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Research Paper

Carbon Stock Estimation of Urban Forests in Selected Public Parks of Addis Ababa and Its Contribution to Climate Change Mitigation

Meseret Habtamu[1], Mekuria Argaw[2]

1.Lecturer, Kotebe Metropolitan University, mesihabenv@gmail.com
2.Associate Professor, Center for Environmental Science, College Of Natural Sciences, Addis Ababa University

Abstract
Urban forests can help to improve the microclimate and air quality. Urban forests in Addis Ababa are important sinks for GHGs as the number of vehicles and the traffic constrain is steadily increasing. The objective of this study was to characterize the vegetation types in selected public parks and to estimate the carbon stock potential of urban forests by assessing carbon in the above, below ground biomass, in the litter and soil. Species which vegetation samples were taken using a systematic transect sampling within value DBH ≥ 5cm were recorded to measure the above, the below ground biomass and the amount of C stored. Allometric models ($Y= 34.4703 - 8.0671(DBH) + 0.6589(DBH^2)$) were used to calculate the above ground and Below ground biomass (BGB) = AGB × 0.2 and sampling of soil and litter was based on quadrates. There were 5038 trees recorded from the selected study sites with DBH ≥ 5cm. Most of the Parks had large number of indigenous species, but the numbers of exotic trees are much larger than the indigenous trees. The mean above ground and below ground biomass is 305.7 ± 168.3 and 61.1± 33.7 respectively and the mean carbon in the above ground and below ground biomass is 143.3±74.2 and 28.1 ± 14.4 respectively. The mean CO_2 in the above ground and below ground biomass is 525.9 ± 272.2 and 103.1 ± 52.9 respectively. The mean carbon in dead litter and soil carbon were 10.5 ± 2.4 and 69.2t ha^{-1} respectively. Urban trees reduce atmospheric carbon dioxide (CO_2) through sequestration which is important for climate change mitigation, they are also important for recreational, medicinal value and aesthetic and biodiversity conservation.
Keywords: *Carbon sequestration, urban forests, climate change and biodiversity*

Introduction

Urban forestry is defined as the planned, integrated and systematic approach to managing urban and peri-urban forests for their contribution to the economic, environmental, sociological and psychological well-being of urban society. In simpler terms, urban forestry is the management of urban vegetation to meet local needs (Kuchelmeister, 1997).

There are eleven public parks in Addis Ababa and 32 private managed parks. The city also has plenty of open-air (roadside and square side) parks. Carbon sequestration potential of urban forests (parks) is hardly studied. Species selection in urban forests is not well planned and needs to be seriously looked to increase ecological and environmental benefit of urban forests. Urban forests in Addis Ababa are affected by various factors such as encroachment, illegal cuttings, absence of law enforcement and improper species (Eyob, 2010). Thus, urban forests are largely neglected and need proper management for urban development.

This study covers the parks that are found in different subcities of Addis Ababa which include Arada , kirkos , Lideta and Gulele subcity and this include the parks of Africa park, Ambassador Park, Ethio- Korea Park, Sheger Park, Lion zoo park , T/haymanot park and Hamle -19 Park.

They are selected based on their area, species diversity, year of establishment and forest condition. This study provides valuable information on the carbon stock potential of forests in each park.

Materials and methods

Vegetation survey

Trees with diameter tree at 1.3 m above the soil surface were measured using a diameter tape. Diameter at breast height (DBH) is the basic measurement standard for trees.

Species identification

Plant identification was done in the field by using Flora of Ethiopia and Eritrea volume 2 Edwards *et al*. (1995); (Edwards *et al*. 2000), and Flora of Ethiopia volume 3 (Hedberg and Edwards 1989), Useful trees and shrubs for Ethiopia (Azene,1993).

Sampling

Soil sampling

In each site sample plots were laid systematically and at each sampling site transect was established. Sampling quadrants of regular shape with dimensions 10 m × 10 m were formed. Inside the 10 m × 10 m quadrant, four 1 m × 1 m sampling units were located. The 1 m × 1 m sampling were divided the 10 m × 10 m plot in four equal parts. A total of 42 soil samples from all parks (appendix 3) were collected. The soil sample in the 1 m × 1 m sampling unit was collected from 30 cm depth using core sampler Auger. The average wet weight and oven dry weight at 105 ^{0}C were recorded. From each 10 m ×10 m sampling quadrant the air dried soil sample was mixed and 100gm sub samples were taken for organic carbon determination in the National soil testing center. The carbon fraction was determined using Walkley-Black Method. Finally, the average bulk density, soil organic carbon and soil organic matter per hectare were calculated.

Litter sampling

Litter samples were collected in the same subplots for soil. Four rectangular sub plot of 1 square meter in size was established at the center of each plot. All the litter (dead leaves, twigs) within the $1m^2$ sub plots were collected and weighed. 100 gm of evenly mixed sub-samples were taken to the JIJE LABOGLASS laboratory to determine oven dry mass from which total dry mass was calculated.

Carbon sequestration measuring methods

The following carbons pools were measured in urban forest carbon estimation.

1. Above-ground tree biomass (AGTB)
2. Below-ground biomass (BGB)
3. Soil organic carbon (SOC)
4. Leaf litter, herbs, and grass (LHG)

Dead wood was not studied due to the absence of dead wood in parks. It is collected for fuel purpose.

Data analysis

The collected data was recorded on excel to analyze the above ground, the below ground biomass, the amount of carbon and CO_2 sequestered in each park. Parameters were compared using SPSS software 20 version. One Way ANOVA and descriptive statistics tasted the relationship between different parameter.

Estimation of parameters

Estimation of carbon in dead litter pool

To determine the biomass of leaf litter, herbs, and grass samples are taken destructively in the field within a small area of $1m^2$. For the forest floor (herbs, grass, and litter), the amount of biomass per unit area is given by:

$$LB = \frac{Wfield}{A} * \frac{Wsub\_sample(dry)}{Wsub\_sample(fresh)} * \frac{1}{10,000}$$

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).

Estimation of carbon in above and below ground pool

Two approaches for estimating the biomass density of trees exist and are more commonly applied. The first directly estimates biomass density through biomass regression equations. The second convert‘s wood volume estimates to biomass density using biomass expansion factors (Brown, 1997). For this research the first method was used.

This equation is applied for dry tropical forests where mean annual rainfall is below 1500mm (Macdicken, 1997).

This Allometric equation has been applied in various studies in similar areas in Ethiopia.

Addis Ababa city receives annual mean rainfall of about 1128 mm. This makes the city classified under dry zone which are receiving annual rain fall between 900 to 1500 mm.

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

Where; Y is above ground biomass,

DBH is diameter at breast height

Below ground biomass (BGB) = AGB × 0.2

Estimation of Soil Organic Carbon

The carbon stock density of soil organic carbon was calculated using the following formula as recommended by Pearson *et al.* (2005). To obtain an accurate inventory of organic carbon stocks in the mineral soil or organic soil, three types of variables must be measured: soil depth, soil bulk density (calculated from the oven-dry weight of soil from a known volume of sampled material), and concentrations of organic carbon within the sample (Robertson *et al*, 1999).

$$V = h \times \pi r^2$$

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:

$$BD = \frac{W_{av,\ dry}}{V}$$

Where, BD is bulk density of the soil sample per,

$W_{av,\ dry}$ is average air dry weight of soil sample per the quadrant,

V is volume of the soil sample in the core sampler auger in cm^3 (Pearson *et al.*, 2005).

$$SOC = BD * D * \% C$$

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 (%)

3.7.4 Total Carbon Stock Density

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.

Carbon stock density of a study area:

$$C_{density} = C_{AGB} + C_{BGB} + C_{Lit} + C_{DWS} + SOC$$

Where:

$C_{density}$ = Carbon stock density for all pools [$t\ ha^{-1}$]

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 [$t\ C\ ha^{-1}$]

C_{DWS} = Carbon in dead wood and stumps

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).

Diversity and evenness of Species in each Park

The diversity of species present in an ecosystem can be used as one gauge of the health of an ecosystem. Shannon's Index is the most applicable index of diversity and accounts for both richness and evenness of the species present (Shannon and Wiener, 1949). Thus, species diversity is a product of species richness and evenness or equitability. The diversity of species in each Park was calculated using the Shannon-Wiener Diversity Index formula. A diversity index is a mathematical measure of species diversity in an area.

The Shannon diversity index (H') is used in this study since it is commonly used to characterize species diversity in an area. The Shannon-Wiener Diversity Index (H') is calculated using the following equation:

$$H' = -\Sigma Pi\ (\ln Pi)$$

Where
Pi is the proportion of each species in the sample.

Shannon's equitability
Shannon's equitability (E_H) or evenness is calculated as follows

$$EH= H' / H max=H' / \ln S$$

Where
H' Shannon diversity index
S Total number of species in the area
Equitability assumes a value between 0 and 1 with being complete evenness (Whittaker, 1972). The species diversity of each park is given on the following table below.

Results and discussion
Different types of species were planted in the selected parks. The types of species were different from Park to Park. *Cupressus lustanica* was widely seen in Sheger, Hamle-19, Ethio-Korea and Ambassador Park than the rest of parks. *Ekbergia capenesis* was largely seen in Lion Zoo Park and *Casuarinas cunninghamiana* was largely seen in T/haymanot Park. *Cupressus lustanica* had the highest density with 2352 individuals that are 46.7 % of the total species while *Ficus carica* had the lowest density with 2 individuals that is 0.04 % of the total species in the study sites. In the studied sites a total of 49 different tree species were recorded and DBH ranging from 5 to 120 cm while height ranging from 1.75 to 40 m. The number of species, their density and the above ground biomass of each park is given below table 1.

Table 1: Species, density and the AGB of parks

Parks	Species	Density	AGB(t ha^{-1})	BGB (t ha^{-1})
Sheger	33	891	562.3	112.5
Africa	24	673	94.3	18.9
Ethio-Korea	23	881	236.6	47.3
Lion zoo park	24	85	477.0	95.4
T/haymanot	13	232	143.4	28.7
Gola	22	345	234.4	46.9
Hamle-19	28	1781	252.7	50.5
Ambassador	16	133	444.9	99.0

Diversity and evenness of Species in each Park
Lion Zoo Park and Ambassador Park had also the largest number of species evenness than the rest of the parks and Hamle-19 Park had the least number of species evenness both Parks had the second and the third largest above ground biomass and carbon stock value. The diversity, evenness, and total number of species in each Park is shown on table 2 below.

Table: 2 The diversity, evenness, and total number of species in each Park

No	Parks	Total no of trees	Total no of species	H'	E_H
1	Sheger	891	33	2.298	0.657
2	Africa	673	24	2.05	0.645
3	Ethio-Korea	881	23	2.201	0.705
4	Lion Zoo	85	24	2.95	0.928
5	T/haymanot	232	13	1.66	0.647
6	Gola	345	22	1.95	0.631
7	Hamle-19	1781	28	0.97	0.291
8	Ambassador	133	16	2.45	0.884

Above ground biomass of each Park

The AGB of species depend on their DBH value and on their age. The older trees with large DBH value will have large AGB. As age of tree increase biomass also increase (Negash, 2007).

The mean above ground biomass in this study sites was 304.9t ha^{-1} which was similar to the mean above ground biomass of church forests which is 276.3t ha^{-1} (Tulu, 2011). The AGC, BGC and BGB increases with increasing AGB. Generally, the mean biomass values recorded in the study sites were greater than the values recommended by IPCC for tropical dry forest 130.00t ha^{-1} (IPCC, 1997c). Above ground biomass and carbon stock of each park is shown on table 3 below.

Table: 3 Above and below ground biomass and carbon stock of each Park

Parks	AGB	C in AGB (t ha^{-1})	CO_2 of AGB (t ha^{-1})
Sheger	562.3	264.3	970.0
Africa	94.3	44.3	162.6
Ethio-Korea	230.0	108.1	396.7
Lion Zoo	477.0	224.2	822.8
T/haymanot	143.4	67.4	247.4
Gola	234.5	110.2	404.4
Hamle-19	252.7	118.8	436.0
Ambassador	444.9	209.1	767.4
Average	304.9	143.3	525.9

Carbon in the below ground biomass

The maximum and minimum below ground carbon stock were 112.6t ha^{-1} in Sheger Park and 18.9t ha^{-1} in Africa Park respectively. Lion Zoo Park had also the next largest below ground carbon stock with 95.3t ha^{-1}.This Park had the most diversified species and the number of exotic and indigenous species are almost equal. The others Parks were the carbon stock between these ranges. Below ground biomass and carbon stock of each Park is shown on table 4.

Table: 4 Total C stock and CO2 sequestered by each park

Parks	BGB	C in BGB (t ha^{-1})	CO_2 of BGB(t ha^{-1})
Sheger	112.6	52.9	194.143
Africa	18.9	8.9	32.6263
Ethio-Korea	46.0	21.6	79.272
Lion Zoo	95.3	44.8	164.416
T/haymanot	28.7	13.5	49.545
Gola	46.8	22.0	80.74
Hamle-19	50.6	23.8	87.346
Ambassador	79.6	37.4	137.258
Average	59.8	28.1	103.2

Carbon stock in dead litter

Litter in parks was not accessible since it was collected for fuel purpose and also it was considered as waste which decrease the neatness of the park so it would be cleaned from the surface for example in Africa park, Ambassador park and Lion zoo park it was difficult to find litter. Especially in Ambassador Park there was no litter at all and also most of the lands were cemented. The dead litter carbon stock estimated in Addis Ababa church forests ranged from 3.37 to 7 t ha $^{-1}$ (Tulu Tolla, 2011).

Dead litter carbon in Menagesha Suba state forest ranged from 0.78 to 13.94 t ha $^{-1}$ (Mesfin, 2011) and the result of this study ranges from 0.7t ha $^{-1}$ to 12.2t ha $^{-1}$ which is greater than the estimates of church forests and less than the estimate of Menagesha Suba state forest.

Soil organic Carbon

Estimating the carbon content of soil in Parks was complicated. It was difficult to find untouched soil since fertilizers were added to the soil to increase the fertility and mostly the soils came from another place. In addition to these public parks were owned by private, it was not possible to dig and take sample of soil, and this was the problem in Ambassador Park. Soil organic carbon of each park is shown in figure 1.

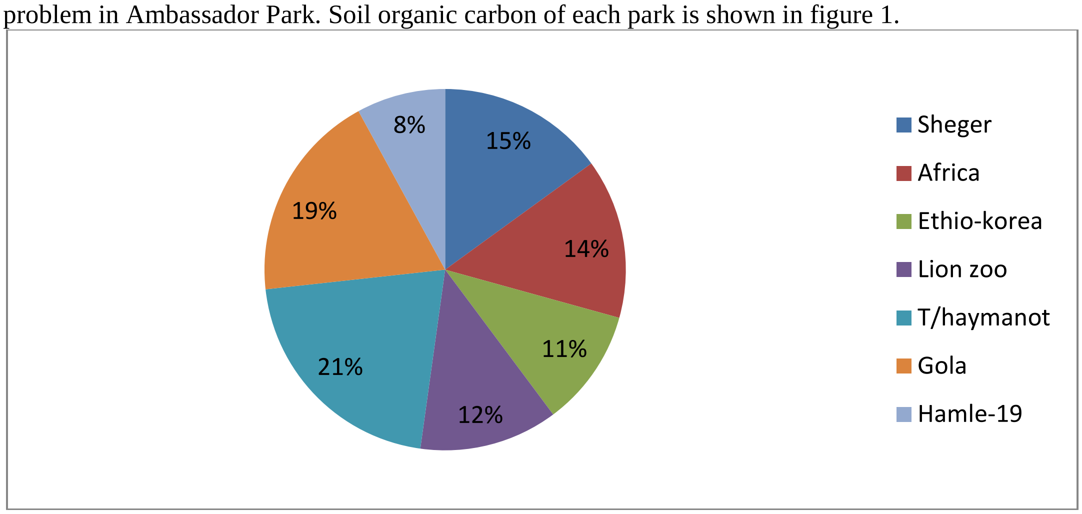

Figure: 1 Soil organic carbon of each park

In the case of Addis Ababa church forests, the amount of SOC density ranges from 99.77 to 162 t ha^{-1} (Tulu, 2011). The amount of soil organic carbon in Menagesha Suba state forest varied from 26.64t to 175 t ha^{-1} with average carbon stock of 121.28t ha^{-1}(Mesfin, 2011). The organic soil carbon in this study ranges from 38.6 t ha^{-1} to 102.1 t ha^{-1}.

The mean soil carbon stock in the study was 69.238±22.068t ha^{-1}. The amount of soil organic carbon in Ambassador Park was not possible to measure due to lack of untouched soil.

The land left for trees was also so small and it was on the borders of the fence in addition it was not allowed to dig the surface to take sample and those planted on the center are cemented around so it was not possible to find the representative soil sample in this park.

Total Carbon Stock of each Park

Over all summations of carbon dioxide sequestered in the above ground biomass was 4207.15t which is much greater than church forests 3332.98t (Tulu, 2011). This result shows the significance of urban forest for climate change mitigation and biodiversity conservation, which was indicated on different literatures. The total Carbon stock and CO_2 sequestered by each Park is given on table-5.

Table: 5 C stock and CO_2 sequestered by soil in each park

No	park	C in soil t ha^{-1}	CO_2 in soil t ha^{-1}
1	Sheger	72.7	266.9

2	Africa	69.3	254.5
3	Ethio-korea	50.9	186.8
4	Lion zoo	60.1	220.6
5	T/haymanot	102.1	380.1
6	Gola	91.0	333.8
7	Hamle-19	38.6	141.6
	Average	69.2	254.9
	Maximum	102.1	380.1
	Minimum	38.6	141.5

Carbon stock in different pools along different altitudes
Above and below ground carbon stocks along different altitudes

According to the altitude of the study sites they were classified as higher, middle and lower class.
The above ground biomass in higher altitude class was higher and also the above ground carbon stock and amount of carbon sequestered was also higher than the others. The lower altitude class also had the least above ground biomass. According to the ANOVA result the relation Altitude and above ground biomass is not statically significant ($F= 0.347$, $p= 0.726$).

Conclusion

A total of 49 species were recorded from all studied sites. *Cupressus lustanica* was the dominant species and *Eucalyptus saligna* was the next dominant species in almost all study sites. The numbers of indigenous species are larger than exotic species, but the numbers of exotic trees are much higher than the indigenous trees in most parks. Hamle-19 Park had the largest number of species, but it was the least diversified Park because of the dominance of certain species. Lion Zoo Park had the least number of trees, but it had largest number of diversified species and it had the second largest above ground biomass.

The parks, which were old in establishment, had species with larger DBH value, this tends the species to have large AGB and those species with large AGB will have large C stock value. Sheger Park was the oldest park and the species had large DBH value and the total AGB was 264.3t ha^{-1} and also the total C stock amount was 400.3t ha^{-1}.
Those Parks which are recent in year of establishment had small value of AGB in this study Africa Park is youngest Park and the AGB was 94.3t ha^{-1} and also less amount of C stock value 129.5t ha^{-1}.
From the selected 8 public parks those with diversified species and with high DBH value had a better potential for sequestration of carbon and better contribution for climate change mitigation for the city.

Recommendations

From this study the following points are given as recommendation:

- Parks with diversified species had better carbon sequestration potential so diversifying of species has a better contribution for carbon sequestration.
- Parks with dominance of certain exotic species had less amount of carbon stock value, evenness of species has also better contribution for carbon sequestration.
- Great emphasis should be given on selection of species; the dominance of certain species decreases the carbon stock potential of Parks.
- Planting diversified trees can make a difference when it comes to fighting climate change.

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