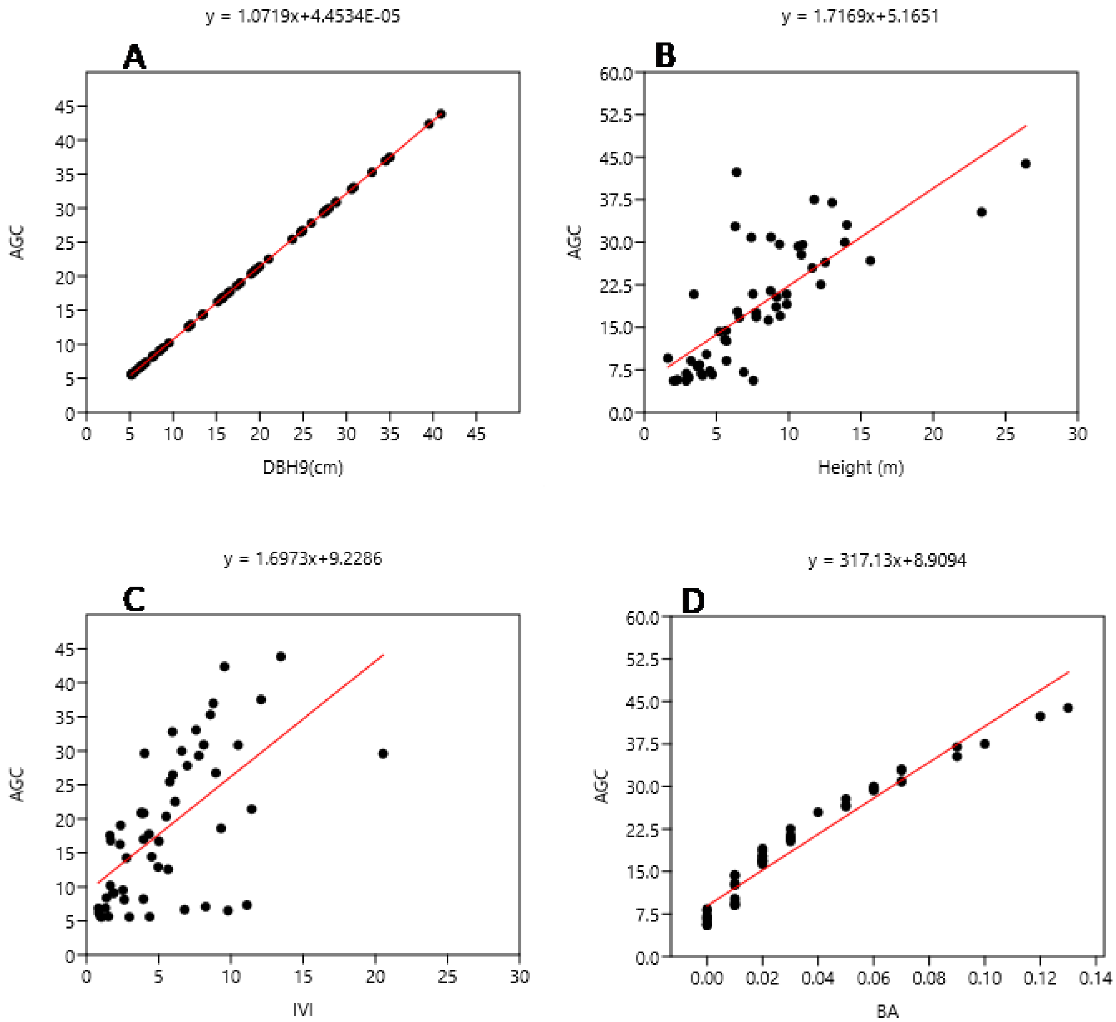

Figure 5. Results of multiple linear regression model showing the impact of characteristic dimension of species (A) (Diamter at breast height (DBH in cm), (B) Height in meter, (C) IVI, and Basal area (BA) on (Above ground carbon), (B) species diversity.

5. DISCUSSIONS

5.1 species composition and diversity

The results of the study revealed that *Croton macrostachyus* followed by *Erythrina brucei* had the highest percentage frequency *Rhamnus prinoide* had the lowest percentage frequencies in the studyarea. According to Lambrecht (1989), frequency was the indication of homogeneity and heterogeneity of vegetation. High value in higher frequency and low value in lower frequency classes reveal constant or similar composition. On the other hand, high percentage of number of species in the lower frequency classes and low percentage of number of species in the higher frequency classes indicates a high degree of floristic heterogeneity. The species that appear in lower frequency classes have irregular occurrence whereas those appearing in higher classes have regular horizontal classes (Lambrecht, 1989). The present study revealed that there was high percentage number of species in higher frequency classes and low percentage number of species in lower frequency classes. This indicated that the woody plant species in the farmscape is has high degree of floristic homogeneity and low heterogeneity.

The mean number of species in each plot was (~6) in each plot that also related to low species diversity or high homogeneity in the study species that could be due to anthropogenic activities in the farmscape such as farmers' preferences for tree species and functions in different localities. For example, farmers maintained many tree and shrub species for environmental services lik soil and wate conservation in the drier regions of Africa. The study showed lower mean number of species when you compare to other studies in an agricultural landscape. For instance, 9 woody plant species were reported in Angetu district of Bale zone (Jara et al., 2017). A total of 55 woody species in agroecosystem of Dallo Manna district (Molla and Kawessa, 2015).

5.2 Population structure

The result of the study showed that the woody species showed high number of individuals in lower DBH class (inverted J shape) that shows high regeneration status. However, this may not be in the agricultural landscape since farmers could preferably use the tree bor shrub species for multiple purposes. For instant the higher DBH classes are preferable for timber purposes. In the study sites tree species important as a source of timber such Podocarpus falcatus, Juniperus procera and others.

5.3 Carbon storage in different Pools

Woody vegetation has a large potential for temporary and lon term carbon storage. In the forest ecosystems, greater carbon was stored in a large, long-lived species and in species with dense wood. Similarly, the results of the present study showed the disproportionate contribution of species to the above ground carbon stock. Tree species with high DBH such as *Albizia schimperiana, Flacourtia indica, Erythrina brucei, Schefflera volkensii, Podocarpus falcatus, Juniperus procera, Nuxia congesta Cordia Africana, Apodytes dimidiate, Cassipouea malosana, Pouteria adolfifriderici, Croton macrostachyus,Acacia abyssinica, Syzygium guineense Eucalyptus globules Millettia ferruginea* and *Ekebergia capensis*contributed for the large amounts of biomass and carbon stocks on the other hand tree/shrub species with low DBH such as *Bersama abyssinica Brucea antidysenterica Argomuellera macrophylla Caulpurnia aurea Justicia schimperina* and *Gnidia glauca* had less contributions. There was unequal contribution of species to carbon stock of the ite could probably be due to the density, age and size difference among species. The empirical data on the potential of tree species to store carbon, increasing the adoption of agroforestry and other carbon-enriching farm practices that meet beneficiaries' priority needs and address climate change issues; and it helps in developing design criteria for appropriate configuration, species selection, and planting density for various agroforestry practices to optimize C sequestration (FAO,2013).

Hence understanding the tree species number, size and their carbon storage in farmscape is very crucial in feeding the alarmingly increasing population while mitigating climate change. The woody species showed an average of AGC of 19 Tone C/ ha which is in the range of global AGC per ha in agroforestry systems i.e. Aboveground biomass C stocks ranged between 0.25 and 56.56 Tone ha-1 (on average 7.9 Tone C ha-1 (Nair 2010). Some studies performed in the above ground carbon storage of trees in agroforestry system in Ethiopia found the values in the global standard. For example, the mean AGC of woody species in Dallo Mana districts recorded 47.82 Tone/ha (Molla and Kawessa, 2019). Other study in Tigray reported the maximum of 11.49 Tone C/ha in agroforestry systems (Gebrewahid and Meressa 2020) which is much smaller than this study, this might be due to difference in agroecologies and the intensity of deforestation of the Ethiopian highlands that could be resulted in less in size and density of trees which in turn impacted the AGC of each species.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

- The woody plant species in agricultural landscape of the Goro district, would be not only for crop production and soil and water conservation but also could contribute to adapt the changing climate by providing provasioning, supporting and regulating services. The result of the study showed that the farmscape contains many diversified plant species. A total of fiftyfour different woody plant species were recorded, of which *Croton macrostachyus followed by Erythrina brucei* where as the least frequent was the most abundant specie was *Embelia schimperi* followed by *Croton macrostachyus.* The common families were Fabaceae and Asteraceae.
- The study area showed the least Shannon index (i.e., 1.5) in which the range of the index real ecological data lays between 1.5-3.5. The area also showed relatively lower, number of woody species (i.e., 6) per plot when compared to other agricultural landscapes in Ethiopia (i.e., 9).
- the population structural composition of DBH and height class distribution of the study area, revealed similar trends in both classes. The densities of tree and shrub species decreases as the DBH and height classes increases. This implies that, the predominance of small sized tree/shrub species in the lower classes than in the upper classes. The analys was of these two parameters in the study forest indicated that higher percentage number of tree species in the lower than in the higher frequency classes.
- Average carbon stocks of the different carbon pools of the study was comparatively lower with most researches done in Ethiopia in carbon sequestration potentials of woody species in the farmscape. Likewise, the study indicates its potentials in the mitigation of climate change.

6.2. Recommendations

Based on the results of the study we would like to forward the following points:

- Woody species in agricultural landscape provide ecosystem services, including food, fodder and fuel wood, contribute greatly to rural communities' daily needs. Income from these products helps to improve livelihoods and build resilient Socio-ecological system in the face of ongoing climate change and variability thus, besides efforts to protect biodiversity and reserves and parks, management of trees in agricultural landscape should be paid attention.
- Woody species in agricultural landscape are under constant pressure from human induced factors such as deforestation due climate change. Land degradation leads to reduction in vegetation cover that will be resulted in soil erosion, depleting soil nutrients. Thus, the low standing biomass of degraded land farming systems and the livelihood of the people making their living from these systems.
- Further studies related to woody species based on farmers preferences is very crucial to plan and manage the whole landscape in Bale zone in general and Goro district in particular.
- Policy development on the woody species management, that would increase the carbon storage potential in living biomass of woody species and helps to facilitate "Green legacy" aimed to plant billions of trees that was launched by Ethiopian government in 2018 to fulfil the goal of the Climate Resilient Green Economy.

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8. Appendix

8. 1 Appendix.1: List of plant species, their families, Afan `oromo names, habit

species	Family	Afan Oromo	Habit
Albizia schimperiana	*Fabacaea*	*Muka Arbaa*	*T*
Flacourtia indica	*Flacourtiaceae*	*Akuukkuu*	*T*
Erythrina brucei	*Fabaceae*	*waleensuu*	*T*
Schefflera volkensii	*Araliaceae*	*gatamaa*	*T*
Podocarpus falcatus	*Podocarpaceae*	*birbirsa*	*T*
Juniperus procera	*Cuppressacea*	*Hindhessa*	*T*
Nuxia congesta	*Loganiaceae*	*naffuroo*	*S*
Cordia africana	*Boraginaceae*	*waddeessa*	*T*
Apodytes dimidiata	*Icacinaceae*	*calalaqaa*	*T*
Cassipouea malosana	*Rhizophoraceae*	*warallo*	*T*
Pouteria adolfifriderici	*Sapotaceae*	*qararoo*	*T*
Croton macrostachyus	*Euphorbiaceae*	*bakkaniisa*	*T*
Acacia abyssinica	*Fabaceae*	*laaftoo*	*T*
Syzygium guineense	*Myrtaceae*	*badeessaa*	*S*
Eucalyptus globulus	*Myrtaceae*	*bargamoo*	*T*
Millettia ferruginea	*Fabaceae*	*sootalloo*	*T*
Ekebergia capensis	*Meliaceae*	*somboo*	*T*
Celtis africana	*Ulmaceae*	*qayyii*	*S*
Vepirs dainellii	*Rutaceae*	*Hadheessa baala bal'aa*	*S*
Dracaena steudneri	*Dracaenaceae*	*Warqee jaldeessa*	*S*
Dombeya torrida	*Sterculaceae*	*Dannisa adii*	*T*
Solanecio gigas	*Asteraceae*	*dilu arbaa*	*S*
Macaranga capensis	*Euporbiaceae*	*Ho'aa*	*T*
Dombeya schimperiana	*Sterculaceae*	*Dannisa diimaa*	*T*
Teclea nobilis	*Rutaceae*	*Hadheessa baala qal'aa*	*S*
Buddleja polystachya	*Budlejaceae*	*qawwisa*	*T*
Rhus glutinosa	*Anacardiaceae*	*daboobesa*	*T*

Grevillea robusta	*Proteaceae*		*T*
Allophylus abyssinca	*Sapindaceae*	*sarara*	*T*
Vernonia amygdalina	*Asteraceae*	*ebicha*	*T*
Pittosporum viridiflorum	*Pittosporaceae*	*soolee*	*S*
Maesa lanceolata	*Myrsinaceae*	*abbayyii*	*T*
Maytenus addat	*Celastraceae*	*konbolcha*	*T*
Acacia etbaica	*Fabaceae*	*doddota*	*T*
Vernonia rueppellii.	*Asteraceae*	*reejjii*	*S*
Vernonia adoensis	*Asteraceae*	*Ulee harree*	*H*
Clausena anisata	*Rutaceae*	*hulumaayii*	*S*
Hypericum quartinianum	*Guttiferaceae*	*Ulee foonii*	*S*
Rytigynia neglecta	*Rubiaceae*	*Mixoo seeraa*	*S*
Oncoba spinosa	*Flacoutiaceae*	*hammarreessa*	*S*
Maytenus gracilipes	*Celastraceae*	*qacamaa*	*S*
Lepido trichilia	*Meliaceae*	*Dhama'ee*	*S*
Embelia schimperi	*Myrsinaceae*	*hanquu*	*S*
Acacia Albida Del.	*Urticaceae*	*Garbii*	*T*
Aspilia mossambicensis	*Asteraceae*	*daalattii*	*T*
Rhamnus prinoide	*Rhamnaceae*	*Geeshoo*	*S*
Celtis Africana	*Ulmaceae*	*Amalaqqa*	*T*
Carissa spinarum	*Apocynaceae*	*agamsaa*	*S*
Bersama abyssinica	*Melianthaceae*	*lolchiisaa*	*S*
Brucea antidysenterica	*Simarobaceae*	*qomaanyoo*	*S*
Argomuellera macrophylla	*Euporbiaceae*	*Timboo jaldeessa*	*S*
Caulpurnia aurea	*Fabaceae*	*ceekataa*	*S*
Justicia schimperina	*Acanthaceae*	*dhummugaa*	*T*
Gnidia glauca	*Thymelaceae*	*diddiksaa*	*T*

8.2 APPENDIX 2: aboveground carbon storage , and characterstic dimension of woody species in the study area

species	DBH (cm)	Height (m)		Individuals	AGC
Albizia schimperiana	40.91	26.41	Fabaceae	64	44
Flacourtia indica	39.54	6.39	Moraceae	15	42
Erythrina brucei	35	11.77	Myrsinaceae	85	38
Schefflera volkensii	34.5	13	Araliaceae	36	37
Podocarpus falcatus	32.94	23.35	Podocarpaceae	59	35
Juniperus procera	30.84	14.02	Guttiferaceae	21	33
Nuxia congesta	30.59	6.29	Loganiaceae	23	33
Cordia africana	28.82	8.76	Rutaceae	70	31
Apodytes dimidiata	28.78	7.4	Sapindaceae	147	31
Cassipouea malosana	27.97	13.88	Apocynaceae	32	30
Pouteria adolfifriderici	27.65	9.35	Sapotaceae	13	30
Croton macrostachyus	27.61	10.95	Boraginaceae	375	30
Acacia abyssinica	27.33	10.65	Fabaceae	82	29
Syzygium guineense	25.95	10.86	Myrtaceae	61	28
Eucalyptus globulus	24.94	15.65	Fabaceae	120	27
Millettia ferruginea	24.68	12.53	Fabaceae	50	26
Ekebergia capensis	23.74	11.63	Dracaenaceae	61	25
Celtis africana	21.02	12.22	Fabaceae	51	23
Vepirs dainellii	19.99	8.73	Rutaceae	257	21
Dracaena steudneri	19.49	7.52	Sterculaceae	40	21
Dombeya torrida	19.43	9.84	Sterculaceae	59	21
Solanecio gigas	19.43	3.42	Asteraceae	65	21
Macaranga capensis	18.98	9.17	Euporbiaceae	40	20
Dombeya schimperiana	17.77	9.86	Euporbiaceae	21	19
Teclea nobilis	17.35	9.12	Rutaceae	182	19
Buddleja polystachya	16.57	6.44	Simarobaceae	66	18
Rhus glutinosa	16.39	7.73	Anacardaceae	7	18

Grevillea robusta	15.87	9.4	Thymelaceae	95	17
Allophylus abyssinca	15.69	7.75	Fabaceae	4	17
Vernonia amygdalina	15.59	6.58	Asteraceae	93	17
Pittosporum viridiflorum	15.16	8.59	Pittosporaceae	16	16
Maesa lanceolata	13.44	5.66	Myrsinaceae	73	14
Maytenus addat	13.29	5.2	Celastraceae	79	14
Acacia etbaica	12.04	5.57	Fabaceae	111	13
Vernonia rueppellii.	11.73	5.69	Asteraceae	154	13
Vernonia adoensis	9.53	4.29	Astereae	35	10
Clausena anisata	8.88	1.63	Ulmaceae	46	10
Hypericum quartinianum	8.48	5.69	Tiliaceae	40	9
Rytigynia neglecta	8.48	3.22	Rubiaceae	48	9
Oncoba spinosa	7.82	3.81	Flacoutiaceae	29	8
Maytenus gracilipes	7.66	3.64	Celastrace	61	8
Lepido trichilia	7.58	3.73	Acanthaceae	65	8
Embelia schimperi	6.84	4.54	Meliaceae	378	7
Acacia Albida Del.	6.61	6.88	Fabaceae	228	7
Aspilia mossambicensis	6.41	3.92	Euporbiaceae	20	7
Rhamnus prinoide	6.39	2.9	Rhamnaceae	8	7
Celtis Africana	6.21	4.71	Proteaceae	195	7
Carwassa spinarum	6.08	4.02	Loganiaceae	331	7
Bersama abyssinica	5.75	3.07	Asteraceae	21	6
Brucea antidysenterica	5.37	2.3	Melianthaceae	16	6
Argomuellera macrophylla	5.27	2.19	Icacinaceae	42	6
Caulpurnia aurea	5.22	7.55	Rhizophoraceae	119	6
Justicia schimperina	5.2	2.03	Cuppressaceae	87	6
Gnidia glauca	5.18	2.89	Flacoutiaceae	20	6

Appendix 8.3: sampled plots, environmental variables amd above ground carbon pool in the study area

Plots	Altitude (m asl)	Slope (%)	Aspect	Individuals	AG carbon pool
1	2213	20	NE	94	1786
2	2230	25	E	84	1596
3	2236	15	E	76	1444
4	2229	10	SE	70	1330
5	2205	42	NE	87	1653
6	2227	45	NE	60	1140
7	2244	30	E	84	1596
8	2238	20	E	71	1349
9	2226	15	SE	74	1406
10	2219	10	SE	55	1045
11	2194	15	NE	80	1520
12	2213	30	NE	75	1425
13	2230	25	E	48	912
14	2248	20	E	42	798
15	2241	25	E	73	1387
16	2234	15	SE	91	1729
17	2217	10	SE	53	1007
18	2187	20	N	45	855
19	2229	35	N	86	1634
20	2247	41	NE	59	1121
21	2251	44	NE	76	1444
22	2255	36	E	68	1292
23	2246	25	E	68	1292
24	2239	20	SE	64	1216
25	2228	15	SE	68	1292
26	2216	15	S	81	1539
27	2183	10	N	66	1254
28	2196	25	N	57	1083

29	2225	30	N	70	1330
30	2248	44	N	67	1273
31	2256	35	N	25	475
32	2268	27	S	72	1368
33	2263	41	S	44	836
34	2249	29	S	47	893
35	2237	45	S	92	1748
36	2220	30	S	72	1368
37	2216	25	S	55	1045
38	2205	5	S	49	931
39	2185	22	N	69	1311
40	2209	27	N	32	608
41	2226	35	N	70	1330
42	2230	45	NW	63	1197
43	2237	25	NW	50	950
44	2244	20	NW	76	1444
45	2259	25	NW	73	1387
46	2263	20	W	74	1406
47	2254	25	W	53	1007
48	2247	25	W	48	912
49	2231	20	SW	32	608
50	2227	35	SW	64	1216
51	2212	12	S	53	1007
52	2201	5	S	65	1235
53	2191	20	NW	59	1121
54	2232	25	NW	51	969
55	2240	45	NW	55	1045
56	2256	30	W	42	798
57	2265	42	W	68	1292
58	2258	25	W	92	1748
59	2251	15	SW	108	2052

60	2242	20	SW	65	1235
61	2239	25	SW	31	589
62	2227	25	SW	52	988
63	2207	43	SW	64	1216
64	2204	40	NW	38	722
65	2223	20	W	93	1767
66	2236	15	W	45	855
67	2221	5	SW	75	1425
68	2205	20	W	48	912
69	2197	35	W	49	931
70	2226	25	W	47	893
71	2202	34	W	64	1216

Appendix 8. 4 . List of woody plant species, and their relative frequency (RF, relative density (Rdens), and relative dominance (Rdo.), their Importance value index (IVI) and their respective ranks (Rank) on vegetation

Item	F	Dom.	Dens.	RF (%)	Rdo (%)	Rdens. (%)	IVI	Rank
Acacia abyssinica	11	0.1	20.5	2.5	3.4	1.8	7.8	15
Acacia etbaica	8	0.0	27.8	1.8	0.7	2.5	5.0	27
Albizia schimperiana	19	0.1	16.0	4.4	7.7	1.4	13.5	2
Allophylus abyssinca	2	0.0	1.0	0.5	1.1	0.1	1.7	45
Apodytesdimidiata	15	0.1	36.8	3.4	3.8	3.3	10.5	6
Argomuellera macrophylla	2	0.0	10.5	0.5	0.1	0.9	1.5	48
Aspiliamossambicensis	3	0.0	5.0	0.7	0.2	0.4	1.3	50
Bersama abyssinica	1	0.0	5.3	0.2	0.2	0.5	0.8	53
Bruceaantidysenterica	2	0.0	4.0	0.5	0.1	0.4	0.9	52
Buddlejapolystachya	7	0.0	16.5	1.6	1.3	1.5	4.3	30
Carissaspinarum	10	0.0	82.8	2.3	0.2	7.3	9.8	7
Cassipoueamalosana	10	0.1	8.0	2.3	3.6	0.7	6.6	19
Caulpurniaaurea	7	0.0	29.8	1.6	0.1	2.6	4.4	29
Celtis africana	13	0.0	12.8	3.0	2.0	1.1	6.1	20
Clausenaanisata	5	0.0	11.5	1.1	0.4	1.0	2.5	40
Cordia africana	12	0.1	17.5	2.8	3.8	1.6	8.1	14
Croton macrostachyus	38	0.1	93.8	8.7	3.5	8.3	20.5	1

Dombeya schimperiana	2	0.0	5.3	0.5	1.4	0.5	2.4	41
Dombeya torrida	4	0.0	14.8	0.9	1.7	1.3	4.0	32
Dracaena steudneri	5	0.0	10.0	1.1	1.7	0.9	3.8	36
Ekebergia capensis	8	0.0	15.3	1.8	2.6	1.4	5.8	23
Embeliaschimperi	11	0.0	94.5	2.5	0.2	8.4	11.1	5
Erythrina brucei	20	0.1	21.3	4.6	5.6	1.9	12.1	3
Eucalyptus globulus	15	0.0	30.0	3.4	2.9	2.7	9.0	10
Flacourtia indica	9	0.1	3.8	2.1	7.2	0.3	9.6	8
Gnidia glauca	2	0.0	5.0	0.5	0.1	0.4	1.0	51
Grevillea robusta	3	0.0	23.8	0.7	1.2	2.1	3.9	33
Grewia ferrugina	10	0.0	48.8	2.3	0.2	4.3	6.8	18
Hypericum quartinianum	3	0.0	10.0	0.7	0.3	0.9	1.9	43
Juniperus procera	12	0.1	5.3	2.8	4.4	0.5	7.6	16
Justicia schimperina	4	0.0	21.8	0.9	0.1	1.9	3.0	37
Lepidotrichilia	4	0.0	16.3	0.9	0.3	1.4	2.6	39
Macaranga capensis	13	0.0	10.0	3.0	1.7	0.9	5.5	25
Maesa lanceolata	9	0.0	18.3	2.1	0.8	1.6	4.5	28
Maytenusaddat	6	0.0	19.8	1.4	0.8	1.7	3.9	34
Maytenusgracilipes	5	0.0	15.3	1.1	0.3	1.4	2.8	38
Millettiaferruginea	9	0.0	12.5	2.1	2.8	1.1	6.0	21
Nuxiacongesta	5	0.1	5.8	1.1	4.3	0.5	6.0	22
Oncoba spinosa	2	0.0	7.3	0.5	0.3	0.6	1.4	49
Pittosporum viridiflorum	4	0.0	4.0	0.9	1.1	0.4	2.3	42
Podocarpus falcatus	10	0.1	14.8	2.3	5.0	1.3	8.6	12
Pouteria adolfifriderici	1	0.1	3.3	0.2	3.5	0.3	4.0	31
Rhamnus prinoide	2	0.0	2.0	0.5	0.2	0.2	0.8	54
Rhus glutinosa	1	0.0	1.8	0.2	1.2	0.2	1.6	47
Rytigynianeglecta	2	0.0	12.0	0.5	0.3	1.1	1.9	44
Schefflera volkensii	11	0.1	9.0	2.5	5.5	0.8	8.8	11
Solanecio gigas	3	0.0	16.3	0.7	1.7	1.4	3.9	35
Syzygiumguineense	11	0.1	15.3	2.5	3.1	1.4	7.0	17
Teclea nobilis	17	0.0	45.5	3.9	1.4	4.0	9.3	9
Urerahypselodendron	13	0.0	57.0	3.0	0.2	5.0	8.2	13
Vepirsdainellii	17	0.0	64.3	3.9	1.8	5.7	11.4	4
Vernonia adoensis	2	0.0	8.8	0.5	0.4	0.8	1.7	46
Vernonia amygdalina	8	0.0	23.3	1.8	1.1	2.1	5.0	26
Vernonia rueppellii.	7	0.0	38.5	1.6	0.6	3.4	5.7	24
Total				100.0	100.2	100.0	300	