SCIREA Journal of Forestry

http://www.scirea.org/journal/Forestry

October 23, 2022

Volume 3, Issue 1, February 2022

https://doi.org/10.54647/forestry22025

Assessment of Exclosure Impact on Carbon Stock and Woody Species Diversity in Tullu Korma, Ejere District, Oromia, Ethiopia: Implication For Climate Change Mitigation

Mulugeta Negeri [1]*, Dejene Adugna [2], Asaye Ayele [2], Biyansa Hirpo [2] and Tamiru Kuru [2]

[1] Ambo University, College of Agriculture & Veterinary Sciences, Department of Plant Sciences, P. O .Box 19, Ambo, Ethiopia

[2] Ambo University, College of Agriculture & Veterinary Sciences, Department of Forestry, P. O. Box 19, Ambo Ethiopia

*Correspondence should be addressed to Mulugeta Negeri (Assoc.Prof.):negerimulugeta@yahoo.com; +251 911896296

ABSTRACT

Globally, the concentration of atmospheric CO_2 is increasing in alarming rate due to anthropogenic activities. The destruction of natural vegetation from different land uses is contributing to the increase of CO_2 in the atmosphere and this is resulting in to the current global warming. Rehabilitation strategies on waste lands and degraded forest areas can contribute to both sink and increase in pool of C as well as increasing of the diversity of both wildlife and plant species diversity. Such conservation goals are achieved by setting strategies like area exclosures, by means of protecting the area from interventions of animal and human beings. So, the current study was aimed at assessments of the role of area enclosures for conservation of biodiversity and its contribution for climate change mitigation. Two land uses were purposively selected and a total of 40 plots were set on transect lines for assessment of woody species diversity and carbon stock in the selected land uses. Within each main plot five 4m*4m and 1m*1m subplots were set to collect data for woody species diversity and soil samples respectively. Litter samples were also collected from a 1m*1m sub plots. A total of 120 soil samples were collected from both land uses. A total of 110 woody species, belonging to 54 families were recorded. Of all woody species 110 and 12 species was recorded in the EXs and adjacent farmland respectively. Abundance, species richness, Shannon diversity index, Simpson diversity index, basal area and stem density were significantly higher in the Exclosures than adjacent farmlands. The average woody species density and basal area of Exclosure was 5315(2830) ha^{-1} & 6(3) for farmland. The Shannon and Simpson diversity indices per plot was 3.19 (±0.37) & 2.25(±0.32) in enclosures and 0.93(±0.09) &0.86(±0.12) in the adjacent farmlands respectively. *Mytanus obscure, Carrisa spinarum* and *Olea europeae* were abundant woody species in the exclosure while *Rhus vulgaris, Podocarpus falcatus* and *Carissa spinarum* were in the adjacent farmland. The mean total carbon stock (biomass plus soil, 0-60cm) was significantly higher in Exclosures (81.17 ± 45.21 $tCha^{-1}$) than adjacent farmland (62.50 ± 43.37 $tCha^{-1}$). The total above ground biomass carbon stocks were significantly correlated with the species diversity. Finally, this study revealed that Enclosures on degraded highlands contributed to improve woody species diversity and total carbon stock of biomass and soil.

Keywords: *Climate change mitigation, Enclosures, Soil carbon, Biomass*

INTRODUCTION

Globally forest accounts about one third of the total landmass (FAO, 2010). Forest resources play a great role on various ecosystem services such as climate change mitigation and supporting livelihoods. Worldwide more than 1.6 billion people depend on forest for food, water, fuel, medicines, traditional cultures and livelihoods (World Bank, 2004). Forest also stores a large amount of carbon both in the above and below ground biomass, soils and in the products (Pan *et al.,* 2011). The African forest coverage was estimated to 675 million hectares, accounting for about 17 % of global forest area and 23 % of the total land area in the region (FAO, 2010). Moreover, it is believed that climate change, deforestation, forest degradation and biodiversity are interlinked to each other (Mandal *et al.,* 2013).

Degradation of vegetation has eventually led to desertification in Africa than any other continent (FAO, 2001). Similarly, forest resources in Ethiopia have been declined to several decades. Recently, FAO (2010) reported annual deforestation rate of 1.0-1.1 % between 1990 and 2010 with a deforestation rate of 141,000 ha per annum between 2005 and 2010. Federal Democratic Republic of Ethiopia (FDRE, 2011) also predicted deforestation rate to be 2.5 % per annum between 2010 and 2030 unless action is taken to change the traditional development path. In the highlands of Ethiopia, deforestation and improper agricultural activities have resulted in soil nutrient depletion, hydrological instability, reduce primary productivity and low species diversity (Solomon *et al*., 2002; Lemenih *et al.,* 2005).

To avert land degradation and enhance species regeneration, the government of Ethiopia has initiated a number of soil and water conservation projects including exclosures in the country (Nedessa *et al.,* 2005). Currently, the country plans to achieve 50 % of its total domestic greenhouse gas (GHG) emissions abatement potential by 2030 through afforestation and reforestation of 5 million ha of forest lands and woodlands (FDRE, 2011). Besides, the country is pledged on the global landscape restoration commitment to restore 15 million ha of degraded land, which is about one-sixth of the country total area and to sequester 1.42 G t CO_2 by 2025. This research proposal is focused on studying the impact of exclosure on woody species diversity and C stock in Tulu Korma areas of Ejere District. Tulu Korma where this study will be carried out is the Center for Indigenous Trees Propagation and Biodiversity Development in Ethiopia. Formerly the area is known as “Center for Indigenous Trees Propagation and Biodiversity Development in Ethiopia” and currently named as “Center for the Restoration of Ethiopia’s Biodiversity and Key Natural Resources”. It was founded by Professor Legesse Negash and established on 10 July 2004 with its primary objectives which envisages providing a platform for research and development on indigenous trees, shrubs, biodiversity, watersheds, and key natural resources including water and soils (Legesse Negash, 2010).

The need to study and assess how well the established exclosures are effective in meeting the intended ecological objectives, such as restoring vegetation diversity and carbon stock of the degraded ecosystem, is explicitly indispensable. However, despite the fact that exclosures have been implemented in Ethiopia for about decades, empirical data on the effectiveness of these protected areas in restoring ecosystem carbon stock are lacking. In fact, there are some studies conducted on these exclosures in northern part of the country (Yami *et al.,* 2006), which have reported the effectiveness of exclosures on restoration of native plants diversity and on ecosystem carbon stock.

Also studies on woody species conservation, biomass and soil carbon stock potential of the exclosures are inconsistent. Reid *et al.* (2004), Mekuria and Aynekulu (2011), Abebe *et al.* (2014) and Yimer *et al.* (2015) reported an increase in soil carbon following the establishment of exclosures on grazing lands, while Young-zhong *et al.* (2005) demonstrated a decrease in soil carbon and Mekuria *et al. (*2014) reported as soil organic carbon are not influenced by exclosure establishment. In addition, the current policy on the biodiversity conservation, climate change mitigation (REDD+ and CDM) strategies and restoration of the degraded land requires reliable and scientific information. Thus, this study was conducted to fill the knowledge gaps of understanding on the roles of exclosures in conservation of floristic diversity and enhancement of carbon stocks in the biomass and soils in Tullu Korma, Ejere district. Hence, the current study was initiated to determine and evaluate the impact of exclosure on carbon stock and woody species diversity in Tullu Korma and compare the floristic composition, diversity, structure of exclosure and adjacent farm land; and further more to compare the Carbon stocks of the woody and non-woody (herbaceous) biomass in exclosure and adjacent farm land; the soil carbon stock of exclosure and farm land; analyze the relationship between carbon stock and biodiversity in the two land uses. This study would contribute for generating scientific evidences on sustainable management and conservation of biodiversity, and climate change mitigation and believed to provide inputs for drafting sustainable natural resources management strategies and scaling up exclosures in the country.

MATERIALS AND METHODS

Description of the Study Area

Location

Tulu Korma exclosure is located at 50–55 km West of Addis Ababa on the high way running from Addis Ababa to Ambo between 09°01.188’ N and 038°21.570’ E within altitude range of 2,163–2,267m. Four neighboring kebeles bordering Tulu Korma are Chiri to the north, Kimoye to the west, Hora to the south and Endode to the east. Addis Alem is the nearest town about 3 kilometers from the center and it is with weather station from where the Ethiopian National Meteorological Service Agency (ENMSA) record weather data (Zewdie Kassa *et al.* 2015).

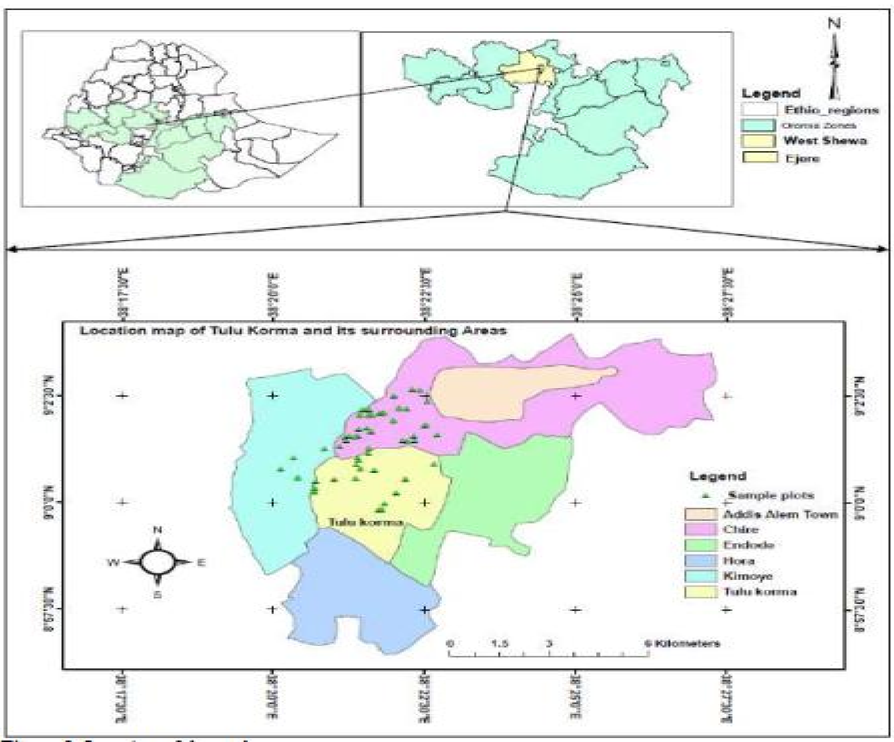

Figure 1: Map of the study area

Climate

According to Zewdie Kassa *et al.* (2015), the annual average minimum and average maximum temperature for 16 years data is 7.4°C and 26.2°C respectively. The annual average temperature and average rainfall for the same years’ data are 16.9°C and 1099 mm respectively

Vegetation

Areas between altitudes of 1800 and 3000 meters have been marked as the Dry evergreen Afromontane forest and grassland complex with the exception of high annual rainfall areas of 1700 millimeters and above (Friis *et al.* 2011). The vegetation of Tulu-korma and its surrounding belongs to such vegetation type and characterized by a canopy dominated by *Juniperus procer*(Cupressaceae), *Podocarpus falcatus* (Podocarpaceae), *Olea europaeasubsp.Cuspidata* (Oleaceae), Croton macrostachyus (Euphorbiacea) and Ficus spp. (Moraceae). Shrubs and bush lands, woodlands and plantations are also available.

Methodology

The methods and procedures that was used to estimate carbon stocks were simple allometric procedures using standard carbon inventory principles and techniques. That is based on data collection and analysis of carbon accumulating in the above-ground biomass, below-ground biomass, leaf litter and soil carbon of forests using verifiable modern methods (Pearson *et al.*, 2005).

Selection and Delineation of sampling site

Initially discussion was held with concerned bodies to explain the purpose of the study and to get permission to conduct the study in the area. Tullu Korma Center for the Restoration of Ethiopia's Biodiversity and Key Natural Resources practiced in Ejere District and adjacent open grazing lands (as control) were purposively selected. In this study, the selected exclosures and adjacent open grazing lands was assumed to exist under similar biophysical conditions before the establishment of the exclosures. This area is selected due to the current condition of woody plant species in the system and extensive availability of native and indigenous tree species. GPS was used for boundary delineation of the study site.

Sampling Technique

Systematic transect sampling techniques were employed to collect data from the exclosures and adjacent open grazing lands for vegetation and soil data. In each of the land use, transects lines were laid at 200m interval and 100m away from the edge. Temporary sampling plots of 20 m × 20 m were laid down at 100 m intervals from each other. Then, a total of 40 plots (20 plots x 2 land use types) were laid down along the transect lines using four wooden pegs and plastic rope.

The first quadrant was assigned randomly at the beginning of the transect line and then, continued with 100m interval. Inside each major plot, five subplots (4m x4 m) four at the corners, and one at the center were established to measure sapling and seedling. In each five 4m x 4m sub-plots, plot with size of 1m *1m was also established to collect soil samples, litter (Figure 2).

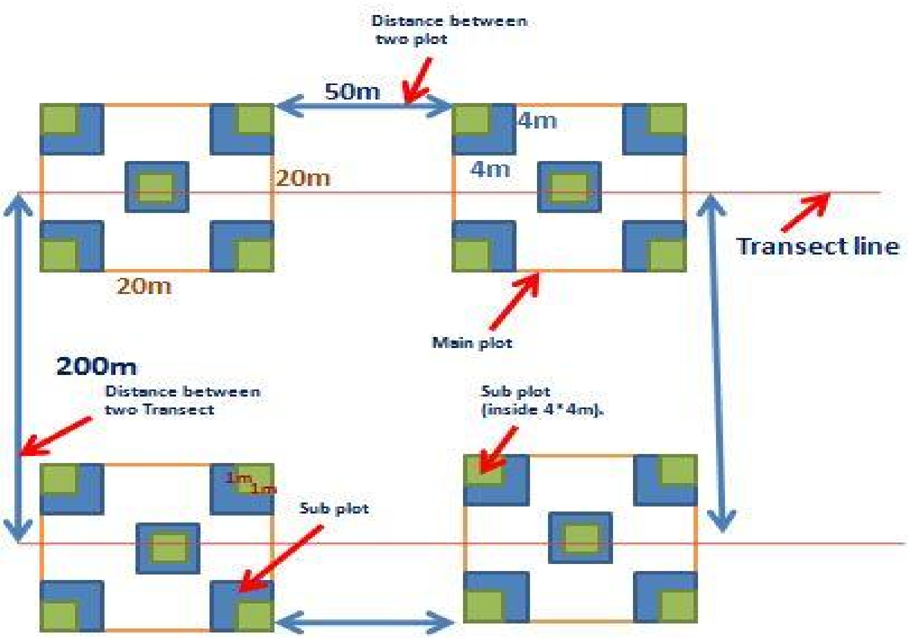

Figure 2: Sampling design for data collection

Methods of data collection

Woody species inventory

Inventory of woody species was conducted in the main plot (20 m*20m). All trees/shrub species dbh ≥ 2.5cm and total height ≥ 1.5 m were recorded and measured. All woody species saplings (dbh <2.5cm and total height 50-150cm height) and seedlings (height 20-50cm) were counted and their name was recorded but not measured. Diameter measurements for matured woody species (dbh≥2.5cm) were taken at breast height (1.3m above ground). Trees on the border of the plot were measured if ≥ 50% of their basal area fallen within the plot while trees on the edge of the plot were excluded. Trees with their trunks inside the sampling plot and branches outside were also considered (MacDicken, 1997). Total height of each woody species was measured using 5m graduated wood frame and for tees >5m using hypsometer, while DBH of the woody species was measured by caliper. In the case of multi-stemmed woody species, each stem was measured separately and the equivalent diameter of the plant is calculated as the square root of the sum of diameters of all stems per plant (Snowdon *et al.,* 2002). Woody vegetation identification was done in the field using key informants and each vernacular name was translated to their botanical names using flora of Ethiopia and Eritrea (Hedberg *et al.,* 1995; Edwards *et al.,* 1997; Edwards *et al.,* 2000; Woldemichael *et al.,* 2010).

Soil sampling

The soil samples were taken from three randomly selected 1m x1m sub-plots established from the corner and center of main plots (400m^2). The sampling was done from the depth of 0-20cm, 21-40cm and 41-60cm using soil augur. The three soil samples were mixed to form a composite sample. A total of 120 soil samples (20 plots x 2 land uses x 3 depths) were collected for soil texture, pH, organic C % and total N. Finally, the soil samples were transported to Soil laboratory.

Litter sampling

Litter sample in this study include dead leaves, branches, twigs, flowers, and dead wood with a diameter of less than 10 cm. Litter samples were collected from three subplots of 1 m x 1 m within main sample plot. The fresh litter from the subplot was collected and weighed right on the site using spring balance. Then subsamples were evenly mixed and 100gm litter was taken and transported to laboratory.

Laboratory Analysis

Litter

The collected litter biomass was air dried for one day and then, oven-dried at 70℃ for 24 hours. Then the samples were weighted, grinded using mortar and pesto then sieved with 2 mm mash. The loss on ignition (LOI) method was used to estimate percentage of carbon in the litter. From the oven dried grinded sample, 3.00 g of each litter subsamples was taken in pre-weighted crucibles, and then put in the furnace at 550℃ for two hours to ignite (Negash and Starr, 2015). Then, the crucibles were cooled slowly for two hours inside the furnace. After cooling, the crucibles with ash will be weighted and litter organic matter fraction was calculated according to

Allen *et al.* (1986). The amount of carbon in the litter was determined by multiplying litter organic matter by 0.5 (Pearson *et al.,* 2007).

Soil

The soil samples for bulk density were oven-dried at 105°C for 48 hours and weighed (Pearson *et al.,* 2007). Bulk density was determined by the core method (Blake and Hartge, 1986). The soil samples for texture, pH and SOC were air dried. Soil textural fractions was analyzed following the hydrometric method after removing organic matter using H_2O_2 and thereafter, dispersing the soils with sodium hexameta-phosphate. The pH value of the soil samples were measured in water and potassium chloride suspension in a 1:2.5 (soil: water ratio). The SOC analysis was made by using Walkley and Black method.

Data Analysis

In the case of multi-stemmed plants (more than 2 stems per plant), the equivalent diameter of the plant was calculated (Snowdon *et al*., 2002):

$$d_e = \sqrt{\sum_{i=1}^{n} d_i^2} \text{ ------------- } \mathbf{EQ1}$$

Where: d_e is diameter equivalent (at breast or stump Height) (cm) and d_i is diameter of the i^{th} stem at the measurement height (cm).

Above- and belowground biomass

Generic allometric equation of Chave (2005) was used for estimation of aboveground biomass of trees/shrubs.

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

Since the plot areas are part of tropical region, carbon content of 50% will be used to convert biomass to carbon stock.

$$AGB_{est.} = 0.0673*(\rho D^2 H)^{0.97}\text{-------------}EQ2$$

Where, AGB is aboveground biomass, ρ is wood density, D average diameter at breast height (at 1.3m), H is tree heght

$$\mathbf{BGB = AGB\ X\ 0.2 - - - - - - - - - - - - - EQ3}$$

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

According to IPCC, 2006 the biomass stock density of a sampling plot is converted to carbon stock densities by default carbon fraction of 0.47, as the dry biomass contains 47% organic carbon in the tropical and sub-tropical region.

Litter biomass and carbon stocks estimation

The amount of biomass in the litter was calculated according to Pearson *et al.* (2005)

$$LB = \frac{W\ Field}{A} \times \frac{W\ sub - sample(dry)}{W\ sub - sample\ (fresh)} \times \frac{1}{10000} - - - - - - - - - EQ4$$

Where: LB is Litter biomass (Mg ha^{-1}), W field is weight of wet field sample of litter sampled within an area of size 1 m^2 (g), A is size of the area in which litter will be collected (ha), W sub-sample (dry) is weight of the oven-dry sub-sample of litter (g), and W sub-sample (fresh) is weight of the fresh sub-sample of litter that will be taken to the laboratory to determine moisture content (g).

The carbon density of litter was then calculated by multiplying biomass of litter per unit area with the percentage of carbon determined for each sample.

$$LBC = LB \times \%C - - - - - - - - - - - - - - - - EQ5$$

Where: LBC is total carbon stocks in the litter in Mg C ha^{-1} and % C is carbon fraction which was determined in the laboratory.

Soil analysis

To determine the SOC, bulk density was determined first by using formula of Pearson et al. (2007):

$$BD_{soil} = \frac{ODW}{CV - \frac{RF}{PD}} ------------- EQ6$$

Where: BD soil is soil bulk density (g/cm^3), ODW is oven dry weight of soil (<2mm fraction) (g/cm^3), CV is soil core volume (cm3), RF is mass of coarse fragments (g), and PD is density of rock fragments (g/cm^3) = 2.65 g/cm3

SOC stocks (Mg C ha^{-1}) was calculated based on the fixed depth (FD) approach which expressed as the product of carbon fraction (%), bulk density (g/cm3), and layer thickness

$$SOC = BD\ X\ Depth\ X\ \%OC\ X\ 100 ----------- EQ7$$

Where: SOC is Soil Organic carbon (Mg C ha^{-1}), BD is bulk density (g/cm3), Depth (cm), %C is carbon fraction and expressed as a decimal fraction.

Total carbon stocks

The carbon stock density of a study area was calculated by summing the carbon stock densities of the individual carbon pools of the stratum

$$TCS = AGBC + BGBC + SOC + LBC ----------- EQ8$$

Where: TCS is total carbon stock for all pools (Mg C ha^{-1}), AGBC is carbon in aboveground biomass (Mg C ha^{-1}), BGBC is carbon in belowground biomass (Mg C ha^{-1}), LBC is the litter biomass carbon (Mg C ha^{-1}) and SOC is Soil organic carbon (Mg C ha^{-1}).

Woody species diversity analysis

Woody species diversity was computed using different diversity indices. Shannon diversity index (’), Shannon equitability/evenness index ( ), species richness ( ), and Simpson diversity index ( ) were calculated and analyzed. These diversity indices provided important information about the rarity and commonness of species in lower, middle and upper altitudes. Species richness was the total number of species in the community. The Shannon-Wiener diversity index (H’) and

Shannon evenness index (Krebs 1989) were used to determine and analyse the diversity of woody species in the study forest.

In spite of the indices that combine species richness with relative abundance, probably the most widely used was the Shannon Index (H'), which made the assumption that a) individuals were randomly sampled from an infinitely large population and b) assumes that all the species from a community were included in the sample and calculated according to Kent and Coker (1992). The Shannon diversity index was calculated from the formula.

$$\mathbf{H'} = -\sum_{i=1}^{n} \mathbf{pixln(pi)} -------------- \text{eq.}(1)$$

Where: **H'** = Shannon-Wiener Diversity Index; **Σ** = Summation symbol; **pi** = the proportion of individuals or the abundance of i^{th} species expressed as a proportional of total cover in the sample and **ln** = log base n (natural logarithms). Equitability or evenness index was calculated from the ratio of observed diversity to maximum diversity using the equation.

$$\mathbf{E} = \frac{\mathbf{H'}}{\mathbf{ln(N)}} = \frac{\mathbf{H'}}{\mathbf{Hmax}} -------------- \text{eq.}(2)$$

Where: **E** = Evenness; **H'** = Shannon-Wiener Diversity Index; **Hmax =ln N; N** = total number of species in the sample. The value of evenness index falls between 0 and 1. The minimum value of H' is 0, which a value for a woody species of a given altitude with a single species and increases as species richness and evenness increases. The higher the value of evenness index, the more even the species was in their distribution within the given area. Species richness is a count of the number of species in a quadrate, area or community, or expressed as number of species per unit area. The Shannon-Weiner diversity index varies between 1.5 and 3.5 and rarely exceeds 4.5. Shannon-Weiner diversity is high when it is above 3.0, medium when it is between 2.0 and 3.0, low when it is smaller than 1.0 (Kent and Cocker, 1992).

Simpson's index (D) is a measure of diversity, which takes into account both species richness, and an evenness of abundance among the species present. The formula for calculating D is presented as:

$$D = \frac{\sum n_i(n_i - 1)}{N(N-1)} Or D = 1 - \sum P^{i2} ----------- eq(3)$$

Where $\mathbf{n}_i$ = the total number of organisms of each individual species

N = the total number of organisms of all species

The value of **D** ranges from **0** to **1**. With this index, **0** represents infinite diversity and, **1**, no diversity. That is, the bigger the value the lower the diversity.

Tree or shrub density and basal area values were computed on a hectare basis. Importance value indices (IVI) were computed for dominant woody species based on their relative density (RD), relative dominance (RDO) and relative frequency (RF) to determine their dominance (Kent and Coker, 1992). It describes the structural role of a species in a stand.

It is useful for making comparisons among stands in reference to species composition and stand structure. Again it compares the ecological significance of species in a given forest type.

Basal area is the cross-sectional area of tree stems at a diameter of breast height. Generally it is a measure of dominance where the term "dominance" refers to the degree of coverage of a species as an expression of the space it occupies and calculated by using the following formula.

$$Dominance(Do) = \frac{\pi D^2}{4} ---------- ------ eq(4).$$

This is $BA\ wich\ is\ \ \pi D^2/4$

Where **BA** = Basal area in $\mathbf{m}^2$ per hectare

D= diameter at breast height

π= 3.14

$$\text{Relative dominance(RD)} = \frac{\text{Basal area of a species}}{\text{Total basal area of all species}} x100 ----- eq(5)$$

$$\text{Relative frequence of species A} = \frac{number\ of quadrats\ in\ which\ species\ occurs}{Total\ number\ of\ quadrats} x100 --eq\ (6)$$

$$\text{Relative density} = \frac{\text{nuber of individuals species A}}{\text{Total Nuber of all species}} x100 ------- eq(7)$$

IVI= Relative density+ Relative frequency of species+ Relative dominance

Ecologists consider IVI as the most realistic aspect in vegetation study (Curtis and McIntosh, 1951). They stated that species with the greatest importance value are the leading dominants of the forest. It is also useful to compare the ecological significance of species (Lamprecht, 1989). The reason why a species produced the highest IVI value is that it has the highest relative density, relative frequency and relative dominance.

Statistical Analyses

The data was organized and analyzed using Microsoft excel 2010 and Statistical Package for Social science (SPSS version 20). Normality (Kolmogorov-Smirnov test) was done to check the data prior to further statistical analysis. To test for differences in carbon stocks among the depth layers, one-way ANOVA was performed. Pearson's correlation coefficient was computed to examine the relationship between woody species diversity and carbon stock.

RESULTS

Woody species composition, diversity and structures

Woody species composition and similarity

In overall, a total number of 110 species belonging to 54 families were recorded. The highest number of species (11) was recorded in Fabaceae, followed by Rosaceae (6) (Appendix 1). All the other families were represented by only 1 to 5 species at both land use types. The total number of woody species share in exclosures and crop field were twelve (12). In the exclosure 110 woody plant species representing 54 families were recorded. Where as in the surrounding crop field, 12 species were recorded representing 10 families. 98 of the 110 woody species were recorded exclusively with exclosures.

The Sørensen's coefficient of similarity for the exclosure and adjacent open grazing land was 20%, showing woody species similarity between the two studied ecosystems. Woody species retained on crop lands and exclosures are remnants of the natural vegetation which has once covered the area. Some of the woody species planted in exclosures are also native to the area. Hence, similarities in woody species composition are expected between the exclosures and crop lands. Accordingly, 19 % of the species in the exclosures were also observed in the crop field, and 100 % of the woody species recorded in the crop field were also observed in the exclosures.

The three most abundant species in the exclosures were *Maytenus obscura,Carissa spinarum,* and *Olea europaea*. Of all the species, *Maytenus obscura* represented about 14% of the total abundance of exclosure. Similarly, *Rhus vulgaris,Podocarpus falcatus* and *Carissa spinarum*were the abundant woody species in the surrounding crop land. *Rhus vulgaris* accounts about 23 % of woody species in the surrounding crop land

Woody species richness, diversity and evenness

Analysis of variance showed that there were strongly significant differences ($p \leq 0.001$) between exclosures and surrounding crop land in terms of mean number of individuals (abundance), number of species (richness) ($p<0.01$), Shannon and Simpson diversity indices per plot but not significant ($p>0.05$) in evenness. However, evenness in the exclosure was slightly higher than adjacent open grazing land (Table 1). The average abundance and species richness in the exclosure was greater than twice as compared to surrounding crop lands.

Table 1: Mean (± SD) of woody species richness, diversity, and evenness in exclosures (EXs) and surrounding crop lands (CL)

Land use type	Species richness	Shannon	Simpson diversity index	Evenness
EXs (n=20)	110(4)[b]	3.19(0.37)[b]	0.93 (0.09)[b]	0.77(0.07)[a]
CL (n=20)	12(2)[a]	2.25 (0.32)[a]	0.86(0.12)[a]	0.90(0.1)[a]
p-value	<0.001	<0.001	<0.001	0.081

Different letters of superscript were significant at $p\leq 0.01$, whereas similar letter not significant at $p\leq 0.05$ using one way ANOVA

Stand structure

Analysis of variance showed that there were significant differences ($p < 0.05$) between exclosure and surrounding crop land in terms of DBH, basal area and stem density (number of stems ha^{-1}) except total height (Table 2). Stem density and basal area in exclosure were very fargreater than crop land.

Table 2: Mean (±SD) DBH, height, basal area and stem numbers for exclosure and surrounding crop land in Tulu korma, Ethiopia

Land use type	DBH (cm)	Height (m)	BA ($m^2 ha^{-1}$)	Stem numbers ha^{-1}
EX (n=20)	5.36(4.22)^a	4.51(1.94)^a	4.66(2.85)^b	5,315(2830)^b
CL (n=20)	11(4.07)^b	5.81(1.30)^a	0.116 (1.20)^a	6(3)^a
p-value	0.036	0.574	<0.001	<0.001

Kruskal Wallis test was conducted to evaluate mean differences between the surveyed two ecosystems Similar letters shows not significant difference and different letters indicate significance differences between groups at $p < 0.05$; ns not significant. (Only woody species with dbh ≥2.5cm were included). Diameter class frequency distribution showed inverted J-shape in the exclosure, this type of frequency distribution was due to the presence of high number of lowest diameter classes which decreases to ward highest diameter class; (Figure 1a).Whereas in the surrounding crop land, the patterns shows poor reproduction and hampered regeneration.

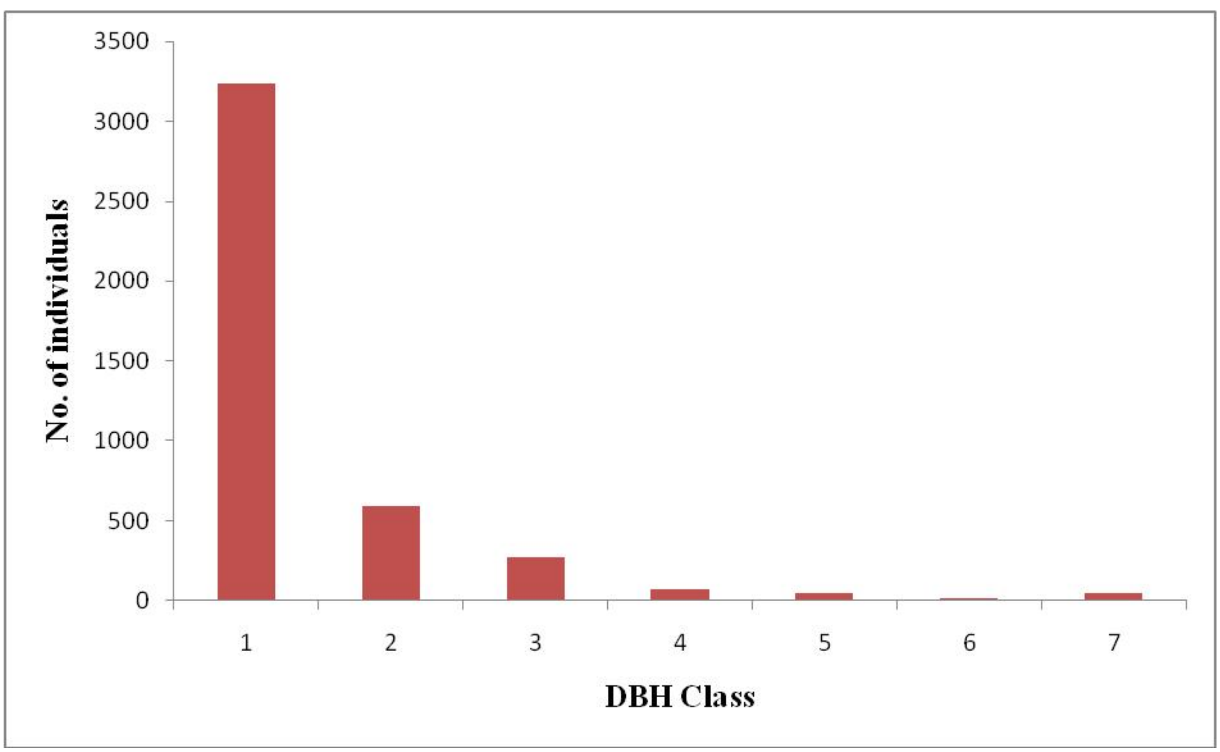

Figure 3: Diameter class and frequency distribution of exclosure.

(Diameter classes: 1 = <2.5 cm; 2=2.5–5 cm; 3=5–7.5 cm; 4=7.5–10 cm; 5=10–12.5 cm; 6=12.5–15 cm; and 7= >15 cm).

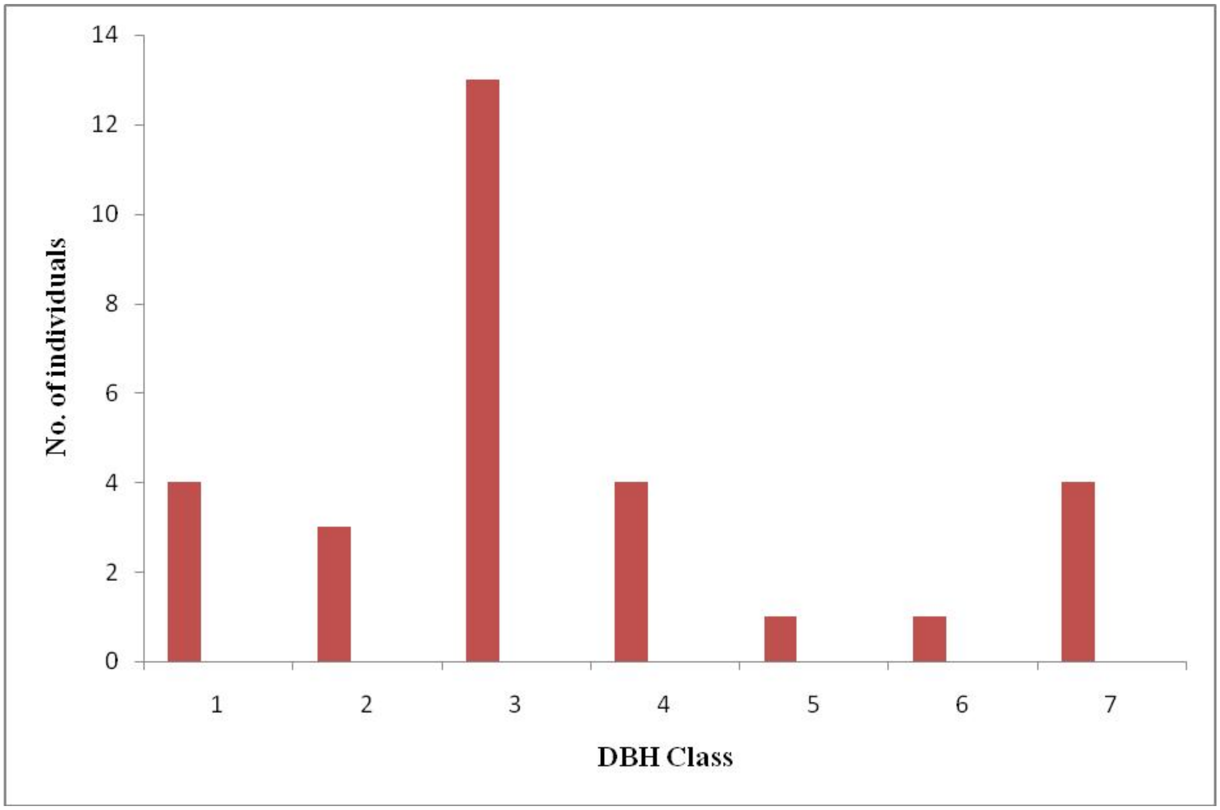

Figure 4: Diameter class frequency distribution of all woody species at surrounding farm land (Diameter classes: 1 = <2.5 cm; 2=2.5–5 cm; 3=5–7.5 cm; 4=7.5–10 cm; 5=10–12.5 cm; 6=12.5–15 cm; and 7= >15 cm).

Above and Belowground C Stocks of Exclosures and Adjacent farmlands

The two land uses composed of different types of woody species. Table 2 shows recorded biomass carbon stocks of Exclosure and the adjacent farmlands. The total biomass carbon (TBC) was 8.61 Mg C ha^{-1} for Exclosure, of which trees account for 94.77% and litter accounts for 5.23%. In farmland, the total biomass carbon (TBC) recorded was 0.89 Mg C ha^{-1} of which all are from trees. There is significant difference between the two land uses in terms of woody biomass carbon composition ($P<0.05$).

Table 1: (Mean ± SD) of above ground biomass Carbon (AGBC), belowground biomass carbon (BGBC), total biomass carbon (TBC) of components in the two land uses (n=20)

Biomass components	Land use systems	Litter	Trees	Total
AGBC (Mg C ha^{-1})	Farmland	-	0.64±1.17	0.64±1.17
	Exclosure	0.45±0.15	6.80±5.23	7.25±6.28
BGBC (Mg C ha^{-1})	Farmland	-	0.25±0.43	0.25±0.43
	Exclosure	-	1.36±1.05	1.36±1.05
Total (Mg C ha^{-1})	Farmland	-	0.89±1.56	0.89±1.56
	Exclosure	0.45±0.15	8.16±6.28	8.61±6.28

Soil Organic C Stocks

The results of SOC stocks recorded in the two land uses are shown in Table 3. The mean SOC stock for Exclosure in the 0-20cm soil layer was 32.42Mg C ha^{-1} and it was 28.50Mg C ha^{-1} for Farmland. Exclosure showed higher amount in SOC stock for this layer. On the other hand, SOC stocks for soil layer in the 20-40cm was 22.53Mg C ha^{-1} and 18.65Mg C ha^{-1} for Exclosure and Farmland respectively. Exclosures showed higher accumulation of SOC stock for this layer. In the third layer for this study the SOC recorded was 17.60Mg C ha^{-1} and 14.34Mg C ha^{-1} respectively The overall mean of SOC stock for the entire depth (0-60cm) for the two land uses was 72.56 Mg C ha^{-1} and 61.50Mg C ha^{-1} for Exclosure and Farmland respectively. Exclosure showed greater SOC stock than that of Farmland. But the difference was not statistically significant ($P>0.05$).

Table 2: (Mean ± SD) of soil organic carbon (SOC) for the two studied Land use systems; **n = 20** for each land use system.

C Stock	Farmland	Exclosure	P
0-20	28.50±13.27[a]	32.42±10.06[b]	0.001
20-40	18.65±5.55[b]	22.53±7.41[a]	0.001
40-60	14.35±3.31[a]	17.63±5.53[b]	0.001
Total	61.50±19.58[b]	72.56±21.95[a]	0.006

Total C Stocks of the Land Uses

The total biomass carbon and SOC stocks at the entire depth (0-60cm) of the two land use systems is shown in Table 4. The mean total biomass C stocks for Exclosure was 8.61 Mg C ha^{-1} and it was 1.00 Mg C ha^{-1} for Farmland. Exclosure showed higher biomass C stock relative to that of Farmland, which is significantly different. The total SOC stocks stored in the two land use systems is shown in Table 3. Exclosure stored relatively higher amount of SOC stocks, and it show significant difference ($P<0.05$) with Farmland. Land use total C stock for Exclosure was 81.17 Mg C ha^{-1} while it was 62.50 Mg C ha^{-1} for Farmland showing higher accumulation in the Exclosure than Farmland. Statistical tests showed that there was significant difference between the two land uses in accumulating C stocks ($P<0.05$).

Table 3*:* (Mean±SD) of biomass carbon, soil organic carbon (SOC) and the land use total (total biomass plus SOC 0–60 cm) carbon stocks (Mg C ha −1) for Exclosure and Farmland.

C Stocks	Exclosure	Farmland	P
Total Biomass	8.61±6.28[a]	0.89±1.156[b]	0.000
SOC 0-60	72.56±21.95[b]	61.50±19.58[a]	0.006
Land Use Total	81.17±45.21[a]	62.50±43.37[a]	0.101

DISCUSSION

Woody species composition, diversity and structures

Though, the initial number of woody species during establishment of the exclosure was not recorded, the evidence from this study indicated that establishing of exclosures enhances the woody species composition. This could be due to the improvement of microclimate and emerging potential of woody species in the exclosures (Mekuria, 2013). In addition, long period of protection from free livestock and human interface allows regeneration of tree and shrubs (Wassie *et al.,* 2005; Zegeye *et al.,* 2011; Mekuria and Yami, 2013). The number of species found in the exclosure was greater than five times of the surrounding crop land which is similar with the finding of Mulugeta (2014) in Gonder, Northern Ethiopia.

The higher species similarity in woody species of the exclosures and surrounding crop lands might be due to similar climatic condition, altitudinal range and catchment. This result was in line with other studies (Birhane *et al.,* 2007; Asmamaw, 2011; Kasim *et al.,* 2015)

Establishing of exclosures enhances the woody species abundances, richness and diversity. The higher woody species abundance indicates the future recovery of the open area would be successful if it became closed. This could be due to minimizing interference of people and domestic animals (Mengistu *et al.,* 2005; Neelo *et al.,* 2015) and exclosures provide favorable microhabitats for plants (Mekuria and Yami, 2013).

According to Adamu *et al.* (2012) the population structure shows the previous disturbance status of plants and helps to forecast their regeneration condition in the future. As compared with the surrounded crop land the number of individuals in exclosures at seedling and sapling stage were very high, confirming that the regeneration potential of the sites (Yami *et al.,* 2006; Mekuria, 2007).There are normal DBH distribution patterns and the inverted J-shaped in Exclosure. It indicates a pattern where species frequency distribution had the highest frequency in the lower DBH classes and gradually decreases towards the higher diameter. A similar trend was also reported from the semi arid areas of northern Ethiopia (Mekuria, 2007).Irregular structures were observed in farm lands which were exposed to selective removal and human management. Therefore, these important on farm trees need critical management for their sustainability.

The higher stem density and basal area in exclosure is related to favorable environmental condition and protecting human and livestock interventions. Similar results were also reported from exclosures of Northern parts of Ethiopia (Mengistu *et al.,* 2005; Birhane *et al.,* 2007; Asmamaw, 2011; Berhe, 2015). The observed basal area is also consistent with other studies reported from several dry tropical forests in Indian ranges between 3.84 and 10.36 m^2 ha^{-1} (Singh and Singh, 1991). The mean dbh was higher in the crop land than the exclosures, this might be due to low number of stem and species type with dbh≥2.5cm. Which means trees with lower diameter class was disappeared because of human and livestock disturbance and trees with large diameter are remained in crop land.

Carbon Stock Potential of the Land Uses

Above and Belowground Biomass Carbon Stocks in Exclosure and Farmland

The result depicted that there is a significant difference between the two land uses in terms of their biomass carbon stock. Exclosure biomass carbon stock is relatively greater than that of the biomass carbon stock of farmland. Such difference might be happened due to the presence of higher amount accumulation of woody biomass in the protected exclosure than that of the open farmland. Farmers cut the tree for the sake of preparation of land to plough and till the land for the production of cereal crops. This pose impacts on the amount of woody biomass on the farm land. On the other hand, farmers intentionally cut large woody trees from their farmlands because the shade of such trees retards the growth of their cereal crops. Another reason of difference might also be arose from the presence of litter biomass in exclosures, whereas there were no any litter biomass recorded under the farmland as the farmland is used for both production of cereal crops and grazing for animals turn by turn.

In comparison with other areas in Ethiopia, the current biomass carbon stock in exclosure of this study area (8.61Mg C ha^{-1}) is almost within the range of exclosure carbon stock studied in Northern Ethiopia, Tigray (2.84 Mg C ha^{-1}, 5.83 Mg C ha^{-1}, and 8.36Mg C ha^{-1}) which was studied on three age groups of exclosures 10, 15, and 20 respectively (Samson Shemelse *et al.,* 2017).

Mekuria (2013) also reported that the biomass carbon stock ranges between 2.0 and 7.0MgC$ha^{-1}$from similar agroecology of this study, but in Nile Basin of Ethiopia biomass carbon stock ranged from 0.6 to 4.2 t C ha^{-1} (Mekuria et al., 2015) which is lower than the current study. The biomass carbon stock of this study was also somewhat smaller when compared with study conducted in highlands of Tigray by Berhe (2015) and higher than the mid highlands report 2 t ha^{-1} by Hailu *et al.* (2014). This difference might be arisen due to either the diameter class they used, species type, adopted allometric equation, management system of the site or other physical factors. At the same time this study was also in line with similar studies conducted in other countries (Cheng *et al.,* 2011; Witt *et al.,* 2011).

Soil organic carbon stock

Soil organic carbon plays a vital role in the global carbon cycle and C pools (Sundarapandian *et al.,* 2015). The rate of soil organic carbon stock was significantly affected by changing in land use type (Lal, 2002; Walker and Desanker, 2004; Girmay *et al.,* 2008; Zhang *et al.,* 2009; Sundarapandian *et al.*, 2015). The soil organic carbon in this study exclosures was higher than the adjacent farm land. This result was in consistent with other studies in highlands of Ethiopia and elsewhere in the tropics (Mekuria and Veldkamp, 2005; Mekuria *et al.,* 2006; Katrien, 2007; Verdoodt, 2009; Witt *et al.,* 2011; Mekuria and Aynekulu, 2011; Hafner *et al.,* 2012; Abebe *et al.,* 2014; Yimer *et al.,* 2015).In contrast, Mekuria *et al.* (2014) and Aynekulu *et al.* (2014) reported that exclsoure did not influence soil organic carbon.

This study showed that SOC stock in exclosure was increased by 52% than that of farm land. This might be due to increased vegetation composition, reduced soil loss through erosion and the subsequent production and decomposition of litter fall from vegetation. In this study exclosure, there is higher dry litter biomass accumulation and herbaceous than adjacent farmland. Litter fall contributes a major role for the return of organic matter to the soil (Ewel, 1976; Vitousek *et al.,* 1995; Liang *et al.,* 2011). As trees improving soil nutrient by increasing input and reduce output, the higher soil organic matter accumulation in the study exclosure might be due to the presence of *Maytenus obscura, Carissa spinarum,* and *Olea europaea which are abundantly found in the exclosures*. In addition, exclosures has higher woody species abundance than adjacent open grazing land which is positively correlated with the SOC stock of this study. In contrast the mean SOC stock in the adjacent farmland is minimal because of animal and human interference.

Soil organic carbon content decreases with soil depth. This is consistent with other studies (Ciais *et al.,* 2011; Yimer *et al.,* 2015; Tesfaye *et al.,* 2016). This might be due to the presence of lower accumulation of organic matter resulting from lower below-ground root biomass in the sub-surface layer (Yimer *et al.,* 2015).

The total SOC stock (0-60 cm)of the study exclosure was comparable and within the range of SOC stock (30-140 t C ha^{-1}) reported in African savannahs and woodlands (Williams *et al.,* 2008) but higher than the central Mozambique wood lands reported by Woollen *et al.* (2012) (40.1 ± 2.5 Mg C ha^{-1}) and study conducted by Tesfaye *et al.,* (2016) at the crop lands of central highland Ethiopia (43.60 ± 4.97 t ha^{-1}). The result of the present was higher than the report by Mulaw (2015) on the mid- highlands of Tigray (15.11- 45.45 $tCha^{-1}$), in the highlands of Tigray by Berhe (2015) (14.4-36.3 $tCha^{-1}$) and also higher than the study conducted by Mekuria, (2013) at four districts found in the highlands of Tigray with mean difference land (26.0 and 53.7MgC ha^{-1}).

Ecosystem Carbon stock

This study showed establishing of exclosures in the degraded forest land enhanced the average total ecosystem carbon stock. In both land use types, the contribution of SOC stock was higher than the total biomass contribution. Similar results were reported in other exclosures (Mekuria *et al.,* 2009 and 2013) The total ecosystem carbon stock in the exclosure was higher than the reports of Berhe (2015) and lower than other studies in Northern Ethiopia (Mekuria *et al.,* 2009 and 2013). Then higher ecosystem carbon stock in the study exclosure was due to excluding human and live stock interferences and disturbance while variation with in similar studies might be due to different in management practices. However, establishing exclosures on the degraded forest and grazing land improves the productivity of land and carbon sequestration potential.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Exclosures on the degraded forest lands in the study area helped to recover woody species diversity and carbon stocks. The establishment of exclosure in the highly degraded forest lands is considered as an important option to restore the woody species composition, richness and diversity. However, unpalatability and resistant to human and livestock disturbance of some woody species also contribute to maintain those species in the adjacent farm land. The total biomass and soil carbon stock increased following the establishment of exclosure, implying that exclosures are potential ecosystem for accumulation of carbon stocks. This is related to exclusion of human and live stock disturbance. Thus, Exclosures on degraded ecosystem enhance biodiversity conservation and climate change mitigation and can be taken part of sustainable natural resource management strategy.

Recommendation

The comparative study result showed that there is high variation of woody species composition and diversity between the farmland and the exclosure. This indicates that more activities are required to make farmers left some woody species on their farmland and restoration activities using indigenous species should be taken into consideration and should be continued in similar agro-ecologies with the study site. The site and species specific biomass equations should be developed for accurate estimation of biomass of indigenous and dominant tree species.

Data Availability statement

Data are available any time on request after publication.

Consent for Publication

All authors have seen and approved their consent for publication and declared that no competing interests exist.

APPENDIX

APPENDIX 1: *List of woody species in the study area*

Appendix 1:

No	Species Name	Familly	Local Name	P A	F L	Life for m
1	*Acacia abyssinica*Hochst.exBenth.	Fabaceae	laaftoo	+	+	T

2	*Acacia albida*Del	Fabaceae	Garbii	+	-	T
3	*Acacia negrii*Pic.Serm	Fabaceae	Dodota	+	-	T
4	*AcanthessenniiChiov*	Acanthaceae	kosorruu	+	-	S
5	*Acokantheraschimperi* (A.DC.) Benth	Apocynaceae	Qararuu	+	-	S/T
6	*Albiziaschimperiana*Oliv	Fabaceae	Ambaltaa	+	-	T
7	*Allophylusabyssinicus (*Hochst) Radlk	Sapindaceae	Sarara	+	-	T
8	*Apodytes dimidiate* E.Mey. exArn.	Icacinaceae	Calalaqaa	+	-	T
9	*Asparagus africanus*Lam.	Asparagaceae	Sariitii1	+	-	S
10	*AsparagusracemosusWilld*	Asparagaceae	Sariitii2	+	-	S
11	*Bersamaabyssinica*Fresen.	Melianthacea e	Lolchiisaa	+	-	S
12	*Bruceaantidysenterica*J.F. Mill.	Simaroubacea e	Qomonyoo	+	-	S
13	*Buddlejapolystachya*Fresen	Loganiaceae	Qawwisa	+	-	S
14	*Caesalpiniadecapetala (*Roth) Alston.	Fabaceae	Arangamaa	+	-	S
15	*Cajanuscajan*	Fabaceae	Atarasimbira	+	-	S
16	*Calpurnia aurea* (Ait) Benth.	Fabaceae	Ceekaa	+	-	S
17	*Capparistomentosa Lam.*	Capparidacea e	arangamaagurraac ha	+	-	S
18	*Carissa spinarum L.*	Apocyanacea e	Agamsa	+	+	S
19	*Ceibapentandra*	Bombacaceae	Mukaxixii	+	-	T
20	*Clausenaanisata (*Willd) Benth.	Myrsinaceae	ulmaayii	+	-	S
21	*Clematis simensisFresen.*	Ranunculacea e	Hiddafiitii	+	-	Cl
22	*Clerodendronmyricoides* (Hochst.) Vatke	Lamiaceae	maraasisaa	+	-	S
23	*Coffeaarabica*L. .	Rubiaceae	buna	+	-	S
24	*Cordiaafricana*Lam.	Boraginaceae	waddeessa	+	-	T

25	*Crotalaria rosenii*(Pax) Milne-Redh. ex Polhill	Fabaceae	Ataraqamalee	+	-	S
26	*Croton macrostachyus*Del.	Euphorbiaceae	bakkanniisa	+	+	T
27	*Cucumisficifolius A. Rich.*	Cucurbitaceae	Hiddiihoolaa	+	-	H
28	*Cucurbitapepo L.*	Cucurbitaceae	dabaaqula	+	-	Cl
29	*Cupressuslusitanica* Miller	Cupressaceae	Gaatiraafaranjii	+	-	T
30	*Cymbogoncitratus*(D.C.) Stapf. .	Poaceae	Tejisaar	+	-	H
31	*Dodonaoeaangustifolia*L.f.	Sapindaceae	ittacha	+	-	S
32	*Dovyalisabyssinica*(A. Rich.) Warb	Flacourtiaceae	Koshommii	+	-	T
33	*Dovyaliscaffra*(Hook. f. &Harv. Hook.f	Flacourtiaceae	Koshommii	+	-	**S**
34	*Dovyalisverucosa (Hochst.) Warb.*	Flacourtiaceae	miximixxaa	+	-	**S**
35	*Dregeaschimperi (Becne.) Bullock*	Asclepiadaceae	Hiddagorisaa	+	-	**Cl**
36	*Echinopskebericho*Mesfin	Asteraceae	qabarichoo	+	+	S
37	*Ekebergiacapensis*Sparrm	Meliaceae	somboo	+	-	T
38	*Embeliaschimperi*Vatke	Myrsinaceae	Haanquu	+	-	S
39	*Enseteventricosum (Welw.) Cheesm*	Musaceae	warqee	+	-	H
40	*Erythrinabrucei*Schweinf.	Fabaceae	waleensuu	+	-	T
41	*Eucalyptus camaldulensis*	Myrtaceae	Baargamoo	+	+	T
42	*Euclearacemosa subsp. schimperi (A.DC.) Dandly*[*]	Ebenaceae	Mi'eessaa	+	-	S
43	*Euphorbia abyssinica*Gmel.	Euphorbiaceae	adaamii	+	-	S
44	*Ficussur*Forssk.	Moraceae	Harbuu	+	-	T

45	*Ficusvasta*Forssk	Moraceae	Qilxuu	+	-	T
46	*Ficussycomorus L.*	Moraceae	Odaa	+	-	T
47	*Ficusthonningi*	Moraceae	dambii	+	-	T
48	*Flacourtiaindica*	Flacourtiaceae	Wantafullaas	+	-	T
49	*Grevillearobusta*	Proteaceae	Giravillaa	+	-	T
50	*Grewiaferruginea*Hochst. ex A. Ric	Tiliaceae	dhoqonuu	+	-	S
51	*Galiniera saxifrage (G. coffeoides)*	Rubiaceae	Mixoo	+	-	T
52	*Hageniaabyssinica*	Rosaceae	Heexoo	+	-	T
53	*Hypericumquartinianum*A. Rich.	Gutiferaceae	Uleefonii	+	-	S
54	*Impatiens spp*	Balsaminaceae	ansoosillaa	+	-	H
55	*JasminumabyssinicumHochst. ex dc*	Oleaceae	Hiddailchibbee	+	-	Cl
56	*Jasminumgrandiflorum* (R.Br.ex.Fresen.) P.S.Green	Oleaceae	qamaxxee	+	-	Cl
57	*Juniperusprocera*Hochst.ex.Endl.	Cupressaceae	GaattiraaOromoo	+	-	T
58	*Justiciaschimperiana*(Hochst. ex Nees) T. Anders.	Acanthaceae	dhumuugaa	+	-	S
59	*Kalanchoepetitiana A. Rich*	Crassulaceae	Bosoqqee	+	-	H
60	*Lippiaadoensis*Hochst.exWalp.	Verbanaceae	Kusaayee	+	-	S
61	*Lippiaadoensis*var. koseret *koshonat*	Lamiaceae	koshonata	+	-	S
62	*Maesalanceolata*Forssk.	Myrsinaceae	abbayyii	+	-	T
63	*Malusdomestica*	Rosaceae	Apple	+	-	T
64	*Malvaverticillata L.*	Malvaceae	Litii	+	-	H
65	*Maytenusarbutifolia (A. Rich) Wiczek*	Celasteraceae	Bitee	+	-	S
66	*Maytenusobscura*(A.Rich) Cuf.	Celastraceae	kombolcha	+	-	S
67	*Maytenusheterophylla (Eekl and Zeyh) Robson*	Celasteraceae	Kombolcha	+	-	T

68	*Milletiaferruginea*(Hochst.) Bak.	Fabaceae	birbirraa	+	+	T
69	*MyricasalicifoliaA.Rich.*	Myricaceae	barooddoo	+	-	T
70	*Myrsineafricana* L.	Myricinaceae	qacama	+	-	S
71	*Nicotianatabacum*L.	Solanaceae	tamboo	+	-	H
72	*Nuxiacongesta*R.Br.ex.Fresen	Loganiaceae	qawwisaa	+	-	T
73	*Ocimumbasilicum L.*	Lamiaceae	basobila	+	-	H
74	Ocimumgratissimum L.	Lamiaceae	BasobilaFaranjii	+	-	S
75	Oleaeuropaeasubsp cuspidate (Wall. ex DC.) Cifferri	Oleaceae	Ejersa	+	+	T
76	*Opuntiacylinderica (Lam.) D.C.*	Cactaceae	Adaamii	+	-	T
77	*Osyrisquadrpartita*Decn	Sanatalaceae	Waatoo	+	-	T
78	*Phoenix reclinata*Jacq.	Arecaceae	meexxii	+	-	T
79	*Phytolaccadodecandra*L. 'Hèrit.	Phytolacaceae	Handoodee	+	-	S
80	*Psidiumguajava*	Myrtaceae	Zeituna	+	-	T
81	*Pittosporumviridiflorum*Sims /*Oliniarochetiana*	Pittosporaceae	Soolee	+	-	T
82	*Podocarpusfalcatus (*Thunb.) R. B.	Podocarpaceae	birbirsa	+	+	T
83	*Pouteriaadolfi-friedericii*	Sapotaceae	Qararuu	+	-	T
84	*Premnaschimperi*Engl.	Verbenaceae	urgeessaa	+	+	S
85	*Prunusafricana*(Hook. f.) Kalkm.	Rosaceae	Hoomii	+	-	T
86	*Prunuspersica*	Rosaceae	Kookii	+	-	T
87	*Pterolobiumstellatum (*Forssk.) Brenan	Fabaceae	Harangamaadiimaa	+	-	S
88	*Rhamnusprinoides*Lyterit.	Rhamnaceae	Geeshoo	+	-	S
89	*Rhamnusstaddo*A.Rich	Rhamnaceae	Qadiidaa			S
90	*Rhusglutinosa*A.Rich.	Anacardiaceae	laboobessa	+	-	T

91	*Rhus vulgaris* Meikle	Anacardiaceae	Xaaxessaa	+	+	T
92	*Ricinuscommunis L.*	Euphorbiaceae	Qobboo	+	-	S
93	*Rosa abyssinica*Lindely	Rosaceae	Inqooxoo	+	-	S
94	*Rubussteudneri*Schweinf	Rosaceae	Goraaenjoorii	+	+	S
95	*Rumexabyssinicus*Jacq.	Polygonaceae	moqimoqiii	+	-	S
96	*Rumexnervosus*	Polygonaceae	dhangaggoo	+	-	S
97	*Rutachalepensis L.*	Rutaceae	cilaatama	+	-	H
98	*Saccharumofficinarum L.*	Poaceae	shankoora	+	-	H
99	*Salix subserrata*Willd.	Salicaceae	Alaltuu	+	-	S
100	*Salvia nilotica*Jacq.	Lamiaceae	Qorichmichii	+	-	S
101	*Schreberaalata (Hochst) Welw*	Oleaceae	daalachoo	+		-
102	*ScolopiatheifoliaGilg*	Flacourtiaceae	Kelf	+		-
103	*SideroxylonoxyacanthumBaill*	Sabotaceae	Biitee	+		-
104	*Syzygiumguineense (Wild.) DC.*	Myrtaceae	baddeessaa	+	-	T
105	*Tacazzeaconferta N.E.Br.*	Asclepiadaceae	Hiddaaananno	+	-	Cl
106	*Tecleanobilis*Del. .	Rutaceae	Hadheessa	+	-	S
107	*Urerahypselodendron (A. Rich) Wedd*	Urticaceae	laanqessaa	+	-	Cl
108	*Vernoniaamygdalina Del.*	Asteraceae	eebicha	+	-	T
109	*VernoniaauriculiferaHiern*	Asteraceae	reejjii	+	-	S
110	*Ziziphusspina-christi*	Rhamnaceae	Qurquraa	+	-	T

"+ " = present ; "-" absent ; Cl woody climber; T= tree; S= shrub H=Herbs

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