ISSN (Online): 2349-1183; ISSN (Print): 2349-9265
TROPICAL PLANT RESEARCH
The Journal of the Society for Tropical Plant Research
6(3): 438–451, 2019
DOI: 10.22271/tpr.2019.v6.i3.054

Research article

Carbon stock in the Dirki woodland vegetation of Central Ethiopia: A case study in Ilu Gelan District, West Shewa Zone, Oromia Regional State

Deresa Abetu[1]* and Tamirat Bekele[2]

[1]Ethiopian Biodiversity Institute (EBI), Jimma Botanic Garden, P.O. Box, 1823, Jimma, Ethiopia
[2]Plant Biology and Biodiversity Management, College Of Natural science, Addis Ababa University, Ethiopia
***Corresponding Author:** deressajimma@gmail.com/deresa.abetu@ebi.gov.et [Accepted: 30 November 2019]

Abstract: The study was conducted in one of the woodland vegetation in central Ethiopia. The main objective of the study was to estimate the total amounts of carbon stock along the altitudinal gradient of Dirki vegetation. Seven transect lines were systematically established along the altitudinal gradient to collect above ground biomass data of woody species of ≥ 5cm diameter. A total of 54 sample plots (400 m^2 = 20 m × 20 m area) were established on each transect line at 25 meter above sea level intervals. From the 54 sample plots, 86 woody species of 39 families were identified and used for the biomass estimation. The average quantity of carbon stored in the woody species was about 137.5 t ha^{-1}; Above Ground Biomass (AGB) 87.77 C t ha^{-1} and below ground biomass (BGB) 17.5 C ha^{-1}. The average carbon stock of lower altitude was larger than the upper altitudinal 103.36 C t ha^{-1} and 34.14 C t ha^{-1}, respectively. This implies that, higher amount of carbon storage was recorded in above ground biomass, and lower at below ground biomass. Even if low woody species biomass and DBH were observed at higher altitude, higher density of woody species was observed at higher altitude than the lower altitude. To sum up, in the woodland ecosystem of the study area the amounts of carbon stock was decreased with increasing altitude. Therefore, to maintain the existing carbon stock in the AGB anthropogenic disturbances that cause loss of carbon from AGB has to be reduced using different management strategies.
Keywords: Biomass - Dirki - Ilu - Galan - Woodland vegetation.

[Cite as: Abetu D & Bekele T (2019) Carbon stock in the Dirki woodland vegetation of Central Ethiopia: A case study in Ilu Gelan District, West Shewa Zone, Oromia Regional State. *Tropical Plant Research* 6(3): 438–451]

INTRODUCTION

The estimated global forests cover is about 4.03 billion hectares, which is approximately 30% of Earth's total land area and 75% of terrestrial gross primary production (GPP) (Pan *et al.* 2013). It was also stated that huge amount of carbon is stored in plant biomass and soils system than the atmosphere. The most important issues and key policy-related reasons for measuring carbon in forests: (1) commitments under The United Nations Framework Convention on Climate Change (UNFCCC), and (2) Potential implementation of the Kyoto Protocol. The UNFCCC, signed by more than 150 countries, requires that all Parties to the Convention commit themselves to develop, publish, and make available to the Conference of the Parties (COP) their national inventories of emissions by sources and removals by sinks of all GHGs using comparable methods (Houghton *et al.* 1997). It was pointed out that, forest ecosystems are regarded as the largest terrestrial carbon pool that have an average biophysical mitigation potential of 5,380 Mt CO2/yr until 2050 (IPCC 2007).

According to Bekele (2002), in Ethiopia factors like deforestation, overharvesting and permanent conversion to other forms of land use are leading to shrinkage of forest resources. In our country, it was also reported that, woodlands are covering huge areas and their carbon stock is much higher than high forests which are 1,263.13 million tons of carbon per 29.55 million hectare in woodland and 434.19 million tons of carbon per 4.07 million hectare in the high forest (Moges *et al.* 2010). According to Moges *et al.* (2010), Ethiopian forests contain about 272 million metric tons of carbon, which is almost 83% of the country's global annual carbon emission (333

Received: 22 April 2019 Published online: 31 December 2019
https://doi.org/10.22271/tpr.2019.v6.i3.054

Mega tone of carbon per year).

In recent time, forest management events are increasingly get due attention and concern for the role of forests as carbon sinks and information on factors that determine the forest carbon stock is given concern (McEwan *et al.* 2011). The carbon storage in forest can be affected by different environmental factors such as altitude, slope and aspect through affecting the patterns of tree species distribution and this further affects carbon stored in forest ecosystem (McEwan *et al.* 2011).

Therefore, this study was intended to estimate and figure out the carbon stock in woodland vegetation along altitudinal gradient and to check out whether there was low carbon stock density in the higher altitudinal gradient than lower altitudinal gradient of the woodland ecosystems.

MATERIALS AND METHODS

The study was carried out in Ilu Gelan District, West Shewa Zone of Oromia Regional State, in Central Ethiopia (Fig. 1). The District is located to west of the Addis Ababa, the Capital of Ethiopia at about 200 km on Addis Ababa to Nekemte asphalts road. IJaji is the central town of the District and is located on geographical coordinates of 08^{o} 59′ 51″ N and 037o 19′ 49″ E with the average altitude of 1812 meter above sea level (masl).

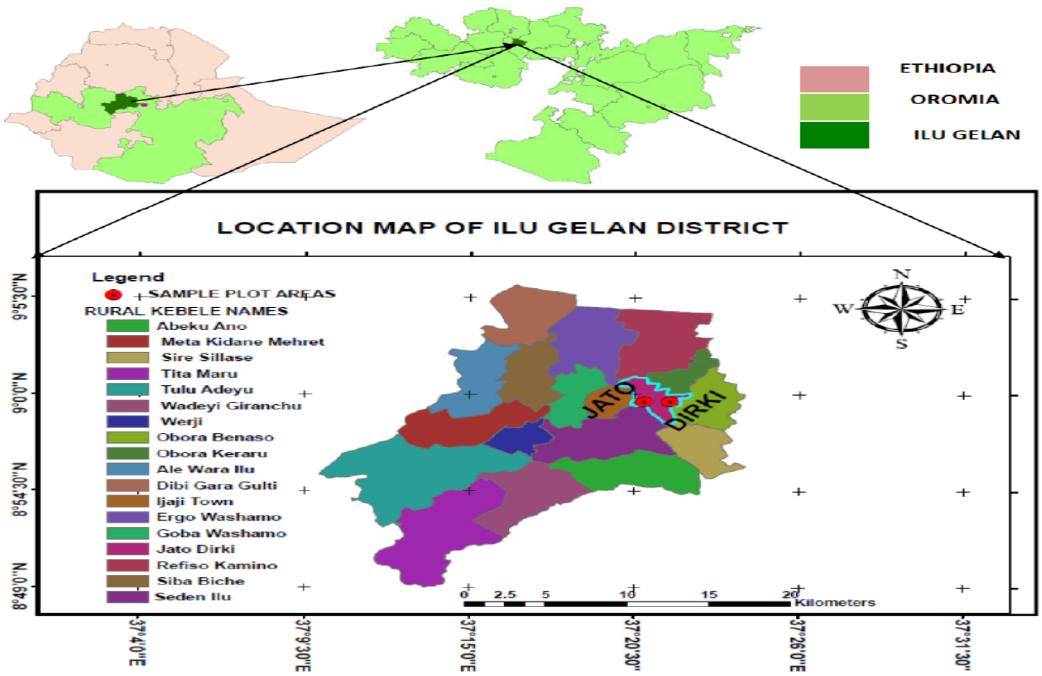

Figure 1. Map of Ethiopia showing Regional states and the study area (Dirki and Jato).

Climate

Meteorological data obtained from National Meteorology Service Agency, indicates that Ilu Gelan area obtains high rainfall between May and September and low rainfall from December to February (Fig. 2). The mean annual rainfall of the study area was 1351 mm and recorded in July and the lowest 11.2 mm recorded in February. The mean maximum temperature over twenty years was 28.1℃ and the minimum was 13.8℃. The highest temperature, 31.7℃, was recorded in February whereas the lowest temperature, 11.2℃, was recorded in November.

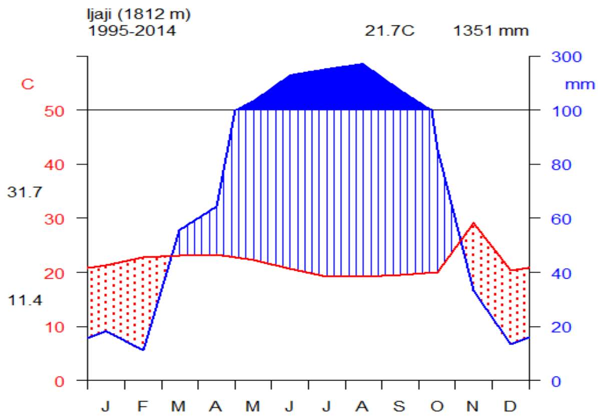

Figure 2. Climadiagram showing rainfall distribution and temperature variation, around Ijaji Town.

Vegetation data collection and identification

The Vegetation data were collected by recording the vernacular and or/scientific names of the woody plant species in the sampling plot. The local name (Afan Oromo) was identified in the field by local field guides. The entire specimens were taken to the National Herbarium (ETH) Addis Ababa University. The vegetation sample and data collection was started in middle half October and November 2014 because this time duration is the flowering and fruiting season for most of the Dirki vegetation. The second final data collection period was during the months of April to May 2015. This time was preferred due to the fact that it is second high rainy season of the study area and it can help plant specimen identification purpose. Before collecting actual data, a reconnaissance survey was conducted on the aspect (North, South, West and East), and altitudinal range of the study area was visited and identified to establish using GPS (Global Positioning System, Garmin map, 62). Based on the reconnaissance survey, study area was classified as altitude ranges of 1803–1902 m as low and 1903–2100 m asl as high altitudinal gradient. From these seven transects identified and 54 sample plots (each plot has 20 m × 20 m = 400 m^2 area) were established to collect vegetation data. Of the total sample plots, 32 plots situated at 1803–2078 m asl and 22 plots at 1905–2136 m asl.

Plant specimens were collected for every plant species of specified DBH, pressed and dried. Finally all of the plant specimens were identified and checked at the National Herbarium (ETH), Addis Ababa University. For each sample plot, altitude and aspect was measured using Garmin map 62 GPS with precision ±7 m and the areas of the woodland of each sample plots was determined by tape meter (steel long 50 m) measurement and the heights of trees were measured using Haga hypsometer and plastic bags were used to collect samples and leaf of litter and weighted in weighing machine.

The scientific names of the woody plant species were identified in National Herbarium (ETH) while the local by vernacular names were recorded on the field by local field guides. The specimens was collected for every species, pressed and dried then transported to the National Herbarium (ETH), Addis Ababa University for identification and confirmation. Kent & Coker (1992) stated that trees with multiple stems with diameter at breast height (DBH) of 1.3 m were treated as a single individual. The DBH of the largest stem was taken as the sample for the measurement. For trees near the plot that have >50% of their basal area falls within the plot was included and, trees overhanging into the plot are excluded, but trees with their trunks inside the sampling plot and branches outside were included (MacDicken 1997, Karky & Banskota 2007). For vegetation sampling, plot size of 20 m × 20 m (400 m^2) was recommended and widely used (Pearson *et al.* 2005). In each plot, trees with a DBH of ≥5 cm were measured for DBH and height because of the life zone (Brown *et al.* 1989).

The most appropriate method for the estimation of biomass is through cutting of trees and weighing of their parts. This destructive method is often used to validate established carbon stock models, less recommended and cost. Thus, carbon stock estimation using nondestructive, in-situ measurements and remote sensing techniques are more popular and widely used across the globe (Clark *et al*. 2001, Wang *et al*. 2003). Based on this fact, the carbon stock estimation technique applied in this research was the nondestructive one.

Statistical analysis

The data collected from field inventory were organized and recorded in Micro soft Excel 2007 spread sheet. The frequencies of each tree species in all 54 sample plots were analyzed. The data obtained from DBH, diameter, height of each species, field weight (Ww), fresh weight (FW) and dry weight (Wdry) of dead litter were Excel 2007 and analyzed using MINITAB software version 16. The relationship between each parameter was tested by descriptive statistics. One way ANOVA test was done to observe the effect of factors (altitude, disturbance and aspect) on woodland carbon stock.

Estimation of above ground biomass (AGB) and carbon

Different models are suggested to estimate above ground biomass and carbon stock of tropical forests (Appendix I). Among these models, the mode suggested by Brown *et al.* (1989) was used in this study because the conditions (rainfall and tree DBH) specified in the model match with the study area conditions. MacDicken (1997) stated that below ground biomass (BGB) is 20% of above ground biomass (AGB) *i.e.*, root-to-shoot ratio value of 1:5. The litter carbon pool includes all non-living biomass with a size greater than 2mm diameter- the limit for soil organic matter (SOM), and smaller than 10 cm diameter - DOM wood. The samples of litter (leaves, twinges, fruits or flowers, and barks) were collected in five square meter subplots of 1 meter square in size inside the main sample plot 20 m × 20 m (400 m^2), which was established at the four corners and one at the center of each sample plot. The five samples of fine litter, including litter within the 1 m^2 subplot were collected and placed in a weighing bag. A composite sample of 100 g of evenly mixed sub-samples were brought to the laboratory for analysis placing in a plastic bag and oven dried at 70ºC for 24 hours and weighed for analysis of total carbon concentrations to determine oven dry mass from which total dry mass and carbon fraction were calculated (Pearson *et al*. 2005). Dead wood was not measured in the woodland due to the nonexistence of dead wood within the sample plots because of uncontrolled production of charcoal (Fig. 3).

The model developed by Brown *et al.* (1989) to estimate above ground biomass has been used due to accuracy and life zone of the study is area fitted with the life zone recommended for the equation with a rain fall less than 1500 mm and the DBH ≥5 cm. It is also noted that this method is nondestructive method and the most appropriate method (Brown 1997, FAO 1997). The general equation that was used to calculate the aboveground biomass is given below:

$$Y = 34.4703 - 8.0671(DBH) + 0.6589(DBH2) \quad \text{(Equation 1)}$$

$$Y = \exp\{- 1.996+2.32 \times \ln (D)\} \quad \text{(Equation 2)}$$

Where, Y is above ground biomass, DBH is diameter at breast height.

The expansion factor was calculated as the area of a hectare in square meters divided by the area of the sample in square meters, that is:

$$\text{Expansion factor} = 10{,}000 \text{ m}^2$$

$$\text{Area of the plot } (20 \text{ m} \times 20 \text{ m } (\text{m}^2) \quad \text{(Equation 3)}$$

The carbon content in litter biomass was also calculated by multiplying herbaceous/litter biomass by 0.47% (IPCC 2006).

Estimation of biomass and carbon in different pool

MacDicken (1997), noted that, the appropriate method used for estimation of below ground biomass (BGB) can be obtained as 20% of above ground tree biomass *i.e.*, root-to-shoot ratio value of 1:5 is used. Thus, the equation developed by MacDicken (1997) to estimate below ground biomass was used.

$$BGB = AGB \times 0.2 \quad \text{(Equation 4)}$$

AGB is above ground biomass, 0.2 is conversion factor (or 20% of AGB). And the carbon content of the biomass is about 47% by dry weight (IPCC 2006), the carbon stock in the biomass was estimated using the formula:

$$\text{Biomass C stock} = \text{Biomass} \times 0.47 \quad \text{(Equation 5)}$$

Biomass carbon stock was then converted in to CO2 equivalent as follows:

$$CO_2 \text{ eq} = \text{biomass C} \times 3.67 \quad \text{(Equation 6)}$$

Estimation of carbon in the litter biomass

According to Pearson *et al.* (2005), estimation of the amount of biomass in the leaf litter can be calculated by:

$$LB = \text{Weight field} \times \text{Wsub sample dry Wsub sample fresh} \times BEF \quad \text{(Equation 7)}$$

Where, LB = Litter (biomass of litter t ha-1); Wfield = weight of wet field sample of litter sampled within an area of size 1 m^2 (g); A = size of the area in which litter was collected (ha); W sub-sample; dry = weight of the oven-dry sub-sample of litter taken to the laboratory to determine moisture content (g); W sub-sample, fresh = weight of the fresh sub-sample of litter taken to the laboratory to determine moisture content (g).

Carbon stocks in dead litter biomass

$$CL = LB \times 0.47\% \quad \text{(Equation 8)}$$

Where, CL is total carbon stocks in the dead litter in t ha^{-1}; LB is litter biomass.

Total carbon stock density

The total carbon stock density was calculated by adding the carbon stock densities of the individual carbon pools using the formula (Pearson *et al.* 2005). Carbon stock density of the study area:

$$\text{C density} = CAGB + CBGB + \text{C Lit} \quad \text{(Equation 9)}$$

Where, C density = Carbon stock density for all pools (t ha^{-1}); C AGTB = Carbon in above ground tree biomass (t ha^{-1}); CBGB = Carbon in below ground biomass (t ha^{-1}); C Lit = Carbon in dead litter (t ha^{-1}).

The total carbon stock was then converted to tons of CO^2 equivalent by multiplying it by 44/12, or 3.67 (Pearson *et al.* 2007).

RESULTS

As presented in Appendix II, total of 86 woody species of 39 families with DBH ≥5 cm were identified from the study area. Among these species *Clausena anisata* (Willd.) Benth. family Rutaceae was the dominant and *Podocarpus falcatus* (Thunb.) R.Br. ex Mirb. family Podocarpaceae was the least dominant (Appendix II).

The DBH classes of woody species were classified in to three: 5–10 cm, 11–15 cm, and ≥16 cm. The DBH ≥16 cm was added together because there was very few number of high DBH plants found with different DBH. The majority of woodland plants were distributed in the first class (5–10 cm) followed by the 3rd class (≥16 cm) and the least woodland vegetation plants were recorded in the 2nd (11–15 cm). This showed that the first classes were occupied by dense and short plants species of woodland vegetation (Fig. 3).

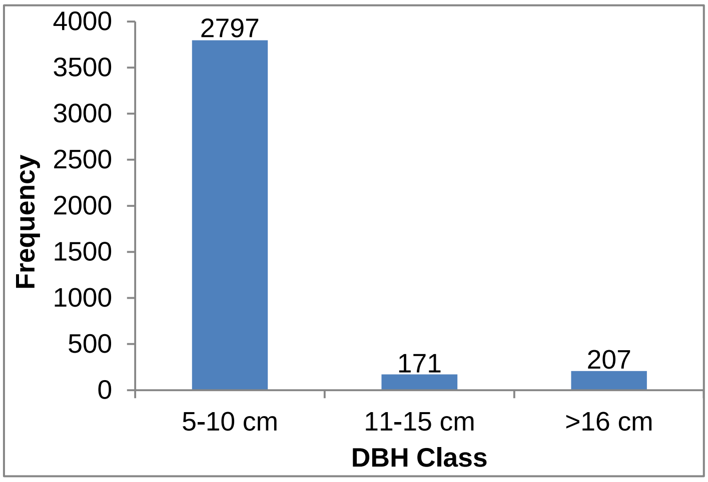

Figure 3. DBH classes of woody plant species of study area.

Woodland vegetation carbon stock

Carbon stock in the three pools: The largest carbon stock was found to be above ground biomass with average of 56.7% followed by below ground pool (5.33%), and the minimum in litter carbon pool (0.006%) (Table 1).

Table 1. Mean Carbon stocks in the different Carbon pools.

Carbon Pools	54 plots	
	Percentage (%)	Mean (t/ha)
Above ground biomass (AGB)	56.700	87.77
Below ground biomass (BGB)	11.304	17.50
Litter biomass	0.015	0.02
Above ground carbon (AGC)	26.650	41.25
Below ground carbon (BGC)	5.330	8.25
Litter carbon	0.006	0.01

Carbon stock and elevation: Based on the result from the mean above ground biomass the lower altitude was 183.23 ton per hectare and 60.49 ton per hectare higher altitude and the result for the mean carbon stock was 86.12 ton per hectare in the lower altitude while 28.43 ton per hectare in higher altitude which was indicated below in (Table 2).

Table 2. Mean biomass and carbon stock t ha^{-1} in different carbon pools along altitudinal gradient.

Carbon Pools (t ha^{-1})	Altitudinal classes	
	1803–1902 Lower altitude	1903–2136 Higher altitude
Above ground biomass (AGB)	183.23	60.49
Above ground carbon (AGC)	86.12	28.43
Below ground biomass (BGB)	36.50	12.10
Below ground carbon (BGC)	17.22	5.69
Litter biomass	0.04	0.05
Litter carbon	0.02	0.02
Total carbon stock	323.13	106.78

The mean averages below ground biomass and below ground carbon stock were relatively similar with above ground biomass and above ground carbon stock. The shown in table 2, the mean below ground biomass for the lower altitude was 36.65 ton per hectare and the upper altitude about 12.10 ton per hectare. The respective mean carbon stock of the low and higher altitude class was 17.22 ton per hectare and 5.69 ton per hectare. Statistically, there was a significant (F= 6.63, P = 0.013) variation between above and below ground carbon stock within the altitude (Table 2).

The amount of litter biomass and carbon stock along the altitudinal gradient was different quite lower than the amount of biomass and carbon estimated above and below ground. As shown in table 3, average amount of the litter biomass at lower altitude was 0.04 ton per hectare corresponds with 0.02 ton per hectare carbon while at higher altitude 0.05 ton per hectare equivalent to 0.02 ton per hectare carbon. This indicates the amount of both litter biomass and carbon accumulated for at lower and higher altitude classes were similar. The total amount of carbon found at higher altitude (0.07 t ha^{-1}) was numerical higher than the lower altitude (0.06) t ha^{-1}, however statistical the difference was non-significant (F= 1.11, *P*= 0.297) (Table 3).

Table 3. Mean litter biomass and carbon stock (t ha^{-1}) along the altitudinal gradient.

Carbon Pools (t ha^{-1})	**Altitudinal classes**	
	1803-1902 Lower altitude	**1903-2136 Higher altitude**
Litter biomass	0.04	0.05
Litter carbon	0.02	0.02
Total carbon stock	0.06	0.07

Total carbon density along altitudinal gradient: This study was aimed to check whether there is low carbon stock density in the higher altitudinal gradient than lower altitudinal gradient. As presented in table 4, the maximum amount of carbon stock was recorded at the lower altitude (103.36 t ha^{-1}) and lower at the higher altitude (34.14 t ha^{-1}). The total carbon stock density sums of each carbon pools in the altitude gradients of the study area. This implies the total amount of carbon stock were lower at higher altitudinal gradient than lower altitudinal gradient.

Table 4. Total carbon stocks (t ha^{-1}) along the altitudinal gradient.

Carbon Pools (t ha^{-1})	**Altitudinal classes**	
	1803-1902 Lower altitude	**1903-2136 Higher altitude**
Above ground carbon (AGC)	86.12	28.43
Below ground carbon (BGC)	17.22	5.69
Litter carbon	0.02	0.02
Total carbon stock	103.36	34.14

Above ground carbon per altitude: As presented in figure 4, at lower altitude large amount of carbon was stored which contain high DBH plant species most. These high DBH plants have greater diameter in the third class and the lower carbon shows the result of first class with 5–10 cm DBH.

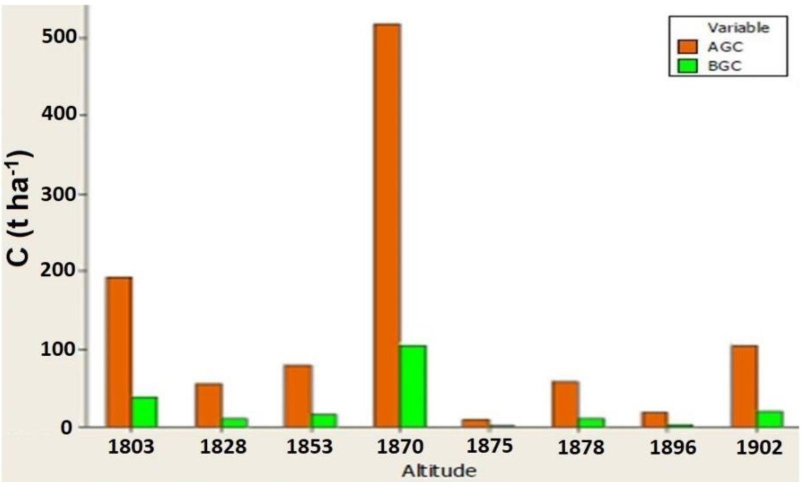

Figure 4. Mean carbon stock at lower altitudinal gradient (1803–1902) study area. [AGC= Above Ground Carbon, BGC= Below Ground Carbon]

The result from the higher altitude of (1903–2136) study area also shows unpattern variation between plots (Fig. 5).

Carbon stocks of different pools and aspect: As showed in table 7, the mean AGC stock was lowest in Gentle (without aspect) (5.13 ton ha^{-1}) and highest in North (58.80 ton ha^{-1}). But other values was observed for carbon stocks in below ground carbon pool with the highest value in Gentle direction (12.05 ton ha^{-1}) and lower value South direction (3.56 ton ha^{-1}). On the other hand, the highest carbon stocks in litter biomass was recorded in the North, South and West (0.02 ton ha^{-1}) and the minimum carbon stock was recorded in East and Gentle (0.01 ton ha^{-1}) direction (Table 5). Totally, for all pools the highest carbon stock was recorded in North aspect (70.62 ton ha^{-1}) and the minimum carbon stock recorded was in the Gentle (17.21 ton ha^{-1}) aspect. Finally, the carbon stock value of each aspect from highest to lowest was put as follow: North > West > East > South > Gentle (no aspect).

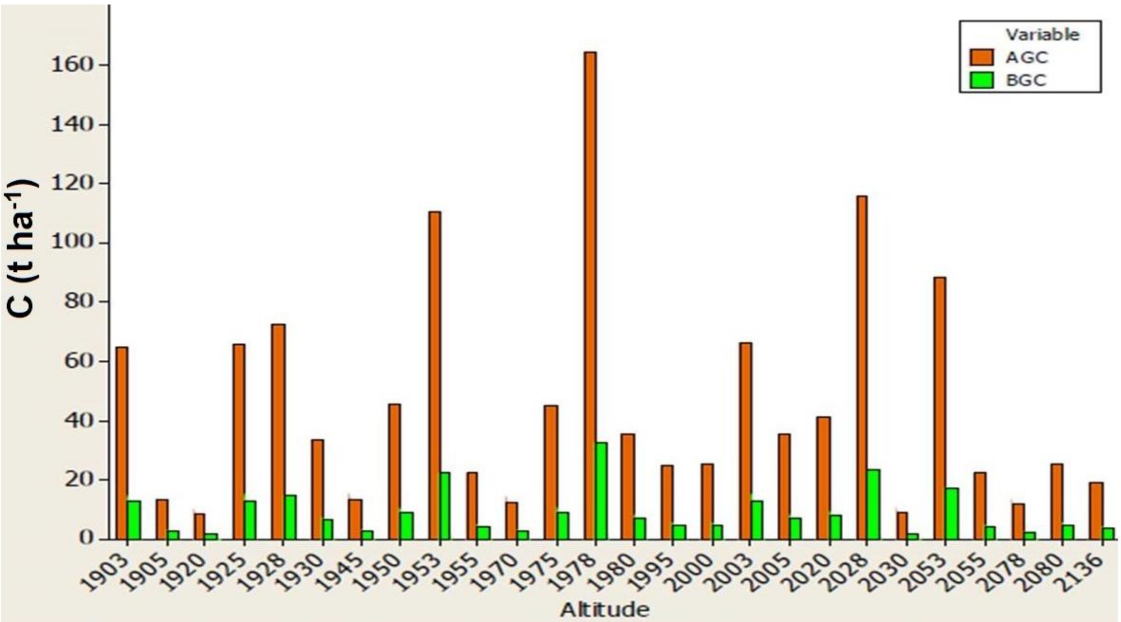

Figure 5. Mean carbon stock of higher altitudinal gradient (1903-2136) study area. [AGC= Above Ground Carbon, BGC= Below Ground Carbon]

Table 5. The Mean carbon stock t/ha of different pools in different plots and aspects.

Aspect	Plot number	Above ground carbon	Below ground carbon	Litter biomass	Litter carbon	Total carbon stock
S	5	17.19	3.56	0.03	0.02	20.80
E	4	22.90	4.58	0.02	0.01	27.51
N	24	58.80	11.76	0.04	0.02	70.62
W	20	31.19	6.24	0.05	0.02	37.50
Gentle (without aspect)	1	5.13	12.05	0.02	0.01	17.21

Disturbance effect on carbon stock with aspect: Table 6 indicated the presence of various kinds of disturbances that could be affected the carbon storage of the woodland vegetation. The human activities that disturb the ecosystem include charcoal production, cutting, grazing cutting, and agricultural expansion were the most important disturbances found throughout the study area. Gentle (without aspect) was one of the most speciously disturbed while the aspects (South (S), West (W) and North (N)) were relatively less disturbed. But, tree cutting and grazing practices were the serious in the N and S aspects, and low in East (E) and West (W).

Table 6. The level of disturbances in different aspect.

Level of disturbances	No of plot	Disturbance type	Aspect				
			Gentle Plot	S Plot	E Plot	W Plot	N Plot
Very high	11	Cutting, Grazing, Charcoal production,	1	3	1	3	3
High	15	Cutting, Grazing, Charcoal production, Agricultural expansion			2	7	6
Medium	23	Cutting, Grazing, Charcoal production and		1	2	11	9
Low	5	Grazing, Small cutting, Charcoal		1			4

Table 7 indicated there was significance variation between the altitudinal gradients for above ground carbon, below ground carbon and litter carbon stock. The variation of a mean carbon stock in relation to altitude, aspect and disturbances where not statistically significant at ($P < 0.005$).

Table 7. Values of significance for one-way ANOVA (P>0.005).

Carbon Pools	F- value	P-value	Gradient
Above ground carbon (AGC)	6.630	0.013	Altitude
Below ground carbon (BGC)	6.630	0.013	
Litter carbon	1.110	0.297	
Above ground carbon (AGC)	0.680	0.612	Aspect
Below ground carbon (BGC)	0.680	0.612	
Litter carbon	1.200	0.299	
Above ground carbon (AGC)	0.940	0.428	Disturbances

DISCUSSION

The mean total carbon stock of above and below ground biomass of the Dirqi woodland vegetation (study area) was comparable with the finding from Ethiopia (Arba Minch) forest (Tulu 2011, Wolde *et al.* 2014), Miombo woodland carbon in Zambia (Shirima *et al.* 2011) and tropical dry and wet forests (Murphy & Lugo 1986). The amount of carbon stored in above ground biomass was higher than belowground. This finding agrees with the finding of Tulu (2011) and Wolde *et al.* (2014). However, it is contradictory with Aticho (2013). This could be due to the fact that the carbon estimation made by Aticho (2013) was based on soil sampling and laboratory analysis whereas the current estimation of below ground carbon was based on models. The total amount of carbon stock of Dirqi vegetation was higher than other findings from Miombo woodland in Tanzania (Saw *et al.* 2014), Miombo woodland in Zambia (Shirima *et al.* 2011) and Miombo woodland in Mozambique (Ribeiro *et al.* 2013). The reason for higher carbon stock density in the study could be due to mixer of dry afromontane forest tree species (*e.g. Olea europaea* L. subsp. *cuspidate* (Wall. & G.Don) Cif., *Carissa spinarum* L. and some remnant trees like *Ficus vasta* Forssk., *Podocarpus falcatus*, *Syzygium guineense* (Willd.) DC., *Prunus africana* (Hook.f.) Kalkman) with high DBH range, higher elevation (1800–2100 m asl) than the other Africa woodlands (300–1700 m), variation in rainfall amount and models used to estimate the carbon stock.

Brown & Lugo (1982) stated that, litter fall in dry tropical forests range between 2.52–3.69 t ha^{-1} $year^{-1}$. Compared to other studies, the mean carbon stock in litter biomass of the current studied is much more less than others, for instance, Miombo woodland in Mozambique (Ribeiro *et al.* 2013) and Menagasha Suba State Forest dry afromontane forest (Sahile 2011). The major reasons include climatic factors limiting carbon content, the total amount of litter fall. The carbon stock of the woodland can also be influenced by the woodland vegetation (species, age and density) and climate factor (Fisher & Binkly 2000). Since the study area is composed of shrubby plants, litter fall intensity is expected to decrease. In addition, in some season, (*e.g.* January up to February the part of the woodland vegetation area is dry and it may have lost its leaf due to high temperature. Also dominant plant species like, *Bersama abyssinica* Fresen., *Clausena anisata*, *Maytenus arbutifolia* (A.Rich.) Wilczek, *Premna schimperi* Engl., *Acacia abyssinica* Hochst. ex Benth, *Calpurnia aurea* (Ait.) Benth., *Syzygium guineense*, *Rhus natalensis* Krauss, *Carissa spinarum*, *Albizia schimperiana* Oliv., *Grewia ferruginea* Hochst. ex A. Rich, *Rhus vulgaris* Meikle, *Osyris quadripartita* Decne, *Olinia rochetiana* A.Juss., *Rytigynia neglecta* (Hiern) Robyns and *Millettia ferruginea* (Hochst.) Bak. control their moisture content which contributed less litter for the study area. The high decomposition rate of organic matter reduce the quality of carbon stoke (Tang *et al.* 2010). Because of disturbances from grazing, sparsely populated plant species and charcoal production the lower altitude litter carbon stock was lower than higher altitudinal gradient.

Comparison of DBH with carbon stock

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

Environmental factors affecting the carbon stocks of different pools

Environmental factors such as altitudinal gradient, disturbance and aspects were affected the carbon storage in different pools. With altitudinal changes many environmental factors such as temperature, precipitation, atmospheric pressure, solar and UV-B radiation, and wind velocity changing rapidly. Because of this fact, altitudinal gradients are among the most powerful “natural experiments” for testing ecological and evolutionary responses of biota to environmental changes (Fang *et al.* 2004, Cui *et al.* 2005, Korner 2007). The carbon stocks of the woodland vegetation were decreasing along the altitudinal gradient; highest at the lower altitudinal and lowest at higher. This may be due to the above mentioned environmental factors, absence of matured large trees at higher altitude and the presence of some big trees at the lower attitude contained rivers that make the condition favorable for tree growth. Because of this in the higher altitudinal gradient, shrubs and secondary vegetation were dominated, and in the lower altitude big mature trees has becomes common.

The highest carbon stock was found in the northern aspect and the least in the gentle part of the woodland vegetation which was perhaps due to the availability of moisture, and seeing protected by the river that surrounded it, matured vegetation (dense) and fertile soil in the northern part and less moisture, scattered tree, shrub dominance, rocky habitat and infertility of soil in gentle part. Different scholars reported altitude has been known to have a major impact on the diversity, biomass and carbon stock in the forest ecosystems (Luo *et al*. 2005, Alves *et al.* 2010). Further, studies reported above and below ground tree biomass and its carbon stock is decline with an increase in altitude (Luo *et al.* 2005, Zhu *et al*. 2011), this agree with the present findings.

Disturbance and carbon stock estimation

Disturbances are the main drivers altering forest structure, creating landscape mosaics, and setting the initial conditions for successional dynamics and structural development (Swanson *et al.* 2011). Human modified woodlands are increasingly prevalent in the tropics (Broadbent *et al.* 2008, Melo *et al.* 2013), hence understanding the effects of human disturbances on woodland carbon stocks is crucial for better practices of woodland management and conservation measures. In this study, there was human disturbances like cutting vegetation, charcoal production, grazing and agricultural practices that affected the above ground carbon stock of the woodland which was similar to previous studies. The spatial pattern of woody biomass described above is subject to frequent and widespread disturbances (Frost 1996) that reduce biomass due to primarily clearance for agriculture (Williams *et al*. 2008), charcoal production (Brouwer & Falcao 2004, Falcao 2008) and fire (Ryan & Williams 2010). In this study disturbance has direct relation with the result of carbon in different pools (Above ground carbon, below ground carbon and, litter carbon).

Various natural or human induced disturbances exert profound impacts on global woodland. According to a recent global assessment of forest more than 60% of the world’s 4 billion ha of forest are recovering from a past disturbance and 3% of the world’s forests are disturbed annually by logging, fire, pests, or weather (FAO 2006). Agricultural expansion has significant impact on forest and woodland and that could contribute for land degradation, biodiversity loss, and GHG emission (IPCC 2007, Walther 2010). These evidences justify the current finding, human disturbance of woodland vegetation for agricultural land expansion that could affect the health ecology and the society.

Different authors reported that the amount of carbon stored in Ethiopian forest varies; It was found to be about 168 Mt C (Brown 1997, Achard *et al*. 2004); 867 Mt C (Gibbs & Brown (2007). As compared to forest lands, the amount of carbon stock in the woodlands is higher than other forest categories because of the higher area coverage 29.55 M ha woodlands of Ethiopia (Moges *et al*. 2010).

CONCLUSION

In the study area, total of 86 woody species of 39 families with stem number of 3175 plants were collected, of which *Clausena anisata* family Rutaceae was the dominant and *Podocarpus falcatus* family Podocarpaceae was the least dominant. The densities of tree species decreases as the DBH and height classes increased in the woodland vegetation. This implies that, the predominance of small sized tree species is in the higher classes than in the lower classes. The analysis of these two parameters in the study woodland indicated that higher percentage of number of tree species in the lower than in the upper frequency classes. The carbon stocks of the study area showed a variation among the plots due to the presence of high biomass plants in some plots and low biomass in other plots due to some remnant primary vegetation.

The lower altitude was high in above ground and below ground carbon stocks while the upper altitude had low carbon stock in carbon pools. This has observed due to the presence of high DBH and high biomass vegetation cover in the lower altitudinal range like *Ficus vasta* and *Syzgiume guiensee*. On the contrary, the litter carbon stock was similar in the upper and lower parts of gradient, due to the uniformity of vegetation coverage through the whole vegetation and the decomposition ability of litter due to high temperature.

The mean above ground carbon and below ground carbon stocks were lowest in gentle and southern part respectively but highest in northern and gentle parts respectively. In other cases, the highest carbon stocks in litter biomass were recorded in the northern, western and southern part equally and the minimum carbon stock was recorded in eastern and gentle aspects, due to the vegetation character and disturbances level at the aspect. Generally, the carbon stocks in the different pools were ranked in decreasing order as follow northern, western, eastern, southern and gentle.

RECOMMENDATION

Based on the findings of this study the following recommendations were made for Dirki woodland vegetation. Awareness creation at all levels of the society on how to use the woodland resource properly with respect to environmental, socio economic benefit, participatory forest management (PFM). Area closer is very important to save the woodland vegetation from degradation.

- In Ethiopia, there are large woodlands conserved in different parts of the country so conducting similar research.
- The carbon stock sequestered in some carbon pools in the present study site is significant so considering all carbon pools (soil carbon).
- For highly threatened species the government should give due attention to plant and replace it by establishing in situ and ex situ for some endangered species.
- Dirki woodland vegetation is facing a variety of threats, including destructive fuel wood collection, uncontrolled (charcoal burning, cutting and free grazing), and agricultural practices with settlement around and near the woodland vegetation must be controlled and managed with the supply of energy save materials.

ACKNOWLEDGEMENTS

The Author would like to thank Jeldu District Administration Office for their Sponsorship and financial support. And, gratefully acknowledges Ilu Gelan District, especially Ijaji area local residents who have been helpful during the field work and who were entirely share their knowledge and experiences at the field work. I would like to thank the staff member of the National Herbarium (ETH), of Addis Ababa University.

REFERENCES

Achard F, Eva HD, Mayaux P, Stibig HJ & Belward A (2004) Improved estimates of net carbon emissions from land cover change in the tropics for the 1990s. *Global Biogeochemical Cycles* 18: GB2008. [DOI: 10.1029/2003GB002142]

Alves LF, Vieira SA, Scaranello MA, Camargo PB, Santos FAM, Joly CA & Martinelli LA (2010) Forest structure and live above ground biomass variation along an elevational gradient of tropical Atlantic moist forest (Brazil). *Forest Ecology and Management* 260: 679–691.

Aticho A (2013) Evaluating organic carbon storage capacity of forest soil: Case study in Kafa Zone Bita District, Southwestern Ethiopia. *American Eurasian Journal of Agriculture and Environmental Science* 13: 95–100.

Bekele T (2002) *Plant Population Dynamics of Dodonea angustifolia and Olea europea subsp. cuspidata in dry Afromontane Forest of Ethiopia*. Acta Universtitatis upsaliens Upssala, Sweden

Wolde BM, Kelbessa E & T Soromessa (2014) Forest Carbon Stocks in Woody Plants of Arba Minch Ground Water Forest and its Variations along Environmental Gradients. *Science, Technology and Arts Research Journal* 3(2): 141–147

Broadbent E, Asner G, Keller M, Knapp D, Oliveira P & Silva J (2008) Forest fragmentation and edge effects from deforestation and selective logging in the Brazilian Amazon. *Biological Conservation* 141: 1745–1757.

Brouwer R & Falcao MP (2004) Wood fuel consumption in Maputo, Mozambique. *Biomass & Bioenergy* 27(3): 233–245.

Brown S & Lugo AE (1982) The storage and production of organic matter in tropical forests and their role in the global carbon cycle. *Biotropica* 14(3): 161–187.

Brown S, Gillespie AJR & Lugo AE (1989) Biomass estimation methods for tropical forests with application to forest inventory data. *Forest Science* 35: 881–902.

Clark DA, Brown S, Kicklighter DW, Chambers JQ, Thomlinson JR, Ni J & Holland EA (2001) Net primary production in tropical forests: an evaluation and synthesis of existing field data. *Ecological Application* 11(2): 371–384.

Cui HT, Liu HY & Dai JU (2005) *Research on mountain ecology and alpine tree line*. Science Press, Beijing.

Falcao MP (2008) Charcoal production and use in Mozambique, Malawi, Tanzania, and Zambia: Historical overview, present situation and outlook. In: *The Conference on Charcoal and Communities in Africa*. INBAR, Maputo, Mozambique.

Fang JY, Shen ZH & Cui HT (2004) Ecological characteristics of mountains and research issues of mountain ecology. *Biodiversity Science* 12: 10–19.

Brown S (1997) Estimating biomass and biomass change of tropical forests: A Primer, Rome, Italy. *FAO Forestry Paper* 134: 110–120.

FAO (2006) *Global forest resources assessment 2005*. Forestry Paper 147, FAO, Rome.

Fisher RF & Binkley D (2000) *Ecology and Management of Forest Soils*. John Willey & Sons, Inc. New York, USA.

Frost P (1996) *The ecology of miombo woodlands*. In: BM Campbell (ed) The miombo in transition: Woodlands and welfare in Africa. Center for International Forestry Research, Bogor, Indonesia, pp. 11–55.

Gibbs HK, Brown S, Niles JO & Foley JA (2007) Monitoring and estimating tropical forest carbon stocks: making REDD a reality. *Environmental Research Letter* 2(4): 045023.

Houghton JT, Meira Filho LG, Lim B, Treanton K, Mamaty I, Bonduki Y, Griggs DJ & Callander BA (1997) *Revised 1996 Guidelines for National Greenhouse Gas Inventories*. IPCC/ OECD/IEA.

IPCC (2006) *Guidelines for national greenhouse gas inventories, Vol* ***4****: Agriculture, Forestry and other land use (AFLOLU)*. Institute for Global Environmental strategies, Hayama, Japan.

IPCC (2007) Highlights from Climate Change 2007: The Physical Science Basis. Summary for Policy Makers. In: *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Institute of Terrestrial Ecology, Edinburgh, pp. 545–552.

Juwarkar AA, Varghese AO, Singh SK, Aher VV & Thawale PR (2011) Carbon Sequestration Potential in above ground biomass of natural reserve Forest of Central India. *International Journal of Agriculture* 1(2): 80–86.

Karky BS & Banskota K (2007) *Reducing Carbon Emissions through Community managed Forests in the Himalaya*. Case study of a community-managed forest in Lamatar, Kathmandu, Nepal, pp. 67–79.

Kent M & Coker P (1992) *Vegetation Description and Analysis: A practical approach*. BP Press, London, 363 p.

Korner C (2007) The use of 'altitude' in ecological research. *Trends in Ecology & Evolution* 22: 569–574.

Luo TX, Brown S, Pan YD, Shi PL, Ouyang H, Yu ZL & Zhu HZ (2005) Root biomass along subtropical to alpine gradients: global implication from Tibetan transects studies. *Forest Ecology Manage*ment 206: 349–363.

MacDicken KG (1997) A Guide to Monitoring Carbon Storage in Forestry and Agro-forestry Projects. In: *Forest Carbon Monitoring Program*. Winrock International Institute for Agricultural Development, Virginia, pp. 87.

McEwan WR, Lin Y, Sun IF, Hsieh C, Su S, Chang L, Song GM, Wange H, Hwong J, Lin K, Yang K & Chiang J (2011) Topographic and biotic regulation of above ground carbon storage in subtropical broad-leaved forests of Taiwan. *Forest Ecology and Management* 262: 1817–1825.

Melo FPL, Arroyo R, Fahrig L, Martinez RM & Tabarelli M (2013) On the hope for biodiversity friendly tropical landscapes. *Trends in Ecology & Evolution* 28: 462–468.

Moges Y, Zawdu E & Nune S (2010) *Ethiopian Forest Resources: Current Status and Future Management Options In View of Access to Carbon Finances*. Ethiopian Climate Research and Networking and the United Nations Development Programme (UNDP) Addis Ababa, Ethiopia, 56 p.

Murphy PG & Lugo AE (1986) Structure and biomass production of a dry tropical forest in Puerto Rico. *Biotropica* 18: 89–96.

Pan Y, Birdsery RA, Phillips OL & Jackson RB (2013) The Structure, Distribution, and Biomass of the World's Forests. *Annual Review of Ecology, Evolution, and Systematics* 44: 593–622.

Pearson T, Walker S & Brown S (2005) *Source book for Land Use*. Land Use Change and Forestry Projects, Winrock International, USA.

Pearson TR, Brown SL & Birdsey RA (2007) *Measurement guidelines for the sequestration of forest carbon*. Northern research Station, Department of Agriculture, Washington, D.C.

Ribeiro NS, Matos CN, Moura IR, Washington-Allen RA & Ribeiro AI (2013) Monitoring vegetation dynamics and carbon stock density in miombo woodlands. *Carbon Balance Manage* 8: 11. [DOI:10.1186/1750-0680-

8-11]

Ryan CM & Williams M (2010) How does fire intensity and frequency affect miombo woodland tree populations and biomass? *Ecological Applications* 21(1): 48–60.

Sahile M (2011) Estimating and Mapping of Carbon Stocks based on Remote Sensing, GIS and Ground Survey in the Menagesha Suba State Forest, (M. Sc. Thesis). Addis Ababa University, Addis Ababa.

Sawe TC, Munishi PKT & Maliondo SM (2014) Woodlands degradation in the Southern Highlands, Miombo of Tanzania: Implications on conservation and carbon stocks. *International Journal of Biodiversity and Conservation* 6(3): 230–237.

Shirima DD, Munishi PKT, Lewis LS, Burgess ND, Marshall AR, Andrew B, Swetnam RD & Zahabu EM (2011) Carbon storage, structure and composition of miombo woodlands in Tanzania's Eastern Arc Mountains. *African Journal of Ecology* 49(3): 332–342.

Swanson ME, Franklin JF, Beschta RL, Crisafulli CM & Della SDA (2011) The forgotten stage of forest succession: early-successional ecosystems on forest sites. *Frontiers in Ecology and the Environment* 9: 117–125.

Tang JW, Cao M, Zhang JH & Li MH (2010) Litter fall production, decomposition and nutrient use efficiency varies with tropical forest types in Xishuangbanna, SW China: a 10-year study. *Plant and Soil* 335: 271–288.

Terakunpisut J, Gajaseni N & Ruankawe N (2007) Carbon sequestration potential in aboveground biomass of thong phaphum national forest, Thailand. *Applied Ecology and Environmental Research* 5(2): 93–102.

Thomas SC (1996) Asymptotic height as a predictor of growth and allometric characteristics in Malaysian rainforest trees. *American Journal of Botany* 83(5): 556–566.

Tulu T (2011) Estimation of Carbon Stock in Church Forests: Implications for Managing Church Forest for Carbon Emission Reduction, (M. Sc. Thesis). Addis Ababa University, Addis Ababa.

Walther GR (2010) Community and ecosystem responses to recent climate change. *Philosophical Transactions of the Royal Society B* 365: 2019–2024

Wang H, Hall CAS, Scatena FN, Fetcher N & Wu W (2003) Modeling the Spatial and temporal variability in climate and primary productivity across the Luquillo mountains, Puerto Rico. *Forest Ecology and Management* 179: 69–94.

Williams M, Ryan CM, Rees RM, Sambane E, Fernando J & Grace J (2008) Carbon sequestration and biodiversity of re growing miombo woodlands in Mozambique. *Forest Ecology and Management* 254(2): 145–155.

Zhu B, Xiangping W, Jingyun F, Shilong P, Haihua S, Shuqing Z & Changhui P (2011) Altitudinal changes in carbon storage of temperate forests on Mt Changbai, Northeast China. Carbon cycle process in East Asia. *Journal of Plant Resource* 10: 1–14.

Appendix I: Models to estimate carbon stock from Above Ground Biomass.

Model	Conditions to be fulfilled	Author
Y = 34.4703 - 8.0671 DBH + 0.6589 DBH^2 R2 = 0.67	DBH ≥ 5 cm Dry (rainfall < 1500 mm)	Brown *et al.* 1989
Y = exp{-1.996 + 2.32 × ln(DBH)} R^2 = 0.89	5 < DBH < 40 cm Dry transition to moist (rainfall > 900 mm)	FAO, 1997
Y = 10 ^ (- 0.535 + log10 (p × r2)) R2 = 0.94	3 < DBH < 30 cm Dry (rainfall < 900 mm)	FAO, 1997
Y = exp{-2.134 + 2.530 × ln (DBH)} R2 = 0.97	DBH < 80 cm Moist (1500 < rainfall < 4 000 mm)	FAO, 1997
Y = exp{-3.1141 + 0.9719 × ln[(DBH2)H]} R2 = 0.97	DBH > 5 cm Moist (1500 < rainfall < 4 000 mm)	Brown *et al.* 1989
Y = exp{-2.4090+ 0.9522 × ln[(DBH2)HS]} R2 = 0.99	DBH > 5 cm Moist (1500 < rainfall < 4 000 mm)	Brown *et al.* 1989

Appendix II: List of woody plant species ≥ 5 cm DBH identified from Study area (T= Tree, S= Shrub and L= Liana).

S.N.	Local Name (Afan oromo)	Scientific Name	Habit	Family
1	Arangamaa	*Pterolobium stellantum* (Forssk.) Brenan	L	Fabaceae
2	Bakkanniisa	*Croton macrostachyus* Del.	T	Euphorbiaceae
3	Ceekaa	*Calpurnia aurea* (Ait.) Benth.	S	Fabaceae
4	Daalachoo	*Olinia rochetiana* A.Juss.	T	Oliniaceae
5	Gambeela	*Gardenia ternifolia* Schumach. & Thonn.	T	Rubiaceae
6	Hidda hoomachoo	*Helinus mystacinus* (Ait.) E. Mey. ex Steud.	L	Rhamnaceae
7	Imalaa	*Albizia schimperiana* Oliv.	T	Fabaceae
8	Kombolcha	*Maytenus arbutifolia* (A.Rich.) Wilczek	S	Celastraceae
9	Koshommii	*Dovyalis abyssinica* (A. Rich.) Warb.	T	Flacourtiaceae
10	Lolchiisaa	*Bersama abyssinica* Fresen.	T	Melianthaceae
11	Mi'eessaa	*Euclea divinorum* Hiern	T	Ebenaceae
12	Rukeessa	*Combretum adenogonium* Steud. ex A. Rich.	T	Combartaceae
13	Ulmaayii	*Clausena anisata* (Willd). Benth.	T	Rutaceae
14	Urgeessaa	*Premna schimperi* Engl.	S	Lamiaceae
15	Waatoo	*Osyris quadripartita* Decne	T	Santalaceae
16	Xaaxessaa	*Rhus natalensis* Krauss	T	Anacardiaceae
17	Abbayyii	*Maesa lanceolata* Forssk.	T	Myrsinaceae
18	Agamsa	*Carissa spinarum* L.	T	Apocynaceae
19	Dhoqonuu	*Grewia ferruginea* Hochst. ex A. Rich	T	Tiliaceae
20	Laaftoo qola adii	*Acacia abyssinica* Hochst. ex Benth	T	Fabaceae
21	Qana'ee	*Schrebera alata* (Hochst.) Welw.	T	Oleaceae
22	Baddeessaa	*Syzygium guineense* (Willd.) DC.	T	Myrtaceae
23	Botoroo	*Stereospermum kunthianum* Cham.	T	Bignoniaceae
24	Qawwisa	*Nuxia congesta* R.Br. ex Fresen.	T	Loganiaceae
25	Xaxessa fakkaata	*Rhus vulgaris* Meikle	T	Anacardiaceae
26	Ejersa	*Olea europaea* L. subsp. *Cuspidata* (Wall.ex G.Don) Cif.	T	Oleaceae
27	Ilkee	*Diospyros abyssinica* (Hiern) F. White	T	Ebenaceae
28	Somboo	*Ekebergia capensis* Sparrm.	T	Meliaceae
29	Akuukkuu	*Flacourtia indica* (Burm.f.) Merr	T	Flacourtaceae
30	Cayii	*Celtis africana* Buerm.f.	S	Ulmaceae
31	Gaafatoo	*Senna ptersiana* (Bolle) Lock	S	Fabaceae
32	Sarxee	*Dalbergia lactea* Vatke	S	Fabaceae
33	Buruurii	*Vangueria apiculata* K. Schum.	T	Rubiaceae
34	Hidda Indirifaa	*Rhoicissus revoilii* Planch.	C	Rhamnaceae
35	Kombolcha adii	*Scutia myrtina* (Burm. f.) Kurz	S	Rhamnaceae
36	Waddeessa	*Cordia africana* L.	T	Boraginaceae
37	Dambii	*Ficus thonningii* Blume	T	Moraceae
38	Sarara	*Allophylus macrobotrys* Gilg	T	Sapindaceae
39	Meexxii	*Phoenix reclinata* Jacq.	H	Arecaceae

40	Odaa	*Ficus sycomorus* L.	T	Moraceae
41	Sootalloo/Birbirra	*Millettia ferruginea* (Hochst.) Bak.	T	Fabaceae
42	Daannisaa	*Dombeya torrida* (G.F. Gmel.) P. Bamps	T	Sterculiaceae
43	Hidda baggii	*Combretum paniculatum* Vent.	L	Combretaceae
44	Arangamaa qamalee	*Capparis tomentosa* Lam.	S	Capparidaceae
45	Bosoqa	*Sapium ellipticum* (Krauss) Pax.	T	Euphorbiaceae
46	Gagamaa	*Olea capensis* L. subsp. *macrocarpa* (C.H. Wright) Verdc.	T	Oleaceae
47	Qacamoo	*Phyllanthus ovalifolius* Forssk.	S	Euphorbiaceae
48	Qolaatii	*Mimusops kummel* A. DC.	T	Sapotaceae
49	Qawwisa	*Buddleja polystachya* Fresen.	S	Loganiaceae
50	Qumbaala/Calalaqa	*Apodytes dimidiata* E. Mey. ex Am.	T	Icacinaceae
51	Gaarrii	*Hymenodictyon floribundum* (Hochst. & Steud.) B.L.Rob.	T	Rubiaceae
52	Rukeessa	*Combertum molle* R. Br. ex G.Don	T	Combertaceae
53	Birbirsa	*Podocarpus falcatus* (Thunb.) R.B. ex. Mirb.	T	Podocarpaceae
54	Hadheessa	*Teclea nobilis* Del.	T	Rutaceae
55	Qaqawwii	*Rosa abyssinica* Lindley	S	Rosaceae
56	Ibicha	*Vernonia amygdalina* Del.	T	Asteraceae
57	Hinnee	*Hypericum quartinianum* A. Rich.	T	Guttiferae
58	Agiraabaa	*Bridelia micrantha* (Hochst.) Baill.	T	Euphorbiaceae
59	Dabaqqaa	*Terminalia macroptera* Giull & Perr.	T	Combretaceae
60	Gaarrii	*Terminalia schimperiana* Hochst.	T	Combretaceae
61	Ittacha	*Dodonaea angustifolia* L. f.	S	Sapindaceae
62	Bunittii	*Galiniera saxifraga* (Hochst.) Bridson	S	Rubiaceae
63	Mixoo	*Rytigynia neglecta* (Hiern) Robyns	S	Rubiaceae
64	Qadiidaa	*Rhamnus staddo* A.Rich.	T	Rhamnaceae
65	Harbuu	*Ficus sur* Forssk.	T	Moraceae
66	Laanqisaa	*Urera hypselodendron* (A.Rich,) Wedd.	L	Urticaceae
67	Qilinxoo	*Ficus mucuso Ficalho.*	T	Moraceae
68	Sokorruu	*Achantus sennii* Chiov.	S	Acanthaceae
69	Bururii	*Vangueria apiculata* K. Schum.	T	Rubiaceae
70	Qacama	*Myrsine africana* L.	S	Myrsinaceae
71	Reejjii	*Vernonia myriantha* Hook.f.	T	Asteraceae
72	Karra waayyuu	*Chionanthus mildbraedii* (Gilg & Schellenb.)	T	Oleaceae
73	Laaftoo	*Acacia persiciflora* Pax	T	Fabaceae
74	Acaacii	*Maytenus gracilipes* (Welw. ex Oliv.) Exell	S	Celastraceae
75	Qola-gurraa	*Rothmannia urcelIiformis* (Hiem) Robyns	T	Rubiaceae
76	Kombolcha	*Maytenus obscura* (A. Rich.) Cuf.	T	Celastraceae
77	Qaqaroo	*Gnidia involucrata* Steud. ex A. Rich.	S	Thymelaeaceae
78	Ilkee	*Diospyros abyssinica* (Hiern) F. White	T	Ebenaceae
79	Qilxuu	*Ficus vasta* Forssk.	T	Moraceae
80	Ambaltaa	*Entada abyssinica* Steud. ex A. Rich.	T	Fabaceae
81	Doddota	*Acacia etbaica* Schweinf.	T	Fabaceae
82	Qarxammee	*Allophylus africanus* P. Beauv.	S	Sapindaceae
83	Ulaagaa	*Ehretia cymosa* Thonn	T	Boraginaceae
84	Gambeela	*Gardenia volkensii* K. Schum. subsp. *volkensii* var. *volkensii*	T	Rubiaceae
85	-	*Combretum nigrican* Lepr. ex Guill. & Perr.	T	Combretaceae
86	-	*Combretum collinum* Fresen.	T	Combretaceae