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Woody Species Diversity and Carbon Sequestration in Asebot Mountain Forest, Ethiopia: Implications for Climate Change Mitigation

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Abstract

The research took place in the Asebot Mountain Forest of Hallaydeghie Asebot National Park (HANP) in Ethiopia to explore the variety of tree species and their ability to store carbon in the dry afromontane forest, which is important for fighting climate change, and to provide useful information for better management of forest resources and protection of biodiversity in the National Park. The stratified systematic sampling technique was used to conduct the forest inventory. For individual tree DBH ≥ 5 cm encountered in each plot, DBH, canopy cover and height were recorded. Carbon stock estimation for the study area was done on four carbon pools: AGC, BGC, DWC, and LHGC, using allometric equation models. Plant species diversity and evenness were undertaken using a biodiversity software application. A total of 36 plant species belonging to 25 plant families were identified. The most species-rich families were Anacardiaceae and Fabaceae (4 spp. each), followed by Apocynaceae, Combretaceae, Boraginaceae, Euphorbiaceae, Ebanaceae, Cupressaceae, Moraceae, Celastraceae and Oleaceae (2 spp. each). The total mean of 125.3987 t/ha carbon stock was estimated in Asebot mountain forest with9 t CO_2e sequestration potential. The study area had a total mean basal area of m^2 ha^{-1} and a carbon credit of 85 US dollars, estimated as a conservative value. This study indicated that Asebot mountain forest plant species were in a good regeneration status and had high potential for climate change mitigation, even if there were high anthropogenic disturbances exerted on them. Nonetheless, analysis of indigenous species such as Olea africana and Podocarpus falcatus are highly degraded for charcoal production and other livelihood benefits. Therefore, efforts should be made to conserve these species through in situ conservation, and it is highly recommended to implement sustainable forest management using an integrated and participatory approach.

Key words and phrases: Carbon Stock, Ecosystem and forest inventor

1. INTRODUCTION:

Climate change is a currentnt global issue that can affect both human health and economic growth,, especially in in developing countries due to their low level of adaptation capacity in case of insufficient economy and low technological advancement. The most effective effective mitigation measure is sequestrating terrestrial carbon dioxide through forest carbon sinkss to reduce the amount of carbon dioxide in atmospheric greenhouse gases. Forests arere the most terrestrial carbon dioxide sequesters and carbon sinks (UNFCCC, 1997).

There is a mostst interrelated relationship between forest and climate, wheree one affects the other,, and the effect of one on the other is very significant and pivotal. Climate change will affect the environmental conditions to which forest trees are adapted and expose them to new pests and diseases, thus creatingng additional challenges for forest management and threateningning the biological diversity in forest ecosystems. In addition to soils, aspect and elevation, climate dictates what will grow when, where and how well. Therefore, changes in temperature, precipitation and other climatic factors have the potential to dramatically affect forests at a nationalal level and similarly worldwide. On the reverse, climate is also shaped and strongly influenced by forests. That means forests are shaped by climate and vice versa (Tamene, 2016).

The current most global issue inthe world todayis One of the environmental matters is the global increasease of carbon dioxide in the atmosphere and its potential effect on climate change. Global warming due to surface temperature rise is mainly related to an increasease in carbon dioxide concentration in the atmosphere (Petit et al., 1999). According to Samalca et al. (2009) and Wigley (1993), when the concentration of carbon dioxide gas in the atmosphere increases, the temperature of the earth’s surface is also expected to increase. At the end of the 20th20th century,, global surface air temperature may increase by 1.4oc to 5.8oc (IPCC, 2001).

The issue of global warming has resulted in the investigationtion of innovative methods that can be used to minimise the atmospheric greenhouses' effect,ct, like carbon dioxide 2000 and 2007; Penman et al., 2003). Methods for capturing carbon dioxide are one of the primary global focuses IPCC, 2007). There are several techniques under investigation for sequestering carbon from the atmosphere. These include ocean sequestration, geological sequestration, and terrestrial sequestration (IPCC, 2000).

Carbon sequestration is the process of removing excess carbon dioxide from the atmosphere and depositing it in the reservoir (UNFCC, 1997). It is the way to mitigate the accumulation of GHGs in the atmosphere released by the burning of fossil fuel and other anthropogenic activities. While a carbon sink is a reservoir that collects and stores carbon-containing chemical compoundss, it removes carbon dioxide through absorption.

Forestss and soil are potential sinks for elevated carbon dioxide emissions and are being considered in the list of acceptable offsets (UNFCCC, 1997). Sustainable forest development and forested landscape expansion are twoo of the key approaches for reducing atmospheric carbon concentration. It is a safe, environmentally acceptable, and cost-effective way to capture and store substantial amounts of atmospheric carbon. The concurrent development of tradable carbon credits provides financial incentives for considering carbon storage in forest management decisions (Siry t al., 2006). Managing forests through agroforestry, forestry and plantation systems is seen as an important opportunity for climate change mitigation and adaptation (IPCC 2007, Canadell, and Raupach 2008).

A number of protected areas form the backbone of of habitat and biodiversity protection in Ethiopia,, which are managed by different institutions at the nationalonal, regional, and local levelss that are highly fragmented. They lack technical and financial capacities, as well as instruments to address the increasing anthropogenic encroachment and to mitigate the impact of climate disasters (Ueli nd Karin, 2016).

Hallaydeghie Asebot NationalPark is a newly developing Ethiopian national park partiallyfrom the wildlifelife reserve area from the AfarAfar side (Hallaydeghie Wildlife Reserve area) and the Asebotebot mountain forest reserve area from the Oromiaomia side by incorporating the grasslandand stem intoto the forestrest ecosystem. Even if ome studies were conducted on Asebot Mount Forest, they did not provide holistic information on wood species diversity and carbon sequestration potential for carbon sinks, and its contribution to climate change mitigation was not yet studied.

Therefore, this study will undertake Woody Species Diversity and Carbon Sequestration Potential of Asebot Mountain Dry Afromontane Forest: Implications for Mitigation of Climate Change, Hallaydegie Asebot National Park, Ethiopia, incorporating these specific objects: -

1. To identify woody species diversity of Asebot mountain ecosystem of Hallaydeghie Asebot National Park (HAPNP).
2. To estimate carbon stock potential of the forest (Above ground, below ground, Dead wood, and litter carbon pools).
3. To determine which plant species can store more carbon along altitudinal gradient
4. To understand the value of protected area in carbon sequestration and carbon credit values.

2. MATERIALS AND METHODS

2.1. The Study Area Description

The study was conducted at Asebot Mountain, a dry afro-montane forest in Hallaydeghie Asebot National Park, which is located between the Affar and Oromia regional administrative states in the northeastern part of Ethiopia. Hallaydeghie Asebot National Park is a newly upgraded national park of the country from two conservation areas: Hallaydeghie wildlife reserve area and Asebot mountain forest reserve area. Hallaydeghie Wildlife Reserve was established in the 1960s as a wildlife reserve area when most of Ethiopia's Wildlife Protected Areas were designated (Hillman, 1993). Asebot Mountain Forest is one of the dry evergreen montane forests of Ethiopia that was established during the 12th century by an Ethiopian saint, Aba/Father Samuel, R. Hiranmai, and Eyasu. (2013). It has two monasteries/churches: Debre Wegeg Aba Samuel, belonging to nuns, and Debre Wegeg Kidist Silassie, which is belonging to monks. The area is found Great Rift Valley in the southwestern Afar and Oromiya Regional Administrative State, between 9°09'49 and 9°37'20" North latitudes and0°18'39" and 40°38'01" East longitudes, with an area coverage of 1099 km². The elevation ranges from 900 m to 2506 m a.s.l. Hallaydeghie Asebot National Park is the only protected area of Ethiopia that has a large population of endangered Grev`y's zebras in the country. The principal aim for the establishment of the upgrading National Park was to protect the endangered Grevy's zebra (Equus grevyi), Beisa oryx (Oryx beisa beisa), Soemmerring's gazelle (Gazella soemmeringi), gerenuk (Litocranius walleri), cheetah (Acinonyx jubatus), leopard (Panthera pardus), lion (Panthera leo), lesser kudu (Tragelaphus imberbis), black-backed and common jackals, caracal, serval cat and wildcats and many others. Gravy's zebra (Equus grevyi) is the flagship species which is commonly found in Hallaydeghie plain grassland and wooded grassland of the park all year. The park is also a habitat for more than 213 species of birds, two of which are globally threatened species (EWNHS, 1996). From the total migratory bird species documented in Ethiopia, 457, over 52%, were found in and around Hallaydeghie Asebot and Awash National Parks (Kassaye and Arega, 2013).

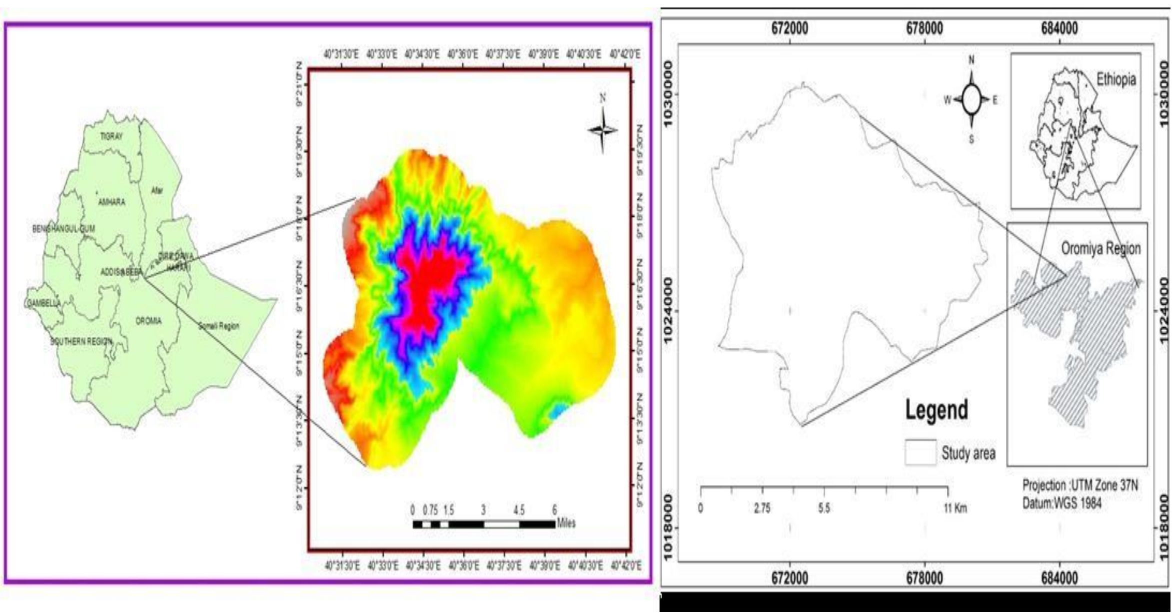

Figure: 1.1. Map of Asabot dry Afromontane forest (Tulu, 2018).

The study area is characterised by arid and semi-arid climatic conditions in the Rift Valley region. Its mean annual rainfall is 793.9 mm, with the mean annual minimum temperature 4.2-21.6 °C and the mean annual maximum temperature 21.6-37.1 °C. The main long rainy season is between June and August, and the short rainy season is between March and May. Generally, rainfall decreases towards the lowland of the northern and northwestern parts of the forest with an increase in temperature and decrease in altitude (Adefires and Worku, 2008).

The Western Harerge zone is dominated by shallow inceptisol; in the Chercher areas, soil ranges from grey to brown and is often stony (Adefires and Worku, 2008). The southern part of the forest with such soil type has been found to be suitable for farming, where farmers grow sorghum, maize, chat and other vegetables around homesteads. The two tree species Juniperus procera and Prunus africana, which are listed in the IUCN Red List, are mostly found in church forests and the Asebot mountain forest (IUCN, 2006). Asebot mountain forest is mostly covered by the East African dry afromontane vegetation, such as Juniperus procera, Podocarpus falcatus, Olea africana, Acacia abyssinica, Crotocroton marcrostachyus, Dodonaea angustifolia, Acacia etbaica, Carissa spinarum, Terminalia species and others predominating the low-lying parts of the mountain (Adefires and Worku , 2008).

2.2. Data Collection Methods

Woody species inventory was applied for the purpose of plant species identification, DBH, Height, biomass, carbon stock and sequestration potential measurement through different sample plot designs based on the study parameters. Three line transects consists of 10m*20m purposively sampling plots laid along transects based on altitudinal variation of the study site was taken while caliper/measuring tape at breast height (DBH, 1.3m) was used to estimate biomass and the size class distribution of trees in a sampling plot. Trees with multiple stems connected near the ground were counted as single individuals and stem circumference was measured separately. To collect samples of herbs, litters and grass 1m*1m subplots was established on each four rectangular corners and in the center of the sample plots following the line transacts.

The topography of Asebot mountain forest ecosystem was down and up, plateaus and hills with varies vegetation structure and plant species diversity. Due to these reasons, the distance between lines transects and sample plots were ranged between 50m-100m based on the topography and density of the forest during woody species inventory survey

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2.2.1. Tree Height, age, basal area and canopy Measurement

Tree height is defined to be the perpendicular distance between the ground level and the top of the tree that is used to estimate or determine the volume of a tree. Tree height was measured using clinometers. According to Zerihun and Yemiru, (2013), we can measure tree height by;

$$\boldsymbol{Ht} = \left(\frac{\boldsymbol{TR-BR}}{\boldsymbol{100}}\right) \times \boldsymbol{D}$$

Ht: Tree height, TR: Top reading, BR: Bottom reading and D: distance between the observer and the base of the tree.

Tree age measurement is necessary to identify at what age trees can sequestrate more carbon dioxide and to determine age influence on trees carbon stock potential. To measure the age of trees in conservation principle, to do this species growth factor is mandatory. As Jens et, al, (2016) A tree's growth factor is the measurement of the width it gains annually. If you know the average annual width of tree ring for that species, you can multiply it by the diameter of the trunk to estimate the tree's age. Different species' growth factors are dependent on their environment - for example, forest trees grow faster than city trees - so this method for determining a tree's age is truly an estimate.

$$\boldsymbol{Tree\ age} = \boldsymbol{Diameter} * \boldsymbol{Tree\ growth\ factor}$$

The main challenge here was that getting species growth factor for each species especially for indigenous plant species. Therefore tree age was done only for the species whose growth factor was available on the database of *useful tropical plants.*

Basal area (BA): Basal area of vegetation refers to the area outline of a plant near ground surface. Basal area calculations will make on the diameter measurements of the stem with DBH of >2.5 cm. It is the actual space covered by the tree and shrub stems. Plants with the largest contribution to basal area are considered as the most important woody species in the forest (Cain and Castro, 1959; cited Mueller-Dombois and Ellenberg, 1994). It is expressed in square centimeter/hectare (cm^2/ha) or m^2/ha. There is a direct relationship between DBH and basal area. Its area is also used to calculate the dominance of species. Basal area was calculated from the general formula:

$\mathrm{BA} = \frac{\boldsymbol{\pi(d)^2}}{\boldsymbol{4}}$ Where, d = Average diameter at breast height a species (m),

$d = \frac{\pi}{\ }$ Where C circumference, π = mathematical symbol (3.14) (Mueller-Dombois and Ellen berg, 1974).

To estimate the amount of canopy cover for each tree measured in the inventory, densiometer method was used. The densitometer had ten grids and by following the grids under the tree number of canopy cover and number of sky cover was counted from four directions. Number of canopy and sky cover was scaled out of ten and the average ratio of canopy and sky cover for each tree was taken. Finally, for each species and sample plot average ratio was taken to estimate the percentage of canopy cover.

The assumption was taken for trees near to together and shares the same canopy crown cover. To assess cover of over story trees (D.B.H. 5.0+ inches), overlapping crowns from neighboring trees were combined such that crown overlap was accounted for, i.e., the cover as it would appear as viewed from above.

2.2.2. Forest Carbon Stock Measurement in different pools

The methods and procedures used to estimate carbon stocks was simply step by step procedures using standard carbon inventory principles and techniques (Pearson *et al.,* 2005). Procedures was based on data collection and analysis of carbon accumulating in the above ground biomass, below-ground biomass, leaf litter, and dead wood carbon of forests using a verified allometric equation methods.

2.2.2.1. Above Ground Biomass (AGB)

The linear regression equation approach was used by the process of selecting regression equation that best fit to the condition of the study area. The Asebot mountain forest has trees with diameter at breast height greater than 5cm and annual rain fall 793.9mm.These conditions falls in the criteria's of Brown *et al* (1989), linear regression equation to calculate the above ground biomass as given below:

$$\boldsymbol{AGB = 34.4703 - 8.0671(DBH) + 0.6589((DBH)^2) \ldots \ldots (equ \ldots 1)}$$

Where, AGB is above ground biomass, DBH is diameter at breast height

Table: 1: Regression equations used by different authors for the estimation of above ground biomass as a function of DBH for general species group.

Equations	Source/Author	General characteristics	Max. DBH
$Biomass = 10(-0.535 + log10basal\ area)$	Brown (1997)	Dry (<900mm rain fall)	30cm
$Y = 10(-0.535 + log10(\pi xr^2)$	FAO (2004)	Dry (<900mm rain fall)	<30cm
$Y = 34.4703 - 8.0671(DBH) + 0.6589(DBH^2)$	Winrock from Brown *et al*, (1989)	Dry (<1500 rain fall)	≥5cm
$Y = \exp\{-2.134 + 2.530xln(DBH)\}$	FAO (2004)	Moist (rain fall 1500-4000mm)	<80cm
$Y = \exp\{-1.996 + 2.32xln(DBH)\}$	FAO (1997)	Dry transition to moist (rain fall >900mm)	5-40cm

2.2.2.2. Estimation of Below Ground Carbon Stock (BGC)

Below ground biomass carbon is directly derived from aboveground plantation carbon using known conversion factors due to it is more complex and time consuming (Geider et al., 2001 cited in Tibebu Y, 2015). Below ground root biomass is projected using root to shoot ratio which varies 20 to 50% depending on species. Though, for carbon accounting purposes conservative values are recommended. Accordingly 20% was used as a conversion factor for below ground biomass from above ground biomass as also recommended by MacD icken (1997); standard method for estimation of below ground biomass can be obtained as 20% of above ground tree biomass i.e., root to shoot ratio value of 1:5 was used. Accordingly BGC was estimated as follows;

$$\boldsymbol{BGB = AGB \times 0.2 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (equ \ldots . 2)}$$

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

2.2.2.3. Estimation of Carbon Stocks in Dead Wood (DWB)

The allometric condition affirmed in REDD philosophy (2009) was utilized to appraise the measure of biomass in standing dead wood.

$$\boldsymbol{DWB = \sum_{n=0}^{i} {}^{1}/_{3} \left({}^{D}/_{200}\right)^2 h * s \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (equ \ldots . 3)}$$

Where, biomass is communicated in kg, h = length (m), D = tree distance across (cm) and s = particular gravity (g cm-3) of wood. The particular thickness was assessed at 0.5 g cm-3 as default esteem, yet can be around 0.8 for thick hard woods and around 0.3 for light species in tropical locales (Hairiah et al., 2001).

The carbon content in dead wood was computed by duplicating absolute biomass of dead wood with the IPCC (2006) default carbon portion of **0.47.**

2.2.2.4. Litters Biomass (LB)

The leaf litter is all dead organic material on top of surface soil. The litter biomass sample was collected within 1m*1m subplots established in the four corners and in the center of sample plots designed. The Sum up of collected litters from the five sub plots was taken as wet weight/ field weight and the average mixture of the litter sample was taken as fresh weight taken to laboratory analysis and oven dried at 105^{O}C within 24 hour (see appendix…1).

$$\boldsymbol{LB = \frac{Wfield}{A} * \frac{Wsub\ sample\ dry}{Wsub\ sample\ fresh} * \frac{1}{10,000} \ldots \ldots \ldots (equ \ldots 4)}$$

Where: LB = Litter biomass (ha-1)
W field = Weight of wet field sample of litter sample within an area of size 1m*1m (g);
A = Size of the area in which litter was collected (ha)
W sub-sample, dry = Weight of the oven-dried sub-sample of litter taken to the laboratory to determine moisture content (g), and

W sub-sample, fresh = Weight of the fresh sub-sample of litter taken to the laboratory to determine moisture content (g).

In all different tissue types and species the carbon content of vegetation is amazingly constant. Carbon content of biomass is almost found between 45 to 50% by oven dry mass (Schlesinger, 1991, as cited in Tibebu Y, 2015). In consideration of this standard, the carbon content of litter vegetation was estimated by simply taking a fraction of the biomass by multiplying 0.5.

$\boldsymbol{C = 0.5 * LB}$ Where C= is carbon content by mass, and LB= is oven- dry biomass. Therefore, total carbons content of litter (ton/ha) =Total dry litter biomass* carbon fraction

$$\boldsymbol{CL = LBM * \%C} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\boldsymbol{equ \ldots..5})$$

Where, CL is total carbon stocks in the litter in ton/ha, %C is carbon fraction determined in the laboratory (Pearson et al., 2005).

2.2.2.5. Estimation of Total Carbon Stock Density of the study area

The aggregate carbon stock was figured by summing the carbon stock densities of the individual carbon pools of the stratum utilizing the Pearson et al. (2005) recipe. Carbon stock thickness of an examination region:

$$\boldsymbol{CT = AGC + BGC + LC + DWC} \ldots\ldots\ldots\ldots. (\boldsymbol{equ \ldots.\ldots.6})$$

Where, CT = Total Carbon stock for all pools (ton/ha), AGC=above ground carbon stock (ton/ha), BGC= underneath ground carbon stock (ton/ha), LC=litter carbon stock (ton/ha) and DWC= Dead Wood carbon (ton/ha). The aggregate carbon stock was then changed over to huge amounts of CO2 comparable by duplicating it by 44/12, or 3.67 as showed by (Pearson et al., 2007).

2.2.3. Carbon Finance Value Calculation

The carbon finance value has great difference across different marketing mechanisms and crosswise time. It is partly administered by the supply and demand of carbon counterbalances. In 2012-2013, most of the carbon projects had a counterbalance average values $6.5/tCO2e. Most of the carbon offsets were REDD+ projects, and currently there is an increasing trend of market saturation which would even make the carbon counterbalance value to be lower (Nicholas, 2014). Therefore an average conservative value of 6.5$/ tCO2e was used for the carbon finance value calculation of the study area.

2.2.4. Data Analysis and Interpretation

The data gathered during data collection was recorded in Microsoft excel to use properly for quantitative calculations. After properly inserting raw data in to Microsoft excel the data gathered was analyzed by using SPSS software to describe the correlation between vegetation type, altitudinal variation, vegetation structure and carbon stock potential of the area. The output of the study was interpreted by using statistical analysis like pie chart, table, graph, and bar graph.

RESULT AND DISCUSSION

3. 1. Result

3.1.1. List of Woody Species recorded, DBH, Height, Basal Area and Age Estimation

During data collection 36 woody species was recorded that categorized in twenty five families; *Juniperus procera* was the abundant species that 71 species of 502 means 17.4% of the total species. *Jacaranda mimosifolia* was the second abundant following *Olea africana which counts 68 and 56 respectively.*

Table: 2. Woody species recorded, Number of individual species and relative abundance of each species of the study area.

S/No.	Species Name	Family Name	Local/Common Name	No. species recorded	Relative Abundance (Pi)
1	*Acacia abyssinica*	*Fabaceae*	Laaftoo/Girar	17	0.033864542
2	*Acacia nilotica*	*Fabaceae*		4	0.007968127
3	*Acacia Senegal*	*Fabaceae*		2	0.003984064
4	*Acokanthera schimperi*	*Apocynaceae*	Qararoo/Mirez	2	0.003984064
5	*Bridelia micrantha*	*Phyllanthaceae*		1	0.001992032
6	*Buddleia polystachya fresen*	*Loganiaceae*	Anfare/Nachilo	6	0.011952191
7	*Celtis Africana*	*Scrophulariaceae*	Qayii/Qawut	5	0.009960159
8	*Combretum collinum*	*Ulmaceae*	Aballo Bale key pod	10	0.019920319
9	*Combretum molle*	*Combretaceae*	Aballo	7	0.013944223
10	*Cordia Africana*	*Combretaceae*	Waddeessa/Wanza	12	0.023904382
11	*Croton macrostachyus*	*Boraginaceae*	Makkaannisa/Bisanna	5	0.009960159
12	*Cupressus lusitanica*	*Euphorbiaceae*	Yeferenj Tsid	2	0.003984064
13	*Cussonia holstii*	*Cupressaceae*		1	0.001992032
14	*Diospyros abyssinica*	*Araliaceae*	Slecheng	4	0.007968127
15	*Dodonaea viscosa*	*Ebenaceae*	Kitkita	7	0.013944223
16	*Ehretia cymosa*	*Sapindaceae*		12	0.023904382
17	*Eucalyptus globulus labill.*	*Boraginaceae*	Nechi bahirzaf	12	0.023904382
18	*Euclea racemosa*	*Myrtaceae*	Dodoho	8	0.015936255
19	*Ficus sur*	*Ebenaceae*	Harbu/Shola	3	0.005976096
20	*Ficus sycomorus*	*Moraceae*	Shibaha	13	0.025896414
21	*Grewia bicolor*	*Moraceae*	Safa	24	0.047808765
22	*Jacaranda mimosifolia*	*Tiliaceae*	Jacaranda	68	0.135458167
23	*Juniperus procera*	*Bignoniaceae*	Yehabesha Tsid	71	0.141434263
24	*Maytenus arbutifolia*	*Cupressaceae*	Komblcha/Sete Atat	29	0.057768924
25	*Millettia ferruginea*	*Celastraceae*	Cheka/Digita	8	0.015936255
26	*Olea africana / europaea*	*Fabaceae*	Ejersa/Weira	56	0.111553785
27	*Olea capensis hochstetteri*	*Oleaceae*	Ejersa Adii/Nech Weira	2	0.003984064
28	*Podocarpus falcatus*	*Oleaceae*	Birbirsa/Zigba	21	0.041832669
29	*Premna schimperi*	*Podocarpaceae*	Chachaho	14	0.027888446
30	*Prunus Africana*	*Verbenaceae*	Hadheessa/Tikur inchet	7	0.013944223
31	*Psydrax schimperiana*	*Rosaceae*	Seged	32	0.06374502
32	*Rhus glutinosa*	*Rubiaceae*	Qamo	17	0.033864542
33	*Rhus natalensis*	*Anacardiaceae*	Tikama	1	0.001992032
34	*Rhus retinorrhoea*	*Anacardiaceae*	Abbayyii/Tilem	14	0.027888446
35	*Schinus molle*		Kundo berbere	1	0.001992032
36	*Sterculia setigera*	*Anacardiaceae*	Lukaluke	4	0.007968127

Eucalyptus globulus had highest average DBH value, average height and basal area that 51.09cm, 15.9 m and 2335.64sq.cm respectively. The second highest DBH and basal area was Juniperus procera 36 cm and 1381.85sq.cm. Grewia bicolor, Dodonaea viscosa and Euclea racemosa were the lowest DBH estimated 8.28, 8.84 and 9.55cm respectively. For the species whose growth factor available on the website of Useful Tropical Plant; tree age was estimated. As the result shows Olea africana/ Europaea and Eucalyptus globulus are the long aged species 123.9 and 100.2 years respectively; while Cupressus lusitanica and Cordia africana were the short aged species 24.2 and 30.5 valued. The total mean basal area of the species registered in the forest was 2.198m2.ha-1

Most of the species were falls in the average DBH values between 10-20cm, while more of them falls between 20-30cm. Around 18 species have average DBH value of 10-20cm that accounts 50% of the species identified in the area. The second range of DBH value was 20-30cm that contains 11 species 30.56% of the total species identified. The other 4 species average DBH value was less than 10cm and the rest 3 species above 30-40cm. Only 1 species has 51.09cm average DBH value.

The height of most species was found between 5-10m that was 21 species which accounts 58.33% of the recorded species. Nine of them fall in the range of less than 5m while five species had 10-15m average height. Only one species *(Eucalyptus globulus) had the average height of 15.09m*

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Table 3: The species average DBH, Height, BA and Age

Sp. Code	Species Name	Av. DBH in cm	AV. Height in m	Av. BA in cm^2	Av. Tree age in years
Sp. 1	*Acacia abyssinica*	23.77	6.29	503.86	95
Sp. 2	*Acacia nilotica*	15.45	5.33	199.64	
Sp. 3	*Acacia Senegal*	14.65	5.4	174.92	
Sp. 4	*Acokanthera schimperi*	13.06	5.90	141.80	
Sp. 5	*Bridelia sicrantha*	32.17	12.10	812.18	
Sp. 6	*Buddleia polystachya fresen*	10.99	5.18	102.40	
Sp. 7	*Celtis Africana*	17.37	7.49	279.66	
Sp. 8	*Combretum collinum*	22.19	7.2	463.93	
Sp. 9	*Combretum molle*	15.22	5.53	204.89	
Sp.10	*Cordia Africana*	26.75	9	561.78	30.5
SP.11	*Croton macrostachyus*	18.79	7.13	316.71	
Sp.12	*Cupressus lusitanica*	12.10	5.7	114.97	24.2
Sp.13	*Cussonia holstii*	9.87	5	76.51	
Sp.14	*Diospyros abyssinica*	32.49	7.95	854.14	
Sp.15	*Dodonaea viscosa*	8.84	5.95	64.59	
Sp.16	*Ehretia cymosa*	13.91	5.83	170.51	
Sp.17	*Eucalyptus globulus .*	51.09	15.9	2335.64	100.2
Sp.18	*Euclea racemosa*	9.55	5.93	74.2	
Sp.19	*Ficus sur*	28.41	10.61	1025.33	39.8
Sp.20	*Ficus sycomorus*	26.79	8.32	778.04	
Sp.21	*Grewia bicolor*	8.28	5.88	53.82	
Sp.22	*Jacaranda mimosifolia*	26.58	9.53	572.61	
Sp.23	*Juniperus procera*	36	11.06	1381.85	57.6
Sp.24	*Maytenus arbutifolia*	16.61	6.37	264.45	
Sp.25	*Millettia ferruginea*	10.75	5.38	99.46	
Sp.26	*Olea africana / Europaea*	29.5	9.49	879.89	123.9
Sp.27	*Olea capensis*	15.66	6.88	232.36	
Sp.28	*Podocarpus falcatus*	30.5	12.6	1087.08	
Sp.29	*Premna schimperi*	10.83	8.8	92.04	
Sp.30	*Prunus Africana*	13.62	6.34	201.47	81.7
Sp.31	*Psydrax schimperiana*	20.69	6.97	405.52	
Sp.32	*Rhus glutinosa*	14.33	5.4	179.14	
Sp.33	*Rhus natalensis*	15.29	10.01	183.44	
Sp.34	*Rhus retinorrhoea*	12.31	5.1	134.73	
Sp.35	*Schinus molle*	24.52	5.6	472.05	
Sp.36	*Sterculia setigera*	19.5	7.45	324.62	
	Total mean average			439.45	

3.1.1.2. Forest canopy Estimation

Acacia senegal, Rhus glutinosa and Cussonia holstii was the highest coverage species with average percentage of 81.25, 71.25 and 70 respectively. While Diospyros abyssinica, Cupressus lustanica and Acacia nilotica was the lowest forest coverage species that have percentage coverage of 22.25, 25 and 33.75 respectively. Forest species that have high canopy cover has pivotal roles in biodiversity conservation and carbon stock potential see appendix 3. 4.1.1.5. Carbon Stock Potentials of the area in different pools

The highest forest coverage was registered in plots 24, 21 and 23 that have the percentage of 138.38, 118.95 and 115.48 respectively. The lowest forest coverage was gained in plots 39, 36 and 29 with the percentage coverage of 28.89, 30 and 38.06 respectively (see appendix…1).

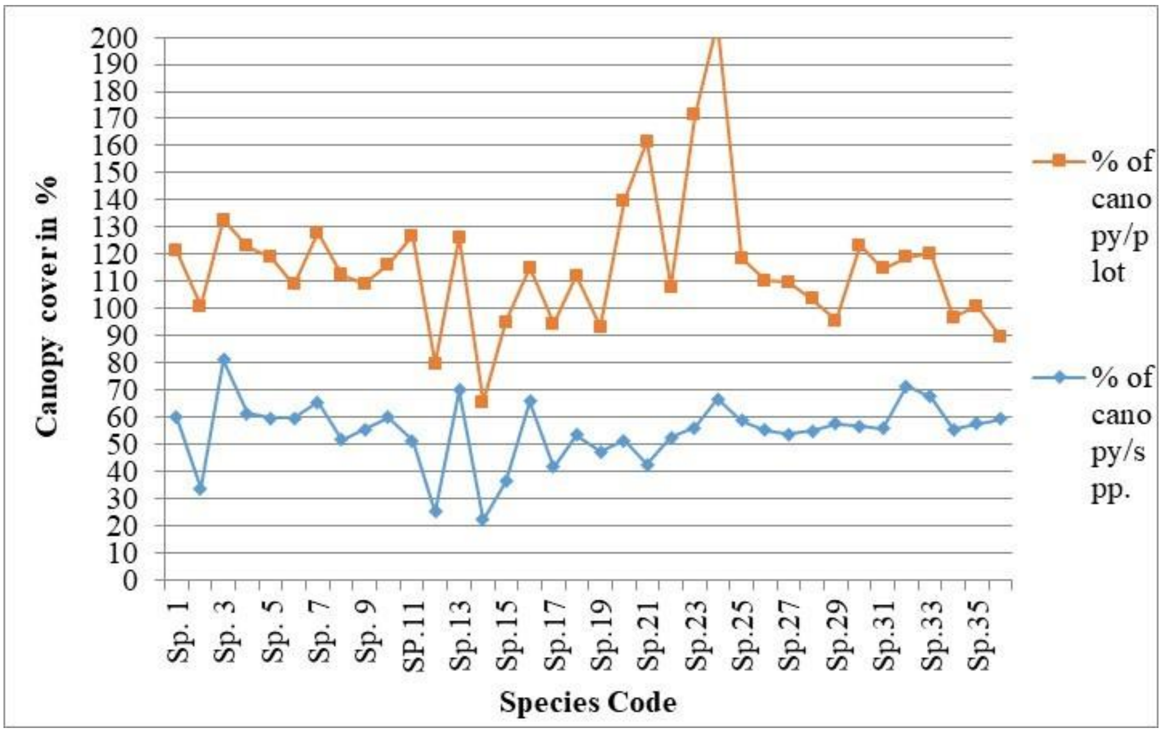

Figure: 2. Average coverage percentage of the species both per plot and per **species**

3.1.2.1. Above Ground and Below Ground Carbon Stock

The above ground carbon stock of the area was estimated for each individual tree. The estimated each individual tree was categorized as their species category and their carbon stock potential was calculated by summing up the value of the individual trees. The above ground carbon stock of the plots was estimated by summing the carbon stock values of every individual tree in the plot. Accordingly, plot number 27, 29 and 19 were the highest above ground carbon stock registered with value of 9.876, 8.679 and 8.511ton/plot respectively. While plot number 37, 50 and 30 were the lowest carbon stock registered in the area that have 0.065, 0.116 and 0.198 ton/plot. Totally, the above ground carbon stock of the area was 100.73778 ton/ha see appendix 5.

A plant biomass and carbon stock has direct relationship. Tree species that have high biomass have high carbon stock potential because the carbon stock potential of any species is 50% its biomass content according to allometric equation.

Below ground carbon stock is based on the above ground biomass of the species as allometric equation of carbon stock estimation. Below ground biomass has a direct relationship with the above ground biomass that is 20% the above ground biomass of the species. Below ground carbon stock potential of every individual tree and each plots were estimated. The average value of the individual tree was taken to estimate below ground carbon stock of the species. Accordingly, the total below ground biomass estimated was 49.22724t/ha and total below ground carbon stock estimated was 24.61561ton/ha see appendix 6.

Table: 4.The above ground biomass, Below Ground Biomass and their carbon stock potential of the area per plots in ton.

Plot	Longitude	Latitude	Altitude	AGB	AGC	BGB	BGC
Pl. 1	0673877	1026774	2244 m.a.s.l	1.25777	0.62889	0.25155	0.12578
Pl. 2	0673903	1026710	2260 m.a.s.l	1.6487	0.82435	0.32974	0.16487
Pl. 3	0673909	1026644	2273 m.a.s.l	2.56335	1.28167	0.51267	0.25633
Pl. 4	0673907	1026533	2285 m.a.s.l	3.77859	1.88929	1.15767	0.57884
Pl. 5	0673901	1026432	2293 m.a.s.l	3.23632	1.61826	0.6473	0.32365
Pl. 6	0673882	1026337	2303 m.a.s.l	1.41037	0.70518	0.28207	0.14104
Pl. 7	0673875	1026213	2318 m.a.s.l	5.04243	2.52122	1.00849	0.50424
Pl. 8	0673856	1026102	2320 m.a.s.l	6.83721	3.41861	1.38961	0.6948
Pl. 9	0673809	1026010	2336 m.a.s.l	4.80855	2.40427	9.6171	4.80855
Pl. 10	0673809	1025888	2365 m.a.s.l	7.15204	3.57662	1.43041	0.7152
Pl. 11	0673705	1025823	2374 m.a.s.l	1.14329	0.57164	0.22866	0.11433
Pl. 12	0673568	1025843	2396 m.a.s.l	2.4555	1.22775	0.4911	0.24555
Pl. 13	0673603	1025827	2401 m.a.s.l	5.89165	2.94582	1.17833	0.58916
Pl. 14	0673354	1025840	2408 m.a.s.l	0.98244	0.49122	0.19649	0.09824
Pl. 15	0673263	1025754	2430 m.a.s.l	0.60396	0.30198	0.12079	0.0604
Pl. 16	0675008	1026504	2164 m.a.s.l	2.09398	1.04699	0.4188	0.2094
Pl. 17	0674925	1026558	2178 m.a.s.l	0.70703	0.35351	0.14141	0.0707
Pl. 18	0674829	1026518	2194 m.a.s.l	4.47993	2.23997	0.75496	0.37748
Pl. 19	0674650	1026194	2228 m.a.s.l	17.02222	8.51111	3.40444	1.70222
Pl. 20	0674733	1026144	2336 m.a.s.l	10.1234	5.0617	2.02468	1.01234
Pl. 21	0674845	1026115	2245 m.a.s.l	10.32208	5.16104	2.06442	1.03221
Pl. 22	0674903	1026027	2243 m.a.s.l	0.48586	0.24293	0.09717	0.04859
Pl. 23	0674584	1026144	2243 m.a.s.l	8.24293	4.12146	1.64859	0.82429
Pl. 24	0674492	1026175	2248 m.a.s.l	10.45564	5.22782	2.09113	1.04556
Pl. 25	0674388	1026134	2256 m.a.s.l	5.21954	2.60977	1.04391	0.52195
Pl. 26	0674258	1026041	2275 m.a.s.l	5.93821	2.96911	1.18764	0.59382
Pl. 27	0674162	1025987	2302 m.a.s.l	19.75111	9.87556	3.95022	1.97511
Pl. 28	0674073	1025969	2336 m.a.s.l	2.39306	1.19653	0.47861	0.23931
Pl. 29	0673782	1025965	2382 m.a.s.l	17.35806	8.67903	3.47161	1.73581
Pl. 30	0673897	1025904	2391 m.a.s.l	0.39607	0.19803	0.07921	0.03961
Pl. 31	0674306	1025958	2264 m.a.s.l	9.09602	4.54801	1.8192	0.9096
Pl. 32	0674266	1025858	2247 m.a.s.l	0.44358	0.22179	0.08872	0.04436
Pl. 33	0674172	1025862	2235 m.a.s.l	2.85682	1.42841	0.57136	0.28568
Pl. 34	0674088	1025666	2213 m.a.s.l	5.02457	2.51259	1.00491	0.50246
Pl. 35	0674042	1025582	2207 m.a.s.l	0.95798	0.47899	0.1916	0.0958
Pl. 36	0674148	1025651	2188 m.a.s.l	4.44812	2.22406	0.88962	0.44481
Pl. 37	0674161	1025548	2139 m.a.s.l	0.13032	0.06516	0.02006	0.01303
Pl. 38	0674270	1025561	2105 m.a.s.l	2.10393	1.05197	0.42079	0.21039
Pl. 39	0674416	1025514	2090 m.a.s.l	1.16338	0.58169	0.23268	0.11634
Pl. 40	0674523	1025498	2070 m.a.s.l	3.69808	1.84904	0.73962	0.36981
Pl. 41	0674609	1025436	2059 m.a.s.l	0.75003	0.37502	0.15001	0.075
Pl. 42	0674772	1025295	2024 m.a.s.l	1.4461	0.72305	0.28922	0.14461
Pl. 43	0674972	1025287	1983 m.a.s.l	0.823	0.4115	0.1646	0.0823
Pl. 44	0675072	1025115	1939 m.a.s.l	0.27216	0.13608	0.05443	0.02722
Pl. 45	0675104	1024915	1918 m.a.s.l	1.72779	0.86389	0.34556	0.17278
Pl. 46	0675241	1024757	1879 m.a.s.l	1.10835	0.55418	0.22167	0.11084
Pl. 47	0675244	1024545	1852 m.a.s.l	0.31193	0.15596	0.06239	0.03119
Pl. 48	0675217	1024349	1824 m.a.s.l	0.51493	0.25747	0.10299	0.05149
Pl. 49	0675259	1024145	1778 m.a.s.l	0.56242	0.28121	0.11248	0.05624
Pl. 50	0675028	1024190	1738 m.a.s.l	0.23276	0.11638	0.04655	0.02228
Total				**201.47356**	**100.73778**	**49.22724**	**24.61561**

The highest below ground carbon stock was registered in plot number 9, 27, 29 and 19 with the estimated value of 4.809, 1.975, 1.736 and 1.702 ton/plot respectively. The

3.1.2.2. Dead Wood Carbon Stock

Unfortunately no fallen dead wood was recorded in the area. Stand dead woods were recorded in the area with the total carbon stock content of 0.899Cton. The highest DWC is registered in plot 10 which contains 0.476 that is 52.9% of the sample plots. Plot number 21 and 37 contains 12% and 11.3 % respectively. The rest DWC is shared by the rest 8 plots. From 50 total plots of the study area dead wood was recorded only in 11 plots. Olea africana (Ejersa/Weira) was the dominant dead wood registered in the area which covers 31.6% of the species recorded. Juniperus procera store more carbon than the others which was 0.356cton.that was 39.6% of DWC estimated in the area. Generally, the total mean average of dead wood carbon stock of the study area was 0.045ton/ha. lowest below ground carbon stock was registered in plot number 37, 50 and 44 that have the estimated value of 0.010, 0.023 and 0.027 ton/plot of carbon stock potential.

3.1.2.3. Litters, Herbs and Grass Carbon Stock

The litters, herbs and grass carbon stock of the study area was done by collecting samples in each five subplots of sample plots and the average representative weight of the litters was taken to the laboratory oven dried. After the whole process total LHGC 0.03510/plot was gained. The highest LHGC was recorded in plots number 50, 47 and 32 that 0.004174, 0.00185 and 0.001021kg/plot. The rest of plots had lowest and almost similar carbon stock potentials in the study area. The carbon stock potential of LHG/ha in the study area was 0.30701kg/ha or 0.00031ton/ha (see appendix ...2).

Table: 5: Dead wood carbon stock of the area per species in kg

Plots	Species Name	DBH in cm	Height in m	DWB	DWC	Total DWB/pl	Total DWC/pl	Total DWC/ha
5	*Acacia abyssinica*	23.25	9.9	0.036	0.017	0.036	0.017	0.85
10	*Juniperus procera*	63.69	28	0.757	0.356	1.012	0.476	23.8
	Olea africana	52.23	14	0.255	0.120			
17	*Dodonaea viscosa*	11.15	4	0.003	0.002	0.003	0.002	0.1
20	*Olea africana*	38.85	9.6	0.097	0.045	0.118	0.055	2.75
	Maytenus arbutifolia	19.11	8.5	0.021	0.010			
21	*Celtis africana*	52.55	12.5	0.230	0.108	0.230	0.108	5.4
28	*Eucalyptus globulus*	42.99	9.1	0.112	0.053	0.112	0.053	2.65
30	*Olea africana*	33.76	11	0.084	0.039	0.084	0.039	1.95
34	*Dodonaea viscosa*	12.74	3.3	0.004	0.002		0.005	0.25
	Dodonaea viscosa	14.33	5.4	0.007	0.003	0.011		
36	*Olea capensis*	13.38	4.4	0.005	0.002	0.005	0.002	0.1
37	*Psydrax schimperiana*	29.94	2.75	0.016	0.008	0.216	0.102	5.1
	Psydrax schimperiana	31.85	7	0.047	0.022			
	Olea africana	40.76	5.4	0.060	0.028			
	Olea africana	44.59	7.04	0.093	0.044			
40	*Olea africana*	19.11	3.5	0.009	0.004	0.086	0.041	2.05
	Psydrax schimperiana	17.52	5.95	0.012	0.006			
	Celtis africana	19.6	19.6	0.065	0.031			
Average in ton							**0.0075**	**45= 0.045ton**

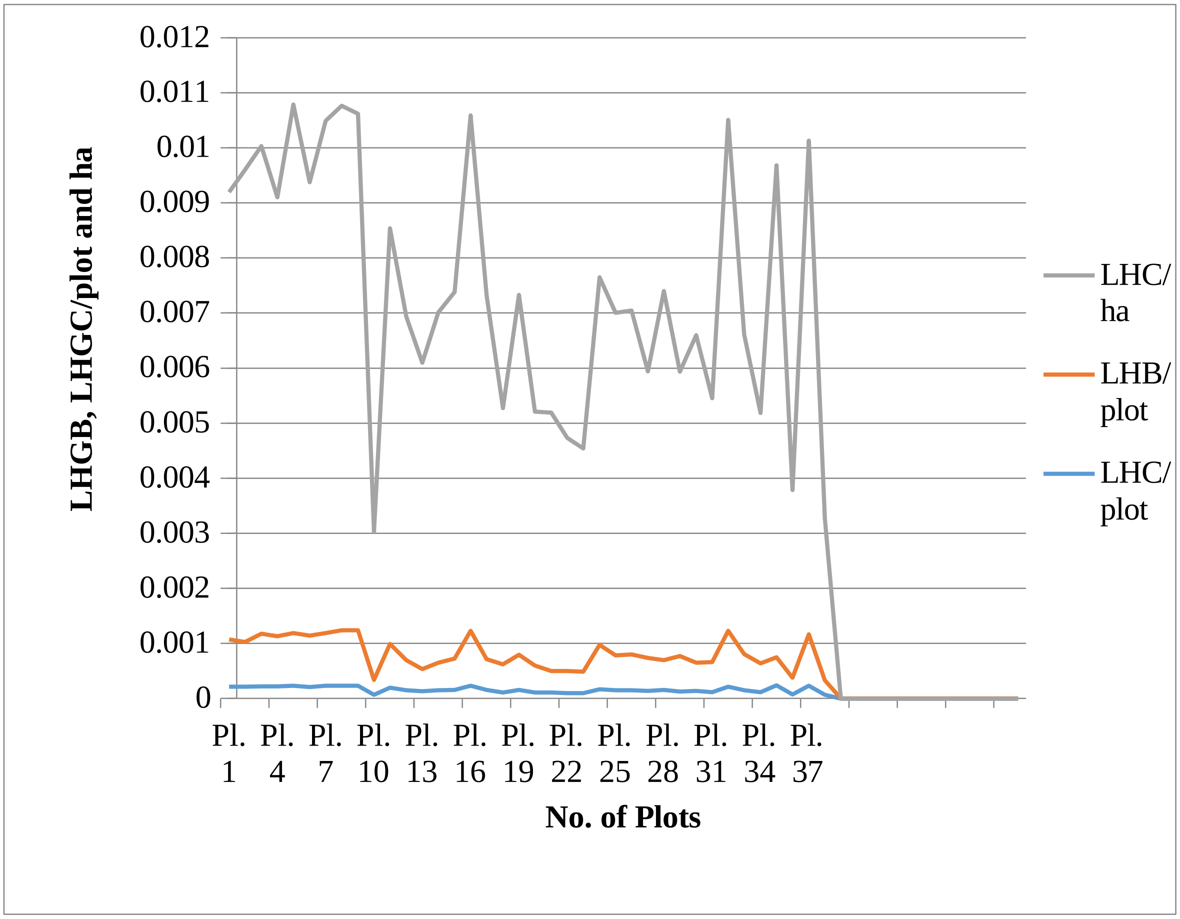

Figure: 3. Litters, herbs and grasses biomass and carbon stock both per plots and per hectare in kg

3.1.3. Total Carbon Stock Density of the Study area

Total carbon stock density of the study area was calculated by the summing up of carbon stock in all pools; above ground, below ground, dead wood and litters carbon stock of the study area per plots. The total carbon stock density of the site was 125.3987t/ha which can be 460.25 tCO2e.

Pools	AGCt/ha	BGCt/ha	DWCt/ha	LHC ton/ha	Total Carbon stock t/ha	Total tCO2e / ha
Carbon Stock Potential	100.737 78	24.6156 1	0.045	0.00031	**125.3987**	**460.25**

3.1.3.1. Carbon Stock of Species and Plots

3.1.3.1.1. Carbon stock of the species

The carbon stock of each plant species was different and also the same plant species accumulates different amount of carbon due to their diameter and height difference. Juniperus procera stocks more carbon than the others which accounts34.664ton/area. Olea africana and podocarpus falcatus were the second and third high carbon stock species which contains 19.496 and 13.688ton/spp. respectively. These species were highly abundant species that can occur in all altitudinal variations of the area. Grewia bicolor, Cussonia holstii and Premna schimperi are the species that stocks less carbon 0.006, 0.010 and 0.012ton/area of the site.

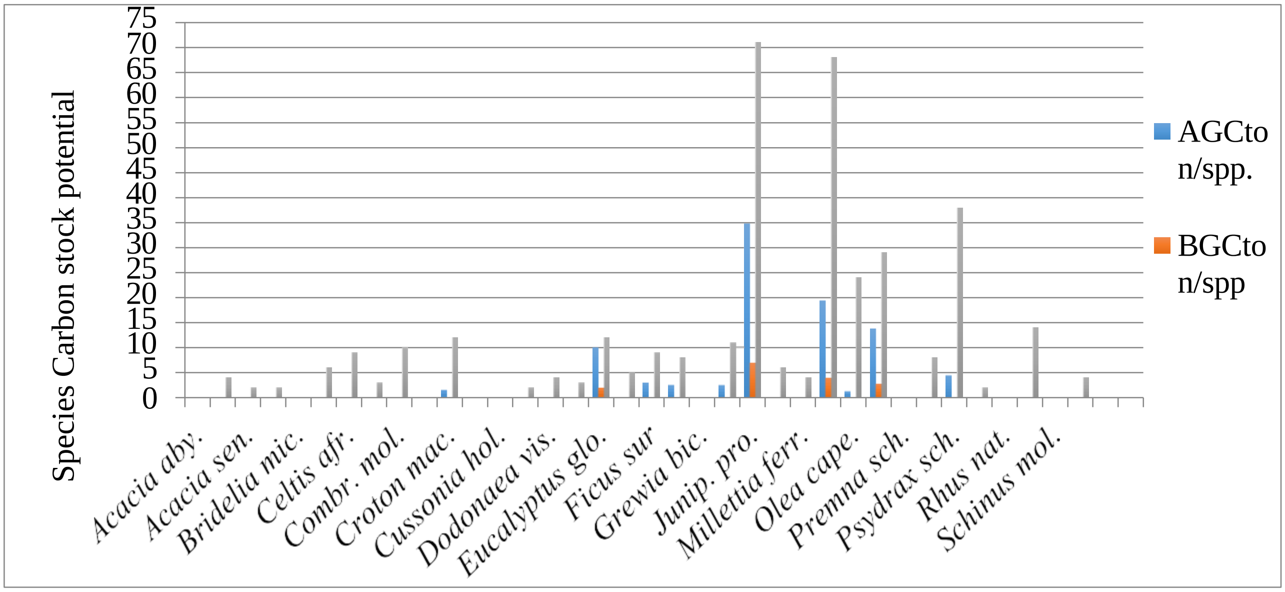

Figure: 4. Carbon stock density of the species in the area in ton

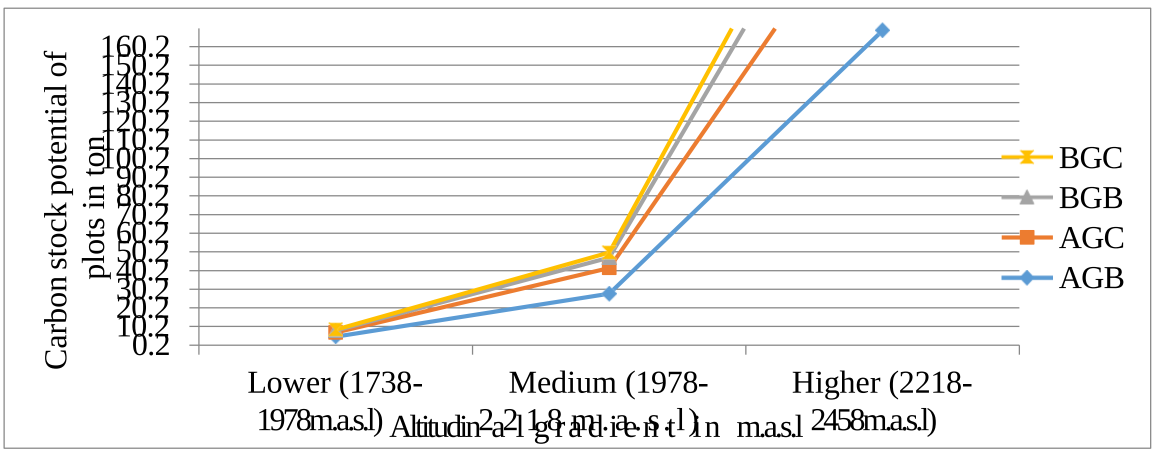

Figure: 5. Carbon stock of the area with altitudinal range in ton

3.1.3.1.2. Carbon Stocks of the plots along altitude gradient

The carbon stock of the area was varied with the variation of plots since the plots were laid on different altitudes which include different types of plant species. Accordingly, plot number 27 contains high carbon stock of the study plots that contains 19.751 ton/plot followed by plot number 29, 19 and 24, which stock 17.358, 17.022 and 10.456 carbon respectively. These plots were categorized into higher altitudes of the area, plateau and top mountain ecosystem that inhabits more diversified plant species. The lowest carbon stock was recorded in plot number 37 that contains 0.130ton/plot followed by plot number 50 and 44 that contains 0.233 and 0.272 ton/plot respectively. These plots were laid in the middle and lower altitude category.

Most carbon stock of the forest was accumulated in higher altitudinal range since more than half of sample plots were laid down on higher altitudes. These was due to the lower altitude of the forest is highly deforested and dominated by herbs, shrubs and small trees. Thirty sample plots were laid on higher altitude that composed diversified long aged species conserved by the monastery for a long period of time. From this result it is clear that altitude has an effect on tree species diversity and DBH since diameter is based on the species age mostly. It also shows that there is high anthropogenic disturbance that affecting the forest surround the lower part.

3.1.4. Carbon Credit Finance

The counter balances of carbon finance value has administered by supply and demand with a great difference across different marketing mechanisms and time. For the case of this study an average conservative value of carbon finance value calculation that $6.5/ tCO2e was used. Accordingly, $6.5/ tCO2e* 460.213229 (2,991.3859885$) of conservative carbon finance value was estimated at the study area. This shows that, the conservation value of Asebot mountain forest ecosystem through carbon sequestration is strongly high.

3.2. DISCUSSION

3.2.1. DBH, Height and Age Correlation with Carbon Stock

Forest has a huge potential to store carbon temporarily and permanently. More carbon stock was observed in long lived species of the study site and also species which are highly populated in the pool, as indicated in Houghton (2001). Mostly the species that long lived had more DBH and height as their age increase their DBH and height also increases. The average value of each individual species was taken to estimate the species DBH, height and basal area. DBH, height and above ground biomass are highly correlated in the study area. Olea africana, Podocarpus falcatus and Juniperus procera was long lived and accumulates more biomass in the study site. Most of the species found in the range of 10-20 cm DBH and 5-10m height. While at the range of >40cm DBH and 15-20m height there was low number of species in the study site. On the first range classes of DBH and height there was medium number of species. Distribution of DBH and height classes in the study site indicated an inverted J-shaped distribution.

Analysis of plant structure in this study forest using frequency distribution of the height and diameter classes of woody species could indicate an insight into their regeneration status (Brokaw 1987; Burrows 1990; Silvertown 1982; Silvertown & Doust 1993). This condition of variations in DBH and height classes shows there is high regeneration status in the study forest. Height can be used as an indicator of age of the plant species. The decrease in number of each height class towards the highest classes showed that the dominance of small-sized individuals in the forest plant species, which was the characteristic of high rate of regeneration. Thus, the general forest plant species decreased with increasing height classes showing an inverted J-shape (Figure: 6.), as indicated by; Ahmed Endris (2016), Hallaydeghie Wildlife Reserve Area; Semere Beyene, (2009), Yangudi Rasa National Park; Molla Mekonnen et al., (2010), Awash National Park; Tesfaye Burju, et al., (2013), Jabat forest and Kiflay Gebrehiwot and Kitessa Hundera, (2014) from Belete forest. This type of population structure shows stable size distribution in natural forests (Teshome Gemechu, 2009). Height class distribution of dry land vegetation is not good indicators of the vegetation regeneration, reproduction and recruitment status of the woody plant species because of these plant species almost all short and medium height by environmental and generically factors in the area.

As the SPSS correlation result shows all trees DBH, height and above ground biomass have high correlation. Since biomass estimation of the species is based on their DBH and height they are a significant correlation (table ...7).

Table: 7.The correlation between DBH, height, basal area and above ground biomass

Correlations					
Variables		Diameter at breast height	Height of the tree	Basal area of the tree	Above ground biomass
Diameter at breast height	Pearson Correlation	1	0.571**	-0.073	0.263**
	Sig. (2-tailed)		0.000	0.149	0.000
	N	399	398	397	399
Height of the tree	Pearson Correlation	0.571**	1	-0.060	0.135**
	Sig. (2-tailed)	0.000		0.237	0.007
	N	398	398	396	398
Basal area of the tree	Pearson Correlation	-0.073	-.060	1	-0.089
	Sig. (2-tailed)	0.149	.237		0.077
	N	397	396	397	397
Above ground biomass	Pearson Correlation	0.263**	0.135**	-0.089	1
	Sig. (2-tailed)	0.000	0.007	0.077	
	N	399	398	397	399

**. Correlation is significant at the 0.01 level (2-tailed).

The total basal area of forest plant species was 2.198 m2 per hectare (appendix 2). It indicates that the majority of woody plant species have moderate/medium thickness or DBH values. The basal area of Asebot mountain forest was less than dry land woodland vegetation of Yangudi Rasa National Park 3.12 m2ha-1 (Semer Beyene, 2009); Babile Elephant Sanctuary 13.9 m2ha-1 (Anteneh Belayneh and Sebsibe Demissew, (2011); ever green lowland forest of Ethiopia, Nechisar National Park 882.23 m2ha-1 (Samson shimelis, et al., 2010). However, basal area of the Asebot mountain forest ecosystem was greater than that of Hallaydeghie Plain woodland vegetation ecosystem of the same area 0.9954 m2 ha-1, Ahmed Endris, (2016) and other areas such as Taltalle woodland (which is 0.44 m2 ha-1, Debissa Lemessa, 2009); Awash National Park (0.822 m2 ha-1 Tamene Yohannes et al., 2013) and Dalfaqar National Park (0.84 m2ha-1, Dereje Mekonnen, 2006). Basal area provides a better measure of the relative importance of the species than simple stem count (Cain and Castro 1959 as cited in Shambel Alemu, 2009; kedir Aliyi et al., 2015). Thus, species with the largest contribution in basal area can be considered as the most important plant species in the forest area.

Eucalyptus globulus had the highest basal area 1.17 m2ha-1(53.42%) followed by Juniperus procera 0.916 m2 ha-1 (41.67%), Podocarpus falcatus 0.544 m2ha-1 (24.75%) and Ficus sur 0.513 m2 ha-1 (23.34%). According to Lamprecht, (1989), high density and high frequency coupled with high BA indicate the overall dominant species of the forest. On the other hand, the least value of basal area in the study site was recorded such as Grewia bicolor (0.027) m2 ha-1, Dodonea viscosa (0.032) m2 ha-1, Euclea racemosa (0.037) m2ha-1 and Cussonia holstii (0.038) m2 ha-1. This may indicate that these species has less ecological importance than species that has high BA, in the forest. Basal area of 80.79 % of forest plant species recorded in the area was found to lie in the ranges between 2218-2458 m.a.s.l that covers average basal area 0.77 m2ha-1 of the total average in the area. This indicates that the basal areas per altitude were varied and very small in lower altitude of the area (figure 6). This could be the small diameter growth of the plant species in the dry land areas because of both the ecological factors (moisture deficit and high temperature) and intensive forest disturbance due to browsing, grazing and wood exploitation for house construction and charcoal making (Debissa Lemessa, 2009).

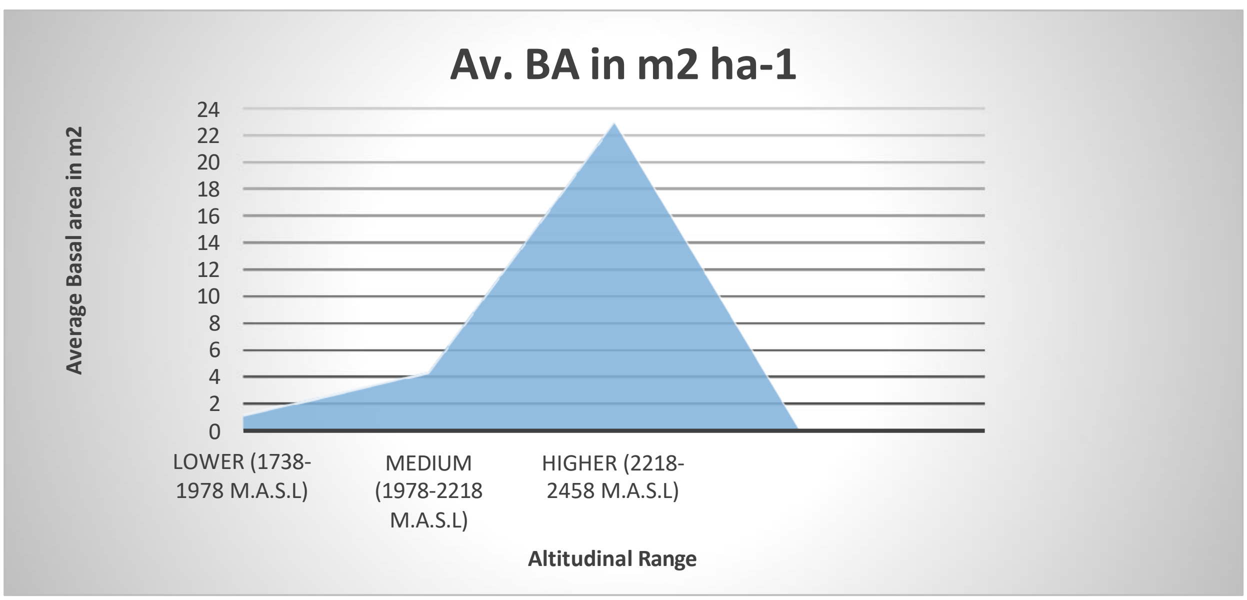

Figure: 6. Basal areas the forest with altitudinal variation in m 2

3.2.3. . Forest Canopy Coverage

Canopy cover plays a great role in the amount of sunlight that reaches the forest floor. Scientists classify forest canopies as open (10-39% of the sky is obstructed by tree canopies), moderately closed (40-69% of the sky is obstructed by tree canopies) or closed (70-100% of the sky is obstructed by tree canopies).

A densitometer is used to measure the amount of light that penetrates the forest canopy. Several types of densitometers exist. A simple densitometer is a device with a mirror apparatus inside that reflects the canopy above. It works somewhat like a periscope. The viewer sees a mirror image above, which allows him/her to estimate how much of the sky above is blocked by tree canopies online canopy cover measurement teachers instruction Pdf: available on http://www.Canopycovermeasurement.com. Accessed on March 2018

The forest canopy was estimated by using densitometer that have ten grids. The number of canopy and sky cover from four directions (north, south, east and west) was registered out of ten and the average was taken for the individual tree and species. Forest canopy was estimated for each individual tree and the average was taken for a single species to get the species canopy cover contribution in the area. Each tree species has its own canopy cover which factored by tree age, structure and leaf style (see appendix…1). Accordingly, the study result shows moderately closed canopy cover that was highly range between 40-69% of the species canopy cover. The canopy cover of the forest per plot was also more range between 40-69% that is moderately closed/covered forest floor. The highest canopy cover was registered in plot 24 that was 138.38%, and followed by plots 21, 23, 20 and 11 with the canopy cover of 118.95, 115.48, 88.61 and 75.42% respectively. These plots were closed canopy cover (the sky was obstructed by the canopy) since their canopy cover was more than 70%.

3.2.4. Biomass Storage in Different Pools

The maximum above ground biomass of the study area was 987.556ton/ha and the minimum was 6.516ton/ha. The total average above ground biomass of the study area was 201.47356ton/ha. The mean value of the above ground biomass of Asebot mountain forest was moderate when compared with the previous researches of afro-montane forest, 266ton/ha, 521.7475 ton/ha, lowland forest, 576.36ton/ha as studied by (Tibebu Yelemfrhat and Kidanemariam Kassahun, 2014). The average value of the three study area 454.7ton/ha falls in the global average ground biomass in tropical wet and dry forests ranged from 213-1173 ton/ha and 30-275ton/ha respectively, as studied by Lugo and Murphy (1986) (Table…8).

The storage of above ground biomass in the study area was different in different species and across altitudinal variation (appendix… 3). This is due to the growth rate of the plant and altitudinal factor as indicated by Tibebu, Y (2014). Lower part of the study area was highly dominated by small trees (saplings) and also there were anthropogenic disturbances for the purpose of fuel wood and other livelihood benefits of the forest. In case of these plant species composition and disturbances as indicated by Bishaw Badeg (2003), the above ground biomass around lower altitude of the area was low.

The litters biomass was vary from plot to plot and slightly low when compared to other areas. There is also high grazing system around lower part of the area in case of pastoralists the surround communities. Some part of the area is occupied by monastery and the residents. The litters were almost all the fallen leaves of the trees that are more decomposed easily and also left over the branch of trees, as also indicated in Demel Teketay (1996) and Tang, et al. (2010), cited in Tibebu Yelemfrhat, (2014). Due to these all disturbances and constraints the litter biomass of the study area was low that is 0.30701kg/plot or 0.00031ton/ha (appendix …2).

Table: 8. Comparison of above ground biomass carbon pools with different study area values

Study area	Author	AGC	BGC	DWC	LHGC
SMNP Lowland forest	Tibebe Yelemfrhat (2014)	270.89	54.178	0.726	0.017
Menagesha Suba State forest	Mesfin Sahile (2011)	133	26.6	-	5.26
Ades forest	Kidanemariam Kassahun (2014)	259.165	52.1946	-	2.34
Humbo forest	Alefu Chinaso (2015)	30.77	14.46	-	12.55
Asebot Mountain forest	Lalisa Mekonnen (2018)	100.73778	24.61561	0.0041	0.00031

From the above five study areas the above ground carbon of Humbo forest is very low. The author stated the reason that Humbo forest was second forest mean, reforested forest from degraded area due to that the forest DBH and height classes were very low resulted in low carbon stock density than other forest areas. On the other hand leaf litters carbon stock of Humbo forest was higher than these five forest areas. The researcher also reasoned as, the difference between sub-sample fresh weight and sub-samples dried weight of the litters were small due to; the litters were dried in dry air condition (low moisture content). This resulted in large proportion of litter biomass, which maximized the total carbon in litters when multiplied by percentage of carbon, Alefu Chinasho (2015).

The above explained reasons indicate that, the type of forest with their DBH and height class has high influence on the carbon stock density of the forest under study. The litter carbon stock of Asebot mountain forest was very low than these five forest areas. This may due to high difference of sub-samples fresh weight and sub-samples dried weight that was ranged from 7-9 g difference between fresh sample and oven dried sample. The reason was that litter was the mixture of wet herbs, shrubs, grasses and fallen leaves that had high moisture content. Even the dry leaf and decayed trees were wet in case of the atmospheric condition of that time.

3.2.5. Environmental Factors Influencing Carbon Stock Density of the Study Area

Altitudinal gradient plays a crucial role in influencing the carbon stock density of the study area. As the result shows the carbon stock of the area varied from plot to plot due to the plots were laid down on different altitudinal gradients starting from lower to higher altitude. The highest carbon stock was accumulated in higher altitude and the lowest carbon stock was accumulated in lowest altitude, as indicated in Tibebu Yelemfrhat (2014). The environmental that affect carbon stock were not only altitudinal gradient; there was also slope and aspect. For this study the altitudinal gradient was only focused due to topography of the area and the study direction. Since the forest was on the peak plateau of the mountain there was a challenge to determine aspect. Especially AGC and BGC were more based on altitudinal variation due to the tree DBH and height was varied with the altitude difference. The slope was also highly related to altitude as the altitude increase the slope also increase and normal inclination. The litters carbon stock also more depend on slope especially around steep slope there is low litters accumulation in case of flood and wind flows of litters on the sleep area. Due to these factors steep areas was covered by small plants like herbs, grasses, shrubs and sapling trees, as indicated in Powers and Schlesinger (2002), cited in Tibebu Yelemfrhat (2014).

4. CONCLUSION AND RECOMMENDATION

4.1. Conclusion

Hallaydeghie Asebot National Park in which Asebot Forest Mountain found is one of Ethiopian protected areas that established for the conservation of endangered Gravey's zebra and peculiar land scape of Asebot mountain forest ecosystem. On the top and middle of Asebot mountain forest there are the earlier and ageist monasteries; Saint Selassie that is for monks and Aba Samuel for Nuns monastery.

The study result shows that in Asebot mountain forest ecosystem a total of 36 different species were recorded from which Juniperus procera and podocarpus falcatus were highly abundant. The DBH and Height class of Asebot mountain forest was found in the range of medium zone. The carbon stock density of the forest is highly dependent on trees DBH; as DBH increases the carbon stock potential also increases which is the same for tree height. The average value of each individual species was taken to estimate the species DBH, height and basal area. DBH, height and above ground biomass are highly correlated in the study area Table 4.7. Most of the species found in the range of 10-20 cm DBH and 5-10m height. While at the range of >40cm DBH and 15-20m height there was low number of species in the study site. On the first range classes of DBH and height there was medium number of species.

Eucalyptus globulus had the highest basal area 1.17 m2ha-1(53.42%) followed by Juniperus procera 0.916 m2 ha-1 (41.67%), Podocarpus falcatus 0.544 m2ha-1 (24.75%) and Ficus sur 0.513 m2 ha-1 (23.34%) ; On the other hand, the least value of basal area in the study site was recorded such as Grewia bicolor (0.027) m2 ha- 1, Dodonea viscosa (0.032) m2 ha-1, Euclea racemosa (0.037) m2ha-1 and Cussonia holstii (0.038) m2 ha-1 .The highest canopy cover was registered in plot 24 that was 138.38%, and followed by plot21, 23, 20 and 11 with the canopy cover of 118.95, 115.48, 88.61 and 75.42% respectively. These plots were closed canopy cover (the sky was obstructed by the canopy) since their canopy cover was more than 70%.

The carbon stock potential of each pool differs from one another due to their biomass difference. The average carbon stock in different pools of Asebot mountain forest was higher than Humbo forest except in litter's carbon stock. And more or less similar to Menagesha Suba State forest carbon stock density. The other forest area carbon stocks were highly more than the Asebot mountain forest. This may due to high deforestation rate of the area which is highly increasing and the lower part of the forest is dominated by shrubs and sapling. Even if the forest is highly disturbed by anthropogenic factors; it has high potential to mitigate climate change since it is the habitat of diversified indigenous plant species which have high carbon stock and carbon dioxide sequestration potential. The maximum above ground biomass of the study area was 987.556ton/ha and the minimum was 6.516ton/ha. The total average above ground biomass of the study area was 201.47356ton/ha appendix 5. The below ground biomass of the study forest was 49. 22774ton/ha while; DWB was 0.0075ton/ha and LHGB was 0.0076kg/ha. The carbon stock potential of Asebot mountain forest was 125.3987t/ha.

Olea africana, Podocarpus falcatus and Juniperus procera was more aged and accumulates more biomass in the study area. The higher altitudinal zone of the area was dominated by large trees and dense forest that contain high carbon stock density. Environmental gradient and altitude played a great roll on the storage of carbon stock in different carbon pool of the study site. The carbon stock of above ground and below ground carbon of the higher altitude showed an exceeding value than the rest of carbon pools this was because of suitable and convenient conditioning and due to the presence of abundant vegetation coverage ,whereas the carbon stock of the litter carbon showed an increasing trend with increasing altitudes. In general the carbon stock potential of the current study has been highly correlated with environmental factor an altitude; and hence played a major roll on climate change mitigation with the means of sequestering carbon. For the current study an average conservative value of carbon finance value \$6.5/ tCO2e was used. The total CO2 sequestration potential of Asebot mountain forest was 460.25 that was calculated by carbon stock potential in ton/ha* 44/12 or 3.67 which is the ratio of molecular weights between carbon dioxide (44) and carbon (12) (pearson et al., 2007). Accordingly, \$6.5/ tCO2e* 460.213229 (2,991.3859885\$) of conservative carbon finance value was estimated at the study area. This shows that, the conservation value of Asebot mountain forest ecosystem through carbon sequestration is strong.

4.2. Recommendation

The Asebot ever green dry montane forest in plateau of Harerge around the Asebot monastery is a home of beauty wildlife resources due its top roof catchments Hallaydegie grass lands of Hallaydegie Asebot National Park. Accordingly the following recommendations are provided for some further studies and ecosystem conservation management systems.

- The present study was limited to Woody Species Diversity and Carbon Sequestration Potential of Asebot mountain dry afromontane forest: implication for mitigation of climate change in the area specifically on tree species with DBH greater or equal to 5cm. It's required further studies on the soil, sapling, seedling, herbs and grasses carbon stock potential of the area would be required to calculate full carbon stock potential of the study area regarding its role in climate change mitigation.
- To determine tree age it is very crucial to get species growth factor. Species growth factor and tree age are not further studied in the area; so it is necessary to do further study on these issues especially on conservation forest ecosystems.
- To determine Asebot mountain forest carbon dioxide sequestration potential there should be seasonal investigation to know the influence of seasonal difference on carbon stock potential of the area.
- Indigenous species like Podocarpus falcatus, Olea africana, Juniperus procera and Cordia africana had high carbon potential and at the same time they are strongly deforesting for the seek of fuel wood energy and livelihood subsistence. There should be optional energy sources and job opportunities to improve the local community's energy source and livelihoods.
- Since the present study was focused on altitude from the environmental factors; there should be detail studies on aspect, environmental factors that affect carbon stock potential of the forest.
- To calculate carbon credit finance/carbon trade there should be country specific values or price for tCO2e. So it is necessary to have carbon credit finance for the country that can be accessed and available for all.

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1. Appendixes

Appendix: 1. Forest canopy per species in the plots and percentage

Sp. Code	Species Name	No. of ind. Spp.	Forest canopy/plot	% of canopy /plot
Sp. 1	*Acacia abyssinica*	17	96	60
Sp. 2	*Acacia nilotica*	4	13.5	33.75
Sp. 3	*Acacia Senegal*	2	16.25	81.25
Sp. 4	*Acokanthera schimperi*	2	12.25	61.25
Sp. 5	*Bridelia sicrantha*	1	41.75	59.64
Sp. 6	*Buddleia polystachya fresen*	6	35.75	59.58
Sp. 7	*Celtis Africana*	5	59	65.56
Sp. 8	*Combretum collinum*	10	15.5	51.67
Sp. 9	*Combretum molle*	7	55.5	55.5
Sp.10	*Cordia Africana*	12	6	60
SP.11	*Croton macrostachyus*	5	56.5	51.36
Sp.12	*Cupressus lusitanica*	2	2.5	25
Sp.13	*Cussonia holstii*	1	7	70
Sp.14	*Diospyros abyssinica*	4	4.5	22.25
Sp.15	*Dodonaea viscosa*	7	14.5	36.25
Sp.16	*Ehretia cymosa*	12	19.75	65.83
Sp.17	*Eucalyptus globulus .*	12	62.25	41.5
Sp.18	*Euclea racemosa*	8	26.75	53.5
Sp.19	*Ficus sur*	3	42.5	47.22
Sp.20	*Ficus sycomorus*	13	41	51.25
Sp.21	*Grewia bicolor*	24	4.25	42.5
Sp.22	*Jacaranda mimosifolia*	68	57.75	52.5
Sp.23	*Juniperus procera*	71	397.25	55.95
Sp.24	*Maytenus arbutifolia*	29	40.05	66.75
Sp.25	*Millettia ferruginea*	8	23.5	58.75
Sp.26	*Olea africana / Europaea*	56	374.25	55.04
Sp.27	*Olea capensis*	2	123.5	53.7
Sp.28	*Podocarpus falcatus*	21	158.75	54.74
Sp.29	*Premna schimperi*	14	5.75	57.5
Sp.30	*Prunus Africana*	7	45.25	56.56
Sp.31	*Psydrax schimperiana*	32	211.5	55.66
Sp.32	*Rhus glutinosa*	17	14.25	71.25
Sp.33	*Rhus natalensis*	1	6.75	67.5
Sp.34	*Rhus retinorrhoea*	14	77.5	55.36
Sp.35	*Schinus molle*	1	5.75	57.5
Sp.36	*Sterculia setigera*	4	23.75	59.38

Plots	Tot. Wt.(Wf)	Fresh wt.	Oven dried wt	% of MC	LB	LC	CL/pl0t	% of OC	CL/ha
Pl. 1	459	91.8	84.9	8.13	0.000212	0.000106	0.000863	38.266733	0.008122
Pl. 2	464.5	92.9	86.4	7.52	0.000216	0.000108	0.000812	39.719159	0.008579
Pl. 3	476	95.2	87.5	8.8	0.000219	0.000109	0.000963	40.480865	0.008855
Pl. 4	476	95.2	87.9	8.3	0.000220	0.000110	0.000912	36.283937	0.007973
Pl. 5	500	100	92.3	8.34	0.000231	0.000115	0.000962	41.594613	0.009598
Pl. 6	451.5	90.3	82.8	9.06	0.000207	0.000104	0.000938	39.776884	0.008234
Pl. 7	500	100	92.3	8.34	0.000231	0.000115	0.000962	40.306326	0.009301
Pl. 8	500	100	91.9	8.81	0.000230	0.000115	0.001012	41.454981	0.009524
Pl. 9	500	100	91.9	8.81	0.000230	0.000115	0.001012	40.822310	0.009379
Pl. 10	146.5	29.3	27.16	7.88	0.000068	0.000034	0.000268	39.736886	0.002698
Pl. 11	421.5	84.3	77.9	8.22	0.000195	0.000097	0.000800	38.762177	0.007549
Pl. 12	318	63.6	59.2	7.43	0.000148	0.000074	0.000550	42.167953	0.006241
Pl. 13	282	56.4	53.2	6.02	0.000133	0.000067	0.000400	41.888656	0.005571
Pl. 14	315.5	63.1	59.1	6.77	0.000148	0.000074	0.000500	43.105169	0.006369
Pl. 15	330.5	66.1	61.5	7.48	0.000154	0.000077	0.000575	43.034602	0.006660
Pl. 16	500	100	92	8.69	0.000230	0.000115	0.000999	40.709882	0.009363
Pl. 17	332	66.4	61.9	7.23	0.000155	0.000077	0.000559	42.685244	0.006606
Pl. 18	240.5	48.1	44	9.34	0.000110	0.000055	0.000514	42.279412	0.004651
Pl. 19	339.5	67.9	62.8	8.12	0.000157	0.000079	0.000637	41.654734	0.006540
Pl. 20	248.5	49.7	45.7	8.75	0.000111	0.000056	0.000487	41.464064	0.004613
Pl. 21	242	48.4	45.3	6.84	0.000113	0.000057	0.000387	41.446273	0.004694
Pl. 22	216	43.2	40	8	0.000100	0.000050	0.000400	42.373756	0.004237
Pl. 23	212.5	42.5	39.4	7.87	0.000099	0.000049	0.000388	41.221590	0.004060
Pl. 24	366.5	73.3	66.8	9.73	0.000167	0.000084	0.000812	39.982703	0.006677
Pl. 25	326	65.2	60.1	8.48	0.000150	0.000075	0.000637	41.390200	0.006219
Pl. 26	329.5	65.9	60.7	8.57	0.000152	0.000076	0.000650	41.164030	0.006247
Pl. 27	297.5	59.5	54.7	8.77	0.000137	0.000068	0.000600	38.090015	0.005209
Pl. 28	338	67.6	63.3	6.79	0.000158	0.000079	0.000537	42.386015	0.006708
Pl. 29	275	55	49.8	10.44	0.000125	0.000062	0.000650	41.478105	0.005164
Pl. 30	297	59.4	55.3	7.41	0.000138	0.000069	0.000512	43.039721	0.005950
Pl. 31	252.5	50.5	46.1	9.54	0.000115	0.000058	0.000550	41.588614	0.004793
Pl. 32	227.5	45.5	41.5	9.64	0.000212	0.000106	0.001021	43.819532	0.009282
Pl. 33	322.5	64.5	59.2	8.95	0.000148	0.000074	0.000662	39.231537	0.005806
Pl. 34	253.5	50.7	46.5	9.03	0.000116	0.000058	0.000525	39.124867	0.004548
Pl. 35	500	100	95.9	4.27	0.000240	0.000120	0.000512	37.267411	0.008935
Pl. 36	161	32.2	29.8	8.05	0.000075	0.000037	0.000300	45.786601	0.003411
Pl. 37	500	100	92.5	8.11	0.000231	0.000116	0.000938	38.780942	0.008968
Pl. 38	147	29.4	27.3	7.69	0.000068	0.000034	0.000262	43.150867	0.002945
Pl. 39	248	49.6	46.3	7.13	0.000116	0.000062	0.000444	43.553763	0.005041
Pl. 40	232	46.4	41.9	10.74	0.000105	0.000052	0.000563	41.254158	0.004321
Pl. 41	276.5	55.3	51.5	7.38	0.000129	0.000064	0.000475	43.350852	0.005581
Pl. 42	232	46.4	26.9	3.85	0.000067	0.000034	0.000129	43.288255	0.002911
Pl. 43	270.5	54.1	50.8	6.5	0.000127	0.000064	0.000413	45.331802	0.005757
Pl. 44	135	27	25	8	0.000063	0.000031	0.000250	44.219701	0.002764
Pl. 45	397.5	79.5	72.5	9.65	0.000181	0.000091	0.000875	43.635123	0.007909
Pl. 46	241	48.2	45.7	5.47	0.000114	0.000057	0.000312	40.733893	0.004654
Pl. 47	303.5	60.7	45.9	32.24	0.000115	0.000057	0.001850	43.395409	0.004980
Pl. 48	197	39.4	36.4	8.24	0.000091	0.000046	0.000375	44.362117	0.004037
Pl. 49	130	26	24.6	5.69	0.000062	0.000031	0.000175	41.290837	0.002539
Pl. 50	635	127	120.16	27.79	0.000300	0.000150	0.004174	20.752831	0.006234
Total	**16363.5**	**3272.7**	**3004.2**	**442.9**	**0.007619**	**0.003813**	**0.03510**	**2052.6861**	**0.30701**

Sp. Code	AGBt/spp.	AGCt/spp.	BGBt/spp.	BGCt/spp.	No. Spp.
Sp. 1	4.879	2.439	0.976	0.488	17
Sp. 2	0.310	0.155	0.062	0.031	4
Sp. 3	0.126	0.063	0.025	0.013	2
Sp. 4	0.090	0.045	0.018	0.009	2
Sp. 5	0.457	0.228	0.091	0.046	1
Sp. 6	0.491	0.245	0.098	0.049	6
Sp. 7	1.361	0.681	0.272	0.136	9
Sp. 8	0.935	0.467	0.187	0.093	3
Sp. 9	0.956	0.478	0.191	0.096	10
Sp.10	0.290	0.145	0.058	0.029	1
SP.11	2.985	1.492	0.597	0.298	12
Sp.12	0.033	0.017	0.007	0.003	1
Sp.13	0.019	0.010	0.004	0.002	1
Sp.14	0.979	0.489	0.196	0.098	2
Sp.15	0.070	0.035	0.014	0.007	4
Sp.16	0.196	0.098	0.039	0.020	3
Sp.17	19.993	9.997	3.999	1.999	12
Sp.18	0.098	0.049	0.020	0.010	5
Sp.19	5.993	2.996	1.199	0.599	9
Sp.20	4.971	2.486	0.994	0.497	8
Sp.21	0.013	0.006	0.003	0.001	1
Sp.22	4.908	2.454	0.982	0.491	11
Sp.23	69.327	34.664	13.865	6.933	71
Sp.24	0.735	0.367	0.147	0.073	6
Sp.25	0.125	0.062	0.025	0.012	4
Sp.26	38.991	19.496	7.798	3.899	68
Sp.27	2.497	1.248	0.499	0.250	24
Sp.28	27.377	13.688	5.475	2.738	29
Sp.29	0.024	0.012	0.005	0.002	1
Sp.30	0.750	0.375	0.150	0.075	8
Sp.31	8.935	4.468	1.787	0.894	38
Sp.32	0.678	0.339	0.136	0.068	2
Sp.33	0.065	0.033	0.013	0.007	1
Sp.34	0.986	0.493	0.197	0.099	14
Sp.35	0.233	0.116	0.047	0.023	1
Sp.36	0.598	0.299	0.120	0.060	4
Total	**201.47356**	**100.73778**	**50.295**	**24.61561**	**407**