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Carbon Stock Potentials of Woody Plant Species in Biheretsige and Central Closed Public Parks of Addis Ababa and Its Contribution to Climate Change Mitigation

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Abstract
City park forests have role in mitigating the effect of climate change. However, more studies have been conducted on carbon stock estimation of forests in wide area. This study was conducted to estimate the carbon potential of Biheretsige and Central Closed Public Parks of Addis Ababa. Current conditions of the study sites, woody plant species, structure and the carbon stock in the different carbon pools were done. Woody species data collection was done by complete listing method. Soil and litter data collection had also been carried out using representative sampling. The result of the present study showed that 4147 woody plant had a DBH ≥5 cm. Total carbon stock densities of the two sites were 149.18±5.28 t ha^{-1}. The mean above and below ground carbon stocks were 25.4±3.7and 5 ± 0.75t ha^{-1}, respectively. Aboveground and belowground biomasses were 50.85±7.45and 10.2± 1.50 t ha^{-1} while the total carbon stock in the litter was 5.175± 2.25 t ha^{-1}. Soil organic carbon (30 cm depth) stock was 113.55±1.05 t ha^{-1}. The carbon stocks in above and below ground biomasses were small as compared to the previous studies. This was because of the lower DBH class value of woody plant species of the study sites and the smaller size of the study area. Litter biomass, litter carbon stock and soil organic carbons were proportional to the previous studies. Therefore, the results of the study showed that woody plant species of the selected Park have positive role in reduction of greenhouse gases and in contributing to climate change mitigation.
Keywords: Carbon stock, Climate change mitigation, Closed Public Park

INTRODUCTION

Climate change is a change in the statistical distribution of weather over periods of time that range from decades to millions of years. It can be a change in the average weather or a change in the distribution of weather events around an average, also climate change may be limited to a specific region, or may occur across the whole Earth (IPCC, 2001). It is clear that human activities contribute about 7GtCs equivalent to the atmosphere each year, up from around 6GtCs in 1990 (IPCC, 2000). On the other hand, the GHGs levels are increasing at their maximum atmospheric concentrations. The extent to which GHGs especially CO_2 absorbed by sinks such as forests have been the focus of international negotiations. Thus, it is widely recognized that large scale reductions in CO_2 emissions are required to fairly strict limits on how much carbon absorbed so as to mitigate the climate change. Fossil fuel combustion, industrial processes, and unprecedented land use conversion have led to rising levels of CO_2 and other GHGs in the atmosphere (Persche *et al.,* 2007).

Forestry can make a very significant contribution to a low-cost global mitigation portfolio that provides synergies with adaptation and sustainable development. However, this opportunity is being lost in the current institutional context and lack of political will to implement and has resulted in only a small portion of this potential being realized at present forestry mitigation activities implemented under the Kyoto Protocol, including the Clean Development Mechanism (CDM), have to date been limited. Opportunities to increase activities include simplifying procedures, developing certainty over future commitments, reducing transaction costs, and building confidence and capacity among potential buyers, investors and project participants (IPCC, 2007).

The carbon dioxide is the largest single greenhouse gas in the atmosphere. It is currently trapping about half of the total heat that contributes to global warming, removing of atmospheric carbon and storing it in terrestrial biosphere, such as planting tree, has been one of the methods stated under the Kyoto Protocol for countries to meet their national carbon reduction targets (FAO, 2009). In order to reduce carbon dioxide from the atmosphere, carbon sequestration in different ecosystem is mandatory. According to UNFCCC (2007) and Bijayain (2008), Carbon sequestration is the process of removing carbon from the atmosphere and depositing it in a reservoir. It entails the transfer of atmospheric CO_2, and its secure storage in long-lived pools, so that the buildup of carbon dioxide concentration in the atmosphere will be reduced.

In urban area parks and open space have a significant amenity value and provide a contrast to the built environment; natural features have positive psychological effects, even for those not consciously appreciative; parks and trees have proven ecological value in urban areas by removing pollution from the air (Taylor and Coalter, 2001). Healthy environments lead to healthy economies and societies. Parks are pollution ameliorators and help counter the pollution that makes cities unbearable and unsustainable. Urban parks with well-maintained vegetation act as physical filters helping to reduce air pollutants. Trees and vegetation in city parks can help reduce air pollution directly by removing and storing carbon dioxide (a dominant greenhouse gas) and indirectly by reducing air temperatures and building energy use in and near parks. These tree effects can reduce pollutant emissions and formation (Nowak & Heisler, 2010).

As the population grows in the Capital City, the demand exceeded the replacing rate and aggravated deforestation due to different diverse need and plan of the city. The green cover starts depleting and consequently the city suffered from soil erosion, environmental degradation and micro-climate imbalances. Thus vegetation coverage of Addis Ababa including individual trees in private yards/land around house/ is estimated at 7,900 ha by the Urban Agricultural Office, covering 14.6% of the total area. About 98% are plantation forests mainly consisting of Eucalyptus. Indigenous forests remain only in small pockets, especially around churches and secured compounds, covering an estimated area of about 250 hectares only. The deforestation of watersheds has resulted in loss of genetic resources, severe soil erosion, flooding of the city, damages to houses and infrastructures, wood scarcity, and deterioration of living conditions (Horst, 2006).

Rapid urbanization increased motorization and economic activity, which leads to increased air pollution. Emissions from mobile sources are said to be the principal contributors to urban air pollution and it is becoming a serious health and environmental threat. In developing cities like Addis Ababa, air pollutants are released by rapidly expanding vehicle fleets and poorly maintained old vehicles. Poor/or lack of regulatory framework specific to vehicular emissions can also be taken as set of contributing factor for urban air pollution (Daniel *et al*., 2010). Thus protecting the established and establishing the new urban forest /woody plant species helps to stabilization of this pollution and help to mitigate GHGs and also act as cooler of the city by capturing the areal temperature.

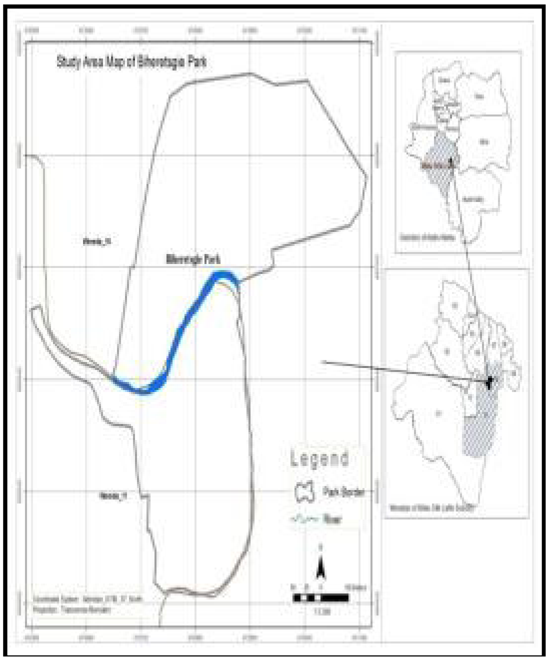
In Ethiopia, assessment of carbon stock potential of forest begun in recent years, though, different studies have been made in Ethiopian forests with various aims. These include Teshome Soromessa *et al.* (2004); Ensermu Kelbessa and Teshome Soromessa (2008); Teshome Soromessa *et al.* (2011); Fekadu Gurmessa *et al*. (2011 & 2012); Adugna Feyissa *et. al.* (2013); Teshome Soromessa (2013); Teshome Soromessa and Ensermu Kelbessa (2013a & 2013b); Abel Girma *et. al.* (2014); Belay Melese *et. al.* (2014); Birhanu Kebede, *et. al.* (2014); Mohammed Gedefaw *et. al.* (2014); Mohammed Gedefaw and Teshome Soromessa (2014); Teshome Soromessa and Ensermu Kelbessa (2014), Tibebu Yelemfrhat Simegn *et al.* (2014); Eyosias Worku and Teshome Soromessa (2015); Muluken Nega Bazezew, *et al.* (2015 a & b); Teshome Soromessa (2015). However, urban park/forest contribution to climate change mitigating value has not yet studied well. So the potential of Urban Closed Public Park Woody Plant Species to carbon storage and its role for climate change mitigation was not addressed before. Therefore the aim of this study is to fill the gaps and show the carbon stock storage potential of Closed Public Parks and their role in climate change mitigation and reducing GHGs beyond its aesthetic/ recreational value by quantifying the amount of organic carbon sequestered in the major pools (above and below ground, dead litter and soil organic carbon pool) in the selected parks.

MATERIAL AND METHODS

Description of the Study Area

The geographical location of Addis Ababa is between $8^0$49′55″ North and $9^0$5′53″North latitude and 38^0 38′16″East and $38^0$54′19″ East longitude and with a total are of 54,000 hectare or 540 km^2. The average altitude of Addis Ababa is 2500 meters above sea level and the range is in between 2100 m to 2900 m. The highest peak is found at Mount Entoto and the lower part is found around Akaki plain. The city is surrounded by the Entoto massive in the north. The upper part of the city is characterized by steep slopes with high mountains, flat topped plateau while the lower part is less steep.

The elevation of the study sites range from 2188 to 2234 meter above sea level and 2310 to 2340 meter above sea level at Biheretsige and Central Public Park respectively.



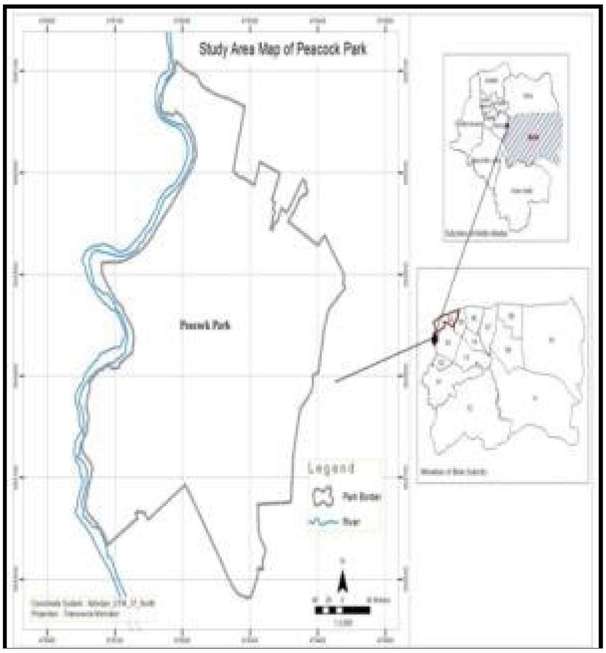


Figure 1. Map of Biheretsige Park Figure 2. Map of Central Park

From the Koeppen's climate classification method Lema Gonfa (1996) summarized classification of Ethiopia climate into five. Out of these, five groups the climate of Addis Ababa fall under Cwb climate group. Its distinct dry month is in winter, mean temperature of the coldest month is below 18^{0}C and for more than four months above 10^{0}C and rainfall of the driest winter month is less than one tenth of the wettest summer month. The rainfall amount and its distribution vary from one area to another and range from 60-200 cm. The data from National Meteorology Agency for this study site indicated in (figure 3) that the mean annual rainfall was 1094 mm, and the maximum mean monthly temperature was 26^{0}C and the minimum mean annual 7.1^{0}C and maximum mean annual temperature which recorded at that specific station was 16.8^{0}C.

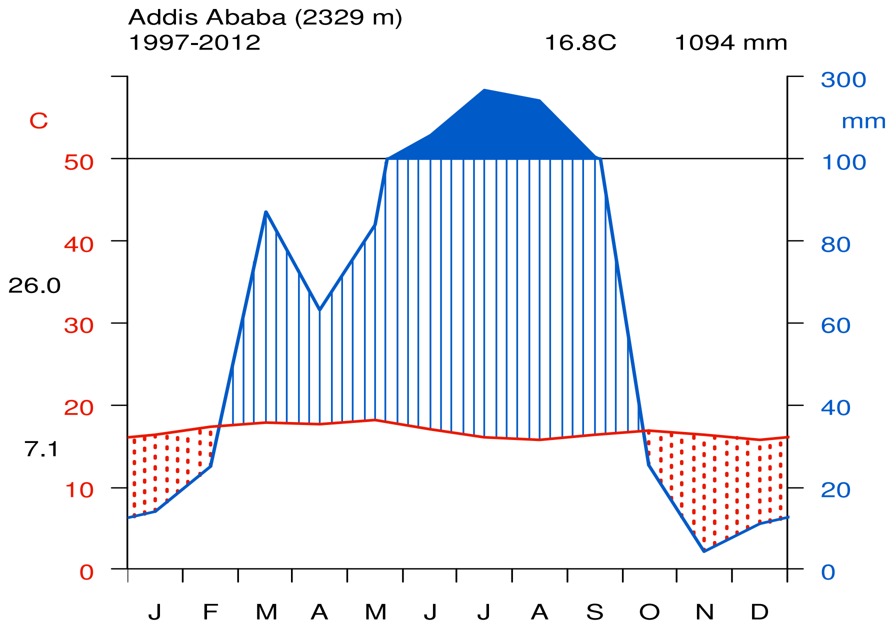


Figure 3. Climadiagram (from Addis Ababa Bole Station)

Methodology

Selection and Delineation of sampling site

Out of thirteen public closed parks in Addis Ababa, Biheretsige and Central Closed Public Park were selected mainly based on size of the parks, the current condition of woody plant species in the park and year of establishment. There are many tools that are available for identifying and delineating project boundaries such as aerial photos, global positioning system (GPS), topographic maps, land records and others. However, for this study GPS was used for boundary delineation of the study site.

Data type

The primary and secondary data were used in order to collect the important data to meet the objectives of this study. Primary data were obtained through field measurements in the study areas and the secondary data were collected from different resources like published and unpublished materials, books, journals, articles, reports, and electronic web sites.

Sampling design

Data were collected from Biheretsige and Central Closed Public Parks by using complete listing method of individual woody plant species which have DBH ≥5 cm from field. The complete listing method is chosen because it was easy to enumerate all the woody plants with in the parks. The area covered by woody plant species was calculated from the coordinate points recorded by GPS. Soil and litter data gathered from each park with in 10 m x10 m quadrat and total of 50 quadrat and 250 subquadrat which were 1 mx1 m used as representative sampling. Litter collected manually from the four corners and center of main quadrat and soil samples collected using soil auger and the wet weight data was recorded. The location of each quadrat was recorded using GPS.

Woody Plant Species Sampling

Both DBH and (1.3 m above the ground) height of the individuals all woody plant species having diameter ≥5 cm was measured. Woody plants which have multiple stems at 1.3 m height were considered as a single individual and DBH of the largest stem was taken. Branched woody plants at 1.3 m were measured at the smallest point below1.3m, where the stem assumes near cylindrical shape. A woody plant with multiple stems or fork below 1.3 m height was treated as a single individual and making on the woody plant using code. Those found on a slope area was measured on the uphill side while height of all listed woody species were measured using Suunto hypsometer in the position where possible to observe the tip of the woody plant (Pearson *et al.*, 2005).

Litter sampling

The litter samples were collected from subquadrat of 1 m × 1 m in each quadrat. From each quadrat at each corner and center of the subquadrat, samples were taken. All litter samples in the sub quadrats were collected by manual from each subquadrat. A 100 gm composite sample was measured for field wet weight and was taken for laboratory analysis at the later stage. The litter samples were oven dried at 105 ^{0}C for 48 h using dry ashing method (Allen *et al.* 1986). Oven-dried samples were taken in pre-weighed crucibles. Then the samples were ignited at 550 ^{0}C for one hour in muffle furnace. After cooling, the crucibles with ash were weighed and percentage of organic carbon was calculated. Finally, carbon in litter t ha-^{1} for each sample was determined. Dead wood was not considered in this study due to the unavailability of it in the study sites.

Soil sampling

The soil samples for soil carbon determination were collected from sample plots laid for litter sampling. In each sub-quadrat one soil sample was taken using core sampler auger at depth of 30 cm from the four corners and center of each qaudrat. Soil sample were mixed homogenously and 100 gm sample was taken from each sample quadrat for the determination of organic carbon in the laboratory using Walkley-Black method. Finally the bulk density, soil organic carbon and soil organic matter were calculated (Pearson *et al.*, 2005).

Estimation of Biomass

Estimation of Aboveground and Belowground Biomass

Aboveground biomass namely stem, stump, branches, bark, seed and foliage includes not only live trees but also live understory (IPPC, 2003). An allometric equation is a statistical relationship between key characteristics dimension of trees that are fairly easy to measure, such as DBH or height, and other properties' that are more difficult to assess, such as aboveground biomass.

From the different available allometric equations to estimate above ground biomass, the model that was developed by Brown *et al* (1989) is recommendable for this study site since the general criteria described by the author fit with the study area. The equation to be used to calculate the above ground biomass is given below:

$Y = 34.4703 - 8.0671(DBH) + 0.6589(DBH^2)$ …………………………………… (eq…1)

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

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

$BGB = AGB \times 0.2$ ……………………………………………………………… (eq….2)

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

AGB).

Estimation Litter Biomass Mass

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

$$LB = \frac{Wfield}{A} * \frac{Wsub_{sample(dry)}}{Wsub_{sample(fresh)}} * \frac{1}{10{,}000} \quad \text{(eq…3)}$$

Where: LB = Litter (biomass of litter t ha^{-1})

W_{field} = 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 were collected (ha);

W sub-sample, dry = weight of the oven-dry 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).

The percentage of organic carbon storage from the dry ashing in the litter carbon pool was calculated as follows (Allen *et al*., 1986):

$$\%Ash = \frac{Wc-Wa}{Wb-Wa} * 100 \quad \text{(eq…4)}$$

$$\%C = (100 - Ash\ \%) * 0.58 \quad \text{(eq… 5)}$$

Where, C= organic carbon (%)

Wa= the weight of the crucible (g)

Wb= the weight of oven dried grind samples and crucibles (g)

Wc = the weight of ash and crucibles (g)

Carbon stocks in dead litter biomass

$$C_L = LB \times \%C \quad \text{(eq…6)}$$

Where, C_L is total carbon stocks in the dead litter in t ha^{-1}, % C is carbon fraction determined in the laboratory (**Pearson** *et al.,* 2005).

Estimation of Soil Organic Carbon

The carbon stock density of soil organic carbon can be calculated as recommended by Pearson *et al.* (2005) from the volume and bulk density of the soil.

$$V = h \times \pi r^2 \quad \text{(eq…7)}$$

Where, V is volume of the soil in the core sampler augur in cm^3, h is the height of core sampler augur in cm, and r is the radius of core sampler augur in cm (**Pearson** *et al.,* 2005). More over the bulk density of a soil sample can be calculated as follows:

$$BD = \frac{W_{av,\ dry}}{V} \quad \text{(eq…8)}$$

Where, BD is bulk density of the soil sample per, $W_{av,\ dry}$ is average air dry weight of soil sample per the quadrat, V is volume of the soil sample in the core sampler auger in cm^3 (**Pearson** *et al.,* 2005)

$$SOC = BD * d * \%C \quad \text{(eq…9)}$$

Where, SOC= soil organic carbon stock per unit area (t ha^{-1}),

BD = soil bulk density (g cm^{-3}), D = the total depth at which the sample was taken (30 cm), and %C = Carbon concentration (%).

Estimation of Total Carbon Stock of the Area

The carbon stock density is calculated by summing the carbon stock densities of the individual carbon pools of the stratum using the Pearson *et al.* (2005) formula. In addition, it is recommended that any individual carbon pool of the given formula can be ignored if it does not contribute significantly to the total carbon stock (Bhishma *et al*., 2010).

Carbon stock density of a study area:

$$C_{density} = C_{AGB} + C_{BGB} + C_{Lit} + SOC \quad \text{(eq...10)}$$

Where: $C_{density}$ = Carbon stock density for all pools [ton ha^{-1}]

C_{AGTB} = Carbon in above -ground tree biomass [t C ha^{-1}]

C_{BGB} = Carbon in below-ground biomass [t C ha^{-1}]

C_{Lit} = Carbon in dead litter [t C ha^{-1}]

SOC = Soil organic carbon, the total carbon stock is then converted to tons of CO_2 equivalent by multiplying it by 44/12, or 3.67 (Pearson *et al.*, 2007).

Statistical Analysis

After the data collection was completed, data analysis of various carbon pools measured in the closed public parks were accomplished by organizing and recording into the excel sheet and different comparison graphs and tables. In order to apply models for biomass estimation, the data obtained from DBH and Height of each species were used, weight of litter and soil were analyzed using Statistical Package for Social Science (SPSS) software version 16.

RESULTS

The Existing Situation of Biheretsige Closed Public Park

The land use /land cover results of Biheretsige Park showed that 69.5% of the area is covered by forest, 11.5% bare land, 3.9% occupied by building and the rest percentage were river, road and grasses (Figure 4).

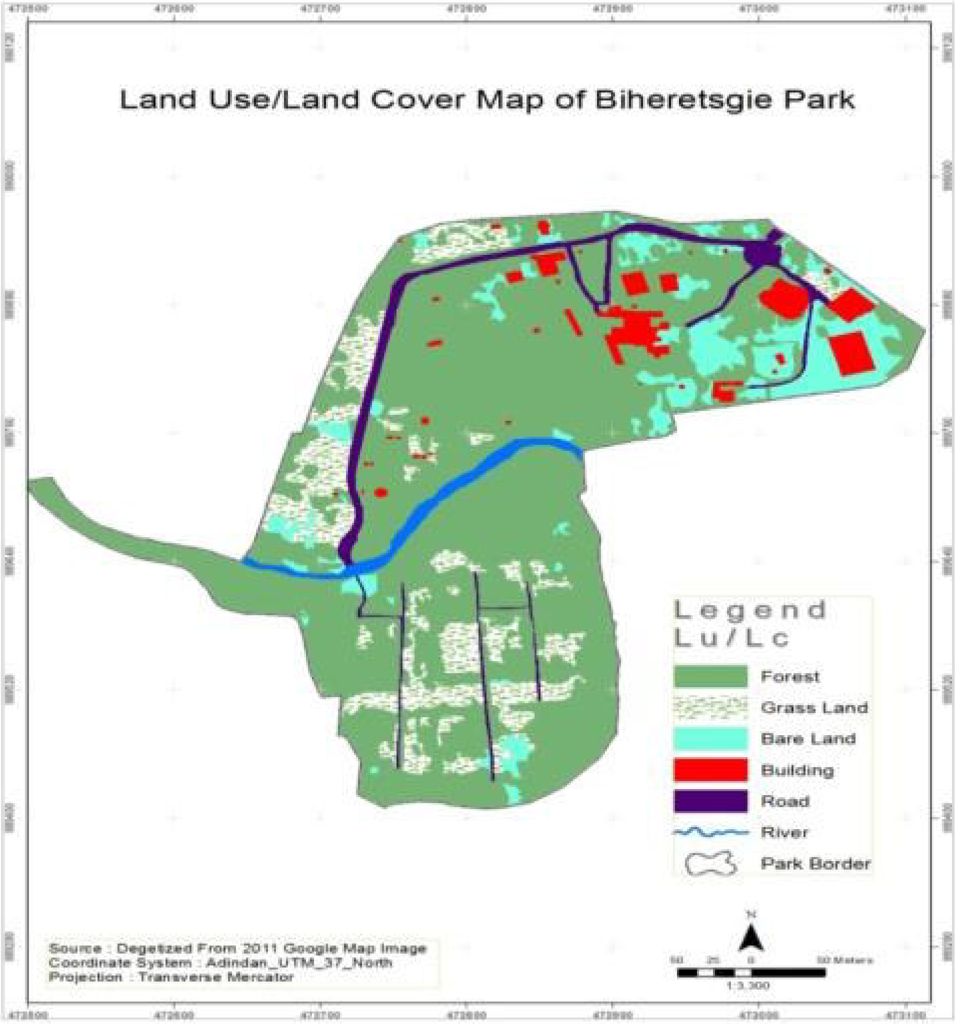


Figure 4. Land use Land Cover Map of Biheretsige Closed Public Park
Source: Digitized from 2011 Google Map Image Coordinate System: Adindam _UTM_37-_North Projection: Transverse Mercator.

The existing situation of Central Closed Public Park

The land use /land cover results of Central Closed Park showed that 50.95% of the area is covered by forest, 23.37% was being cultivated by the surrounding people and the rest 8.45% is used for settlement and the reaming was covered by road, grass and bare land as shown in Figure 5.

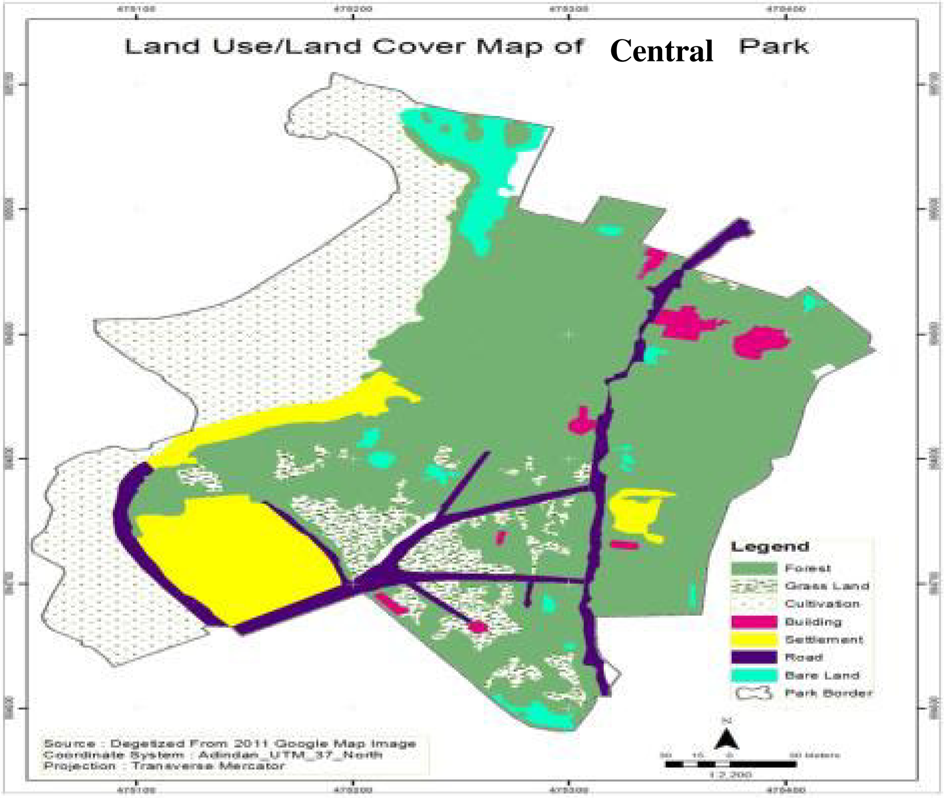


Figure 5. Land use Land Cover Map of Central Closed Public Park
Source: Digitized from 2011 Google Map Image Coordinate System: Adindam _UTM_37-_North Projection: Transverse Mercator

Characteristics of Woody Plants in Biheretsige and Central Closed Parks

Data pertinent to DBH, Height, Density and Frequency of woody plants were given in Tables 1 & 2. According to these results, the following species had higher frequency % and density as recorded at Biheretsige Park. These include *Casuarina cunninghamiana*, *Cupressus lusitanica, Acacia melanoxylon, Jacaranda mimosifolia, Phoenix reclinata* and *Sesbania sesban.* Species having lower number of individuals, frequency% and density were *Ficus exasperata, Eucalyptus saligna, Pinus radiata, Persea americana, Olea capensis* subsp. *macrocarpa*, *Coffea arabica*, *Punica granatum, Hagenia abyssinica* and *Mangifera indica.* At Central Park, those species which had high number of occurrence were *Acacia melanoxylon*, *Grevillea robusta*, *Jacaranda mimosifolia*, *Cupressus lusitanica* and *Eucalyptus globulus.* These species had also high percent frequency and density. However, species like *Ficus sycomorus, Punica granatum, Prunus africana, Acacia abysinica, Cupressus sempervirens, Allopylus abyssinicus, Carissa spinarum, Callistemon citrinus*, *Eriobotrya japonica, Erythrina brucei* and *Acacia saligna* had few number of occurrence and recorded least frequency percent and density.

Table 1. Botanic name of species, total number of woody plant species, mean DBH and Height, frequency % of species and density at Biheretsige Closed Public Park

No	Botanic name	Height (m)	DBH (cm)	No of woody plant	% frequency of species	Density/ha
1	*Acacia melanoxylon* R.Br.	12.9	21.5	127	5.5	9.1
2	*Acacia abyssinica* Hochst, ex Benth	6.11	24.42	26	1.1	1.9
3	*Acacia decurrens* Willd.	11.57	28.03	33	1.4	2.4
4	*Acacia saligna* (Labill.) Wendl.	4.978	12.05	18	0.8	1.3
5	*Acacia brevispica* Harms Notizbl.	2.7	13.73	12	0.5	0.9
6	*Acacia mearnsii* De Willd.	3.1	10.5	11	0.5	0.8
7	*Acacia seyal* Del	14.53	41.6	47	2	3.4
8	*Araucaria biramulata* J. Buchholz.	18.87	38.72	8	0.3	0.6
9	*Bauhinia variegata* L	5.34	10.96	16	0.7	1.1

No	Botanic name	Height (m)	DBH (cm)	No of woody plant	% frequency of species	Density/ha
10	*Bougainvillea glabra* Choiv.	2.8	19.61	19	0.8	1.4
11	*Callistemon citrinus* (Curts) Skeels	6.61	15.36	42	1.9	3
12	*Melaluca Dendron* L.	9.87	18.58	36	1.6	2.8
13	*Carissa spinarum* L.	2.41	14.63	17	0.7	1.2
14	*Casimiroa edulis* La Llave	4.8	12.48	13	0.6	0.9
15	*Casuarina cunninghamiana* Miq.	12.3	19.73	356	15.4	24.4
16	*Cestrum elegans* Schltdl.	3.53	10.49	23	1	1.6
17	*Citrus aurantifolia* (Ouistm.) Swingle	3.33	13.41	46	2	3.3
18	*Clausena anisata* (Willd.) Benth.	2.76	7.8	9	0.4	0.6
19	*Coffea arabica* L.	2.62	6.07	4	0.2	0.3
20	*Cordia africana* Lam.	7.9	20	25	1.1	1.8
21	*Croton macrostachyus* Del.	10.51	23.42	20	0.9	1.4
22	*Cupressus lusitanica* Mill.	5.2	14.93	321	13.9	22.9
23	*Cupressus sempervirens* L	15.31	26.2	16	0.7	1.1
24	*Dovyalis abyssinica* (A. Rick) Warb.	2.87	24.42	36	1.6	2.3
25	*Dracaena steudneri* Engler	4.72	24.32	33	1.4	2.4
26	*Duranta erecta* L.	3.79	12.21	29	1.3	2.1
27	*Eriobotrya japonica* (Thunb.) Lindl	3.1	12.82	16	0.7	1.1
28	*Erythrina abyssinica* Lam. ex. DC	5.3	14.02	13	0.6	0.9
29	*Erythrina brucei* Schweinf.	8.35	27.01	10	0.4	.07
30	*Eucalyptus camaldulensis* Dehnh.	21.33	32.64	56	2.4	4
31	*Eucalyptus citriodora* Hook.	19.17	21.31	34	1.5	2.4
32	*Eucalyptus globulus* Labill.	21.83	39.58	26	1.1	1.9
33	*Eucalyptus saligna* Smith	17.66	35.33	3	0.1	0.2
34	*Euphorbia abyssinica* Lam. ex. DC	7.76	29.02	19	0.8	1.4
35	*Euphorbia candelabrum* Kotschy	4.8	13.92	17	0.7	1.2
36	*Euphorbia pulcherrima* Klotzsch.	3.24	8.67	24	1	1.7
37	*Ficus carica* L.	4.1	12.26	20	0.9	1.4
38	*Ficus exasperata* Vahl	4.1	14.68	5	0.2	0.4
39	*Ficus sur* Forssk.	10.18	28.05	26	1.1	1.9
40	*Ficus thonningii* Blume	9.77	28.81	81	3.5	5.8
41	*Grevillea robusta* R. Br.	12.89	20.96	53	2.3	3.8
42	*Hagenia abyssinica* J.F. Gmel.	17.8	33.1	5	0.2	0.4
43	*Hibiscus rosa-sinensis* L.	2.89	10.09	21	0.9	1.5
44	*Ceiba pandathra* L.	18.27	58.21	11	0.5	0.8
45	*Jacaranda mimosifolia* D. Don	6.46	13.75	73	3.6	5.2
46	*Juniperus procera* Hochst. ex. Endl.	13.35	26.68	44	1.9	3.1
47	*Justicia schimperiana* Stapf	3.96	8.83	13	0.6	0.9
48	*Mangifera indica* L.	1.7	6.06	5	0.2	0.4
49	*Maytenus senegalensis* (Lam.) Exell.	3.92	15.98	9	0.3	0.6
50	*Millettia ferruginea* (Hochst.) Bak.	8.24	12.17	20	0.9	1.4
51	*Morus alba L.*	2.37	8.25	5	0.2	0.4
52	*Olea capensis* L. subsp. *macrocarpa* (CA. Wright.) Verde.	9.9	22.23	3	0.1	0.2
53	*Olea europaea* sup sp. *cuspidata*	5.5	11.3	6	0.3	0.4
54	*Persea americana* Mill.	4.5	16.37	4	0.2	0.3
55	*Phoenix reclinata* Jacq.	8.35	33.39	94	4.4	6.7
56	*Pinus radiata* D.Don.	22	39	3	0.1	0.2
57	*Pinus patuala* Schiede. ex Schltdl.	12.38	26.08	13	0.6	0.9
58	*Podocarpus falcatus* (Thunb.) R.B.ex.Mirb.	13.39	23.07	45	1.9	3.2
59	*Psidium guajava* L.	4.7	15.03	6	0.3	0.4
60	*Punica granatum* L.	5.65	13.52	4	0.2	0.3
61	*Sambucus nigra* L.	3.87	14.8	8	0.2	0.6
62	*Schinus molle* L.	5.43	17.26	30	1.3	2.1
63	*Sesbania sesban* (L.) Merr.	3.96	9.12	89	3.8	6.4
64	*Spathodea campanulata* P. Beauv.	7.74	23.1	20	0.9	1.4
65	*Tylosema* sp.	8.33	12.27	9	0.4	0.6
66	*Vernonia amygdalina* Del.	5.94	17.83	29	1.3	2.1

Table 2. Botanical Name of Species, mean Height and DBH and population of Each Species, Frequency % of and Density per hector at Central Closed Public Park.

No	Botanic name	Height (m)	DBH (cm)	No of woody plant	% frequency of species	Density/ha
1	*Acacia mealanoxylon* R.Br.	10.73	19.49	102	5.6	9.6
2	*Acacia abysinica* Hochst, ex Benth	3.4	8.02	5	0.3	0.5
3	*Allopylus abyssinicus* (Hochst.) Radlkofer	3.12	10.17	4	0.2	0.4
4	*Acacia decurrens* Willd.	13.42	22.8	7	0.4	0.7
5	*Acacia saligna* (Labill.) Wendl.	8	17.86	3	0.2	0.3
6	*Acacia brevispica* Harms Notizbl.	7.42	18.72	4	0.2	0.4
7	*Acacia mearnsii* De Willd.	4.66	7.88	8	0.4	0.8
8	*Acacia seyal* Del	8.63	29.63	6	0.3	0.6
9	*Bauhinia variegata* L.	5.42	13.82	17	0.9	1.6
10	*Bougainvillea glabra* Choisy.	6.66	11.36	3	0.2	0.3
11	*Callistemon citrinus* (Curts) Skeels	6.25	17.5	4	0.2	0.4
12	*Melaleuca dendron* (L.)L.	6.38	12.18	17	0.9	1.6
13	*Carissa spinarum* L.	4.12	9.72	4	0.2	0.4
14	*Casuarina cunninghamiana* Miq.	6.29	10.94	48	2.6	4.5
15	*Cordia africana* Lam.	14.04	74.55	7	0.4	0.7
16	*Croton macrostachyus Del.*	13.1	29.43	51	2.8	
17	*Cupressus lusitanica* Mill.	6.95	14.28	623	34	3.6
18	*Cupressus sempervirens* L.	19	22.8	4	0.2	0.4
19	*Dovyalis abyssinica* (A. Rick) Warb.	5.3	24.13	6	0.3	0.6
20	*Dracaena steudneri* Engler	6.36	24.09	21	1.1	2
21	*Ekebergia capensis* Sparrman.	26.16	54.62	18	1	1.7
22	*Eriobotrya japonica* (Thunb.) Lindl	6.45	11.8	4	0.2	0.4
23	*Erythrina brucei* Schweinf.	8	19.7	1	0.1	0.1
24	*Eucalyptus camaldulensis* Dehnh.	14.4	20.42	5	0.3	0.5
25	*Eucalyptus globulus* Labill.	27.72	39.12	142	7.8	13.4
26	*Euphorbia candelabrum* Kotschy	8.38	16.16	6	0.3	0.6
27	*Ficus sur* Forssk.	6.5	24.04	7	0.4	0.7
28	*Ficus sycomorus* L.,	9.1	26.3	2	0.1	0.2
29	*Grevillea robusta* R. Br.	18.82	25.54	332	18.1	31.3
30	*Hibiscus rosa-sinensis* L.	2.82	10.67	4	0.2	0.4
31	*Jacaranda mimosifolia* D. Don	9.75	17.08	103	5.6	9.7
32	*Juniperus procera* Hochst.ex. Endl.	11.29	24.95	12	0.7	1.1
33	*Justicia schimperiana* (Hochst. ex Nees) T.Anderson	3.07	8.42	20	1.1	1.9
34	*Maytenus senegalensis* (Lam.) Exell.	3.47	10.92	7	0.4	0.7
35	*Millettia ferruginea* (Hochst.) Bak.	11.25	17.01	9	0.5	0.8
36	*Olea capensis* L. subsp. *macrocarpa* Verde.	13	22.88	6	0.7	0.6
37	*Olea europaea* sup sp. cuspidata	6.37	19.26	11	0.6	1
38	*Phoenix reclinata* Jacq.	5.65	37.7	13	0.7	1.2
39	*Pinus patula* Schiede.ex Schltdl.	13.16	19.38	41	2.2	3.9
40	*Podocarpus falcatus* (Thunb.) R.B.ex.Mirb.	9.42	12.5	15	0.8	1.4
41	*Chorisa speciosa* St.Hil.	3.5	8.76	3	0.2	0.3
42	*Prunus africana* Calcm.	8.4	11.96	5	0.3	0.5
43	*Psidium guajava* L.	3.58	9.76	36	2	3.4
44	*Punica granatum* L.	6	10.96	3	0.2	0.3
45	*Schinus molle* L.	3.75	12.84	12	0.7	1.1
46	*Spathodea campanulata* P. Beauv.	10.4	22.98	60	3.3	5.7
47	*Tecoma stans* (L.) Juss	3.64	8.62	5	0.3	0.5
48	*Vernonia amygdalina* Del.	3.28	10.27	7	0.4	0.7

Carbon Stock in AGB Carbon Pools

Result of the Above Ground Biomass Carbon Pools in both study sites showed that Central Close Park has more carbon pools than Biheretsige Park (Table 3).

Table 3: Summary of carbon in aboveground pool with maximum and minimum per /species from both study sties.

Study site	**Carbon pool**				
	AGB				
Biheretsige	Total (ton)	Ton/ha	Max (ton) /species	Min (ton) /species	Mean
	607.1	43.4	70.3	0.042	0.26
Central park	617.6	58.3	134.9	0.044	12.9

Study site	**Carbon pools**							
	AGB	AGC	BGB	BGC	LB	LC	SOC	*Total carbon t/ha*
Biheretsige park (ton ha^{-1})	43.4	21.7	8.7	4.3	0.11	5.4	112.5	*143.9*
Central park (ton ha^{-1})	58.3	29.1	11.7	5.8	0.104	4.95	114.6	*154.45*
Mean	50.85±7.45	25.4±3.7	10.2000±1.50	5.05±.75	.107±.003	5.175±.225	113.55±1.05	*total 149.18±5.28*

Total carbon stock of Biheretsige and Central Closed Public Park

The total carbon stock of the study area was calculated by summing all the carbon value of each pool, which was above ground and below ground carbon, litter carbon and soil organic carbon for the two sites. The total value was 149.18±5.28 (Table 4).

Table 4: The total carbon stock in both study sites

Comparison of Biomass and carbon stock at the study sites

From analyzed results, lowest carbon stock found in dead litter pools while the highest was in soil at both study sites in ton ha^{-1}. However, it showed little difference in each pool of carbon which may be due to the sample carbon content for litter and soil. Above ground and below ground carbon stock difference was seen because of DBH differences and the number and type of woody plant listed. Biheretsige had wide area and more number of woody plants listed when compare to Central Park even though the carbon stock in above ground pool was better at Central Park (Figure 6).

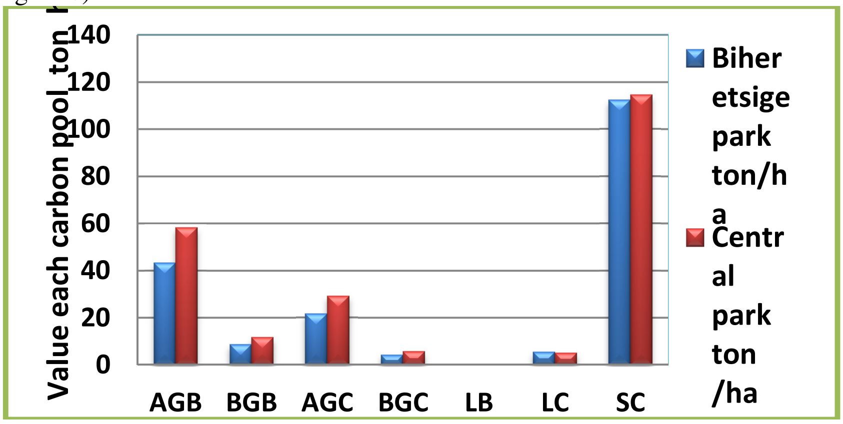


Figure 6. Comparison of Biomass and Carbon Stock of the Study Sites

As observed in table 5 the value of each study site was under the range of recommendable carbon stock. This shows that the woody plant species have an important role in climate change mitigation by sequestering large amount of carbon dioxide. This study has small mean value of above and below ground carbon stock as compared with other studies having same climate class and this is due to small area and lower class of DBH value of woody plant species.

Table 5: Comparison mean of this study with means of previous study.

Study site	***AGC***	***BGC***	***LC***	***SOC***
Selected church forest (by Tulu Tolla,2011)	129.86	25.97	4.95	135.94
Biheretsige and Central Closed Public Park	25.4	5.1	5.17	113.55

DISCUSSION

Carbon Stock and Biomass of the Study Sites

From Biheretsige Park the minimum and maximum AGB per tree were 0.042 ton tree^{-1} and 70.3 ton tree^{-1} with mean value of 0.26 ton tree^{-1}, while the total biomass stored was 607.1 ton and 43.4 ton ha^{-1}. The BGB minimum and maximum of this site was 0.008 and 14.6 ton tree^{-1} respectively with mean value of 0.052 ton tree^{-1}. The total BGB was 121.4 ton with 8.7 ton h^{-1}.

On the other hand, AGB of Central Park with the smallest and highest value ton per tree were 0.044 ton tree^{-1} and 134.9 ton tree^{-1} respectively with the mean value of 12.9 ton tree^{-1} while the total AGB was 617.3 ton with 58.3 ton ha^{-1}. The total BGB for the same park was 123.5 ton with 11.6 ton h^{-1}. Higher AGB was recorded from Central Park. This could be due to the DBH difference of woody plant species at the sites since DBH is one factor that affects carbon stock. The other scenario could be the type and number of woody specie listed that had brought the difference. These considered as source of variation in AGB and carbon.

The amount of carbon stock and carbon dioxide sequestered in above ground and below ground at Biheretsige Park were 303.6 ton and 21.7 ton ha^{-1} with the mean value of 0.13 ton per woody species, showing that preventing one woody plant from cutting can store 0.13 ton carbon on the average. Maximum AGC was recorded from *Casuarina cunninghamiana,* which had 35.1 ton per species. A species that had least AGC was *Coffea Arabica,* which was 0.0021 ton per species. Those woody species that had small mean value were *Mangifera indica* and *Coffea arabica* which were 0.005 ton per woody species and in *Ceiba pandathra* relatively higher mean value was found, which was 1.08 ton per species. Species which had high above ground carbon stock could be attributed to their high number of population/individuals listed in the area and their DBH value. On the contrary, those species that had least carbon stock value were due to small number of population and small classes DBH were observed. The total $AGCO_2$ was 1114.04 ton with 78.6 ton ha^{-1}. BGC was 60.7 ton with 4.3 ton ha^{-1} while $BGCO_2$ was 222.8 ton total with 15.9 ton ha^{-1}. At Central Park, a total of 308.6 ton with 29.1 ton ha^{-1} AGC and $AGCO_2$ 1132.7 ton and 106.9 ton ha^{-1} was recorded. In this site there was a total of 61.7 ton and 5.8 ton ha^{-1} BGC and $BGCO_2$ 226.4 ton and 21.4 ton ha^{-1}. In *Eucalyptus globulus* AGC stock shows maximum value per species (67.5 ton) and in *Chorisa speciosa* it was 0.0022 ton per tree, which is the least record in the site. The mean maximum in *Cordia africana was* 4.81 ton of AGC per species while there was minimum AGC 0.007 ton per species in *Acacia mearnsii, Tecoma stans* and *Acacia abyssinica.* Above ground biomass of these study sites was lower than the previous study on the Selected Church Forest in Addis Ababa (Tulu Tolla, 2011). This may be due to woody species in the study area that are sparsely distributed, very young and shrubs which results with small mean ABC stock when compared to the Church Forest. Generally, the results of the present study is between the range that reported for the global above ground biomass and carbon stock in tropical dry and wet forests which range 13.5-122.85 t ha^{-1} and 95-527.85 t ha^{-1}, respectively (Murphy and Lugo,1986). At the same time Brown (1997) reported a carbon density of 101 tons ha^{-1} for high forests in Ethiopia. Also Murphy and Lugo (1986) indicated that the Global above ground biomass in tropical dry and wet forest ranged from 30-273 t ha^{-1} and 213-1173 t ha^{-1}. So, the study sites woody plants have a potential to reduce GHGs from the surrounding similar to that of forest in wide area.

The litter carbon stocks of the study sites were almost similar except the number of sample taken. The mean carbon stock in litter pool of this study was higher than that of the value recorded on Selected Church Forest in Addis Ababa (Tulu Tolla, 2011). And two fold of the value reported to tropical dry forest was 2.1 ton ha^{-1} (IPCC, 2006). This could be due to the amount of litter fall and the potential of carbon stock influenced by climate and woody plant type which means species, density and age (Fisher and Binkly, 2000). The soil carbon stock and carbon sequestration potential of the study sites have similar proportion in Biheretsige and Central Park. Few differences between the two study sites could be attributed to SOM difference in the area.

The mean value of SOC of this study have proportional value to the study conducted at Selected Church Forest and Menagasha Suba State Forest (Tulu Tolla and Mesfin Sahile, 2011) which had 135.94t ha^{-1} and 121.28t ha^{-1} while the value of this study has 113.55±1.05ton ha^{-1}. It indicates that the higher mean of SOC than the rest pool was due to the availability of good content of SOM which results in maximum carbon storage in soil (Sheikh *et al.*, 2009) while CO_2 values have similar trend as of SOC which was 417.32±6.540 t ha^{-1}. This indicated that soil contribute for climate change mitigation by sequestration of GHGs in addition to social service.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study was conducted at Biheretsige and Central Closed Public Park. The sites contain diverse number of species which were 66 at Biheretsige 48 species at Central. In Biheretsige, *Casuarina equsitifolia*, *Cupressus lusitanica, Acacia mealanoxylon, Jacaranda mimosifolia, Phoenix reclinata,* and *Seasbania sesban* were abundant at the site while *Ficus exasperata, Eucalyptus saligna, Pinus radiata, Persea americana, Olea capensis* L. subsp. *macrocarp*, *Coffea arabica*, *Punica granatum*, *Hagenia abyssinica, Mangifera indica* were found to be the least abundant species. At the Closed Central Park, *Acacia mealanoxylon*, *Grevillea robusta*, *Jacaranda mimosifolia, Cupressus lusitanica* and *Eucalyptus globulus* relatively had high frequency and density. However, *Ficus sycomorus, Punica granatum Prunus africana, Accacia abyssinica, Cupressus sempervirens, Allopylus abyssinicus, Carissa spinarum, Callistemon citrinus, Eriobotrya japonica, Erythrina brucei* and *Accacia saligna* were least abundant ones. With increasing DHB, density and % frequency decrease at both study sites showing that the presence of more tree species in the lower class than the upper classes. The mean carbon stocks of the different carbon pools of the study sites were lower than most research done in the country related to carbon sequestration potential of forests, even if the results were within the range of considerable proportion. The presence of range value of carbon stock in the sites indicates its potentials to the mitigation of climate change by absorbing greenhouse gases from the atmosphere. Altitude and aspect had no effect on the carbon pool, but the DBH of the woody species or age of tree and the size of the area had highly affected the above ground carbons stocks. The carbon sequestration in this forest is comparable with the forest in the country indicating that the contribution of Park Forest around Addis Ababa city for carbon sequestration and urban climate regulation is significant.

Recommendations

- This study can contribute as a base line research for the contribution of city Public Park to climate change mitigation in addition to its recreation value.
- There are a number of parks throughout the town of country which are designed for the purpose of recreation and some of it is just have the name but there is no more number of tree and poor management on it. In the future it should be recognized that their role in climate change mitigation and preparing the urban area park for carbon finance behind beautification of the cities, can help for the entry point of climate finance.
- Doing carbon sequestration research and organizing the data for the country is mandatory to knowing the amount of country emission and offset of CO_2 in city. This helps the country to plant more trees to compensate it.
- To sustain forest in the study site, creation of awareness for the public, government body and the rest who concern about the beautification of city with a clean air is mandatory.

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