Journal of Ecosystem & Ecography

Habtamu and Elias, J Ecosys Ecograph 2022, 12:2

Review Article

Open Access

Role of Urban Forests for Carbon Emission Reduction in Addis Ababa: A Review

Meseret Habtamu[1]* and Eyasu Elias[2]

[1]*Department of Environmental Science, College of Natural & computational Sciences, Kotebe Metropolitan University, Addis Ababa, Ethiopia*
[2]*Center for environmental science, College of Natural & computational Sciences, Addis Ababa University, Addis Ababa, Ethiopia*

Abstract

Urban forests improve the microclimate and air quality. The objective of this review was to appraise research findings and to summarize the most important literatures on the role of urban forests for carbon emission reduction in Addis Ababa. Total number of identified papers were 11 that studied carbon sequestration potential of urban forests in Addis Ababa and of this church forests (three), public parks (three), botanical garden (one), Mountain forest (Three) and KMU compound included in the review of this paper. The selected research papers used similar allometric equations to calculate carbon stock of the different carbon pools. The mean carbon in the above ground and below ground biomass is 110.84 ± 46.33 t ha-1 and 21.68 ± 9.31 t ha-1 respectively. The mean carbon in dead litter and soil carbon were 6.33 ± 5.72 t ha-1 and 121.02 ± 48 t ha-1 respectively. The variations of carbon stocks in the different urban forest types relate to area, density and size of trees available in each site. In addition to reducing atmospheric carbon dioxide through sequestration, which is vital for climate change mitigation, urban trees are also beneficial for recreational, medical, aesthetic, and biodiversity conservation.

Keywords: Carbon sequestration; Climate change; Urban forests

Introduction

Urban forests can help to mitigate the effects of climate change by lowering atmospheric carbon dioxide [1]. Urban areas are home to more than half of the world's population. Urbanization is estimated to result in 6 billion urban dwellers by 2050. Cities will be exposed to climate change from greenhouse gas induced radiative forcing, and localized effects from urbanization such as the urban heat island. Carbon dioxide emissions and climate change are two of the most urgent challenges in today's society. Carbon dioxide (CO_2) is a common greenhouse gas and a major contributor to global warming. It accounts for 72% of total anthropogenic greenhouse gas emissions and accounts for 9-26% of the greenhouse effect [2].

Addis Ababa, the capital and the most populated city of Ethiopia a rapid and unplanned expansion and commercial development, along with population pressure is deteriorating the city environment with time. The high rate of urbanization, use of fuel wood and charcoal as biofuel, have all contributed to the degradation of green spaces in Addis Ababa. Encroachment, illegal cuttings and the planting of inappropriate species all have an impact on urban forests of Addis Ababa [3]. The city faced challenges from flooding, threats to human comfort and environmental injustice. Because of their significance in sequestering and storing carbon, urban forests are becoming significant in meeting climate mitigation goals. Urban forests are increasingly important due to their role in sequestrating and storing carbon and thus helping to meet climate mitigation goals.

Urban forest in Addis Ababa covers over 5000 ha of land. Eucalyptus species predominate in the city's forests and mainly found in the northern part of the city. Urban forests absorb carbon dioxide and can be used to mitigate regional and global warming. Forests provide social benefits such as improved health, employment, education, recreation, and community building.

Though they are small in number and fragmented, several studies have been investigated on carbon sequestration of urban forest (Public parks, church forests and botanical gardens) in Addis Ababa. For instance, different studies showed that urban forests in Addis Ababa have a significant contribution in carbon emission reduction and have different ecosystem services mitigating urban heat island effect and sequestering and storing of Carbon [4].

The review on role of urban forest for carbon emission reduction in Addis Ababa is required for appraising research findings and to support polices on restoration of urban green space.

Objectives

The general objective of this review paper is to appraise research findings and to summarize the most important literatures on the role of urban forests for carbon emission reduction in Addis Ababa.

Materials and Methods

Research question and review protocol

What is the role of urban forests to sequester carbon?

In order to achieve the aim of the review paper on the role of urban forests for carbon emission reduction in Addis Ababa the collected data were extracted and total of 11 secondary data were used.

Search strategy

Researches of potential interest were identified by creating a comprehensive search algorithm. Literatures were identified using internet-wide search engines (Google and Google Scholar). The search was done from November 10 to 30, 2020. For each of the key words, substituting synonyms were also tested to check for any missed relevant reports. For inclusion and exclusion of articles in this review,

***Corresponding author:** Meseret Habtamu, Department of Environmental Science, College of Natural & computational Sciences, Kotebe Metropolitan University, Addis Ababa, Ethiopia, Tel: + 251913587556, E-mail: mesihabenv@gmail.com

Received: 2-Jan-2022, Manuscript No: jee-22-51104, **Editor assigned:** 4-Jan-2022, PreQC No: jee-22-51104 (PQ), **Reviewed:** 17-Feb-2022, QC No: jee-22-51104, **Revised:** 21-Feb-2022, Manuscript No: jee-22-51104(R), **Published:** 28-Feb-2022, DOI: 10.4172/2157-7625.1000316

Citation: Habtamu M, Elias E (2022) Role of Urban Forests for Carbon Emission Reduction in Addis Ababa: A Review. J Ecosys Ecograph 12: 316.

the following four criteria were set and implemented.

- The report/article must be original research article,
- Each study must have evaluated carbon stock estimation of urban forest
- Each study area must be in Addis Ababa.
- The study time period should be from 2010-2021.

Urban forest carbon storage estimation

The Allometric equation used in all selected research papers is similar. The equation used (Table 1) is applied for dry tropical forests where mean annual rainfall is below 1500mm [5]. Annual rainfall in Addis Ababa ranges from 900 to 1500 mm.

Results and Discussion

The selected research papers are original research paper conducted on the role of urban forests for carbon sequestration in Addis Ababa. Total of 11 papers were identified 11 and of this church forests (three), public parks (three), botanical garden (one), Mountain forest (Three) and KMU compound included in the review of this paper [6]. List of the selected research papers with their total area and number of sites is shown on the following table below.

Above and below ground carbon

A total of 34 sites were studied in church forests with total area of 71.22 ha, 14 public parks with total area of 64.74 ha, three mountain forests with area of 11,873.42 ha and a botanical garden of 936 ha and a study from Kotebe metropolitan university area of 5.42 ha that represents urban forests of Addis Ababa. These areas are different in terms of their total area, year of establishment and forest conditions [7].

From the selected urban forests highest AGC was recorded in church forests with 132.92 t ha^{-1}, followed by Botanical garden 102.63 t ha^{-1}. The lowest AGC and BGC were recorded in KMU 75.57 t ha^{-1} and15.04 t ha^{-1} as shown on the following Figure 1 below.

The mean AGC 110.84 t ha^{-1} is higher than the values recorded in Chilimo forests (90.25 t ha^{-1}) and Sekele- Mariam forest (37.54 t ha^{-1}). The mean above ground carbon stock of urban forests is lower as compared with other natural forests [8].

Below ground Carbon followed the same trend as the above ground Carbon. The minimum BGC was in one of the public park and maximum BGB was in Entoto forest and their values were 5.1 and 34.4 t ha^{-1} respectively. The differences observed in carbon stocks related to area, density and size of trees available in each site [10]. The factors affecting carbon stock distribution might be management in the particular site, available place or area for planting new tree, infrastructures, purpose of the areas and human interference and year of establishment's, biomass increase as age of tree. The AGC and BGC of each selected urban forests is shown on the following Table 2 below.

Table 1: Commonly used allometric equations for measuring different carbon pools in the selected study areas.

No	Carbon pools	Basic formula	References
1	AGB	$Y = 34.4703 - 8.0671(DBH) + 0.6589\ (DBH^2)$	[1]
2	BGB	BGB = AGB*0.2	[2]
3	SOC	SOC = BD*D* % C	[3]
4	CL	CL = LB*% C	[4]

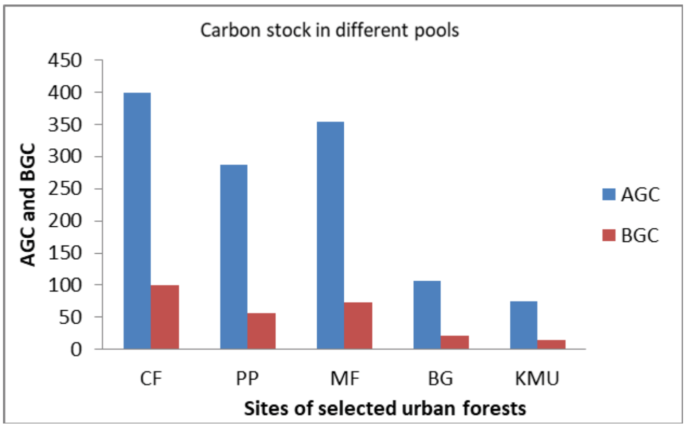

Figure 1: AGC and BGC of selected urban forest sites (CF= Church Forests, PP = Public Parks, MF= Mountain Forests, BG = Botanical Garden KMU = Kotebe Metropolitan University).

Table 2: List of selected papers.

No	Study site	No of study sites	Total Area (ha)	Reference
1	Church forests	7	37.14	[5]
2	Church forests	10	23.49	[6]
3	Church forests	17	10.59	[7]
4	Public parks	2	24.82	[8]
5	Public parks	4	16.6	[9]
6	Public parks	8	23.32	[10]
7	Botanical garden	1	936	[11]
8	Yeka forest	1	5.42	[12]
9	Yerer forest	1	6000	[13]
10	Entoto forest	1	5868	[14]
11	KMU	1	5.4	[15]

According to Brown above ground carbon stock are 47 t ha^{-1} for tropical dry forest and 36 t ha^{-1} for sub-Sahara Africa country while IPCC assessment, 126 t ha^{-1} was reported for tropical dry forest and 72 t ha^{-1} for open sub-Sahara Africa country. According to Murphy estimates for tropical dry forests range between 30 and 273 t ha^{-1} while Defries recorded 55 t ha^{-1} C for tropical dry forest and 30 t ha^{-1} C for open forest in sub- Sahara Africa country. Generally, literatures recorded carbon stock in the above ground biomass for tropical dry forest which receiving annual rain fall between 900-1500 mm were ranged between 30-126 t ha^{-1} carbon stock. The mean above-ground biomass of these urban forests 110.84 t ha^{-1} is in the range of recommended for tropical dry forest. Addis Ababa receives about 1128 mm of rain on an annual basis. This makes the city classified under dry zone which are receiving annual rain fall between 900 to 1500 mm [9].

The average carbon density of 110.84 t ha^{-1} of the urban forest of Addis Ababa is three times higher than the 33.22 t ha^{-1} average carbon density recorded from the urban forest of Shenyang, China. This suggests that Addis Ababa's urban forests have the potential to trap a significant quantity of carbon and help to mitigate climate change.

Soil organic carbon

From the selected research papers only eight of them measured SOC. In the study sites in 0.30 cm depth mineral soils 223.56 t ha^{-1} maximum and 92.23 t ha^{-1} minimum value carbon stocks were recorded in Gulele botanical garden and public park forests respectively (Figure 2 and Table 3). In some of the selected studies soil organic carbon was not studied (Entoto forest, KMU and Church forest) which might hinder to know the estimated figures of urban SOC. According to

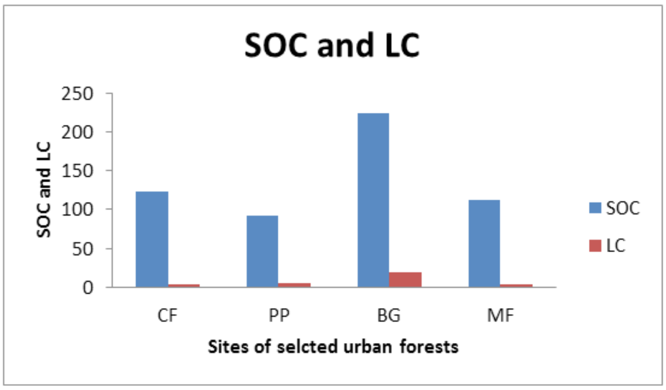

Figure 2: SOC and LC of selected urban forest sites.

Table 3: AGC and BGC of selected urban forest sites.

No	Study site	No of study sites	Total Area (ha)	Reference
1	Church forests	129.86	25.97	[2]
2	Church forests	112.9	17.82	[4]
3	Church forests	156	31.2	[6]
4	Public parks	25.4	5.1	[1]
5	Public parks	118.74	23.75	[3]
6	Public parks	143.3	28.1	[5]
7	Botanical garden	102.63	20.53	[11]
8	Yeka forest	42.26	8.43	[12]
9	Yerer forest	140.6	28.12	[10]
10	Entoto forest	102.7	34.4	[8]
11	KMU	75.57	15.11	[9]
	Average	110.84	21.68	

Tsegaye, it was difficult to determine the carbon content of the soil in the parks, because most soils were brought in from outside to boost the park's soil fertility [10].

Soil stores 2 to 3 times more carbon than CO_2 in the atmosphere and 2.5 to 3.0 times more than carbon stored in plants in the terrestrial ecosystem. The average value of soil organic carbon in urban forests 121.02 t ha^{-1} is similar with the natural forest of 121.28 t ha^{-1} in Menagasha Forest, higher than Zequalla Monastery forests of 57.62 t ha^{-1} and relatively comparable with 158 t ha^{-1} in the high elevation forested areas of the Taita Hills in south-eastern Kenya. This value is also substantially lower when compared to other natural forest in Ethiopia. For example Danaba community forest 186.4 t ha^{-1} Gedeo Forest 183.69 t ha^{-1} and Sekele-Mariam forest 138.79 t ha^{-1}. Generally studies indicate that mean carbon captured in the soil pool was relatively greater than the other carbon pools [11].

As reported in Luke, 2018, the average soil organic carbon in Ethiopia ranges from 94 to 133 ton/ha, urban forests SOC is in the range of this value. A difference in SOC among studies related to differences in tree species, soil nutrient availability, climate, topography and disturbance. In addition soil carbon stocks are influenced by factors such as climate, geology and weathering history, and biotic variables such as species composition and density. SOC and LC of each study sites are shown on the following Table 4 below.

Litter carbon

From the selected research papers only eight of them measured LC. The maximum 18.64 t ha^{-1} and 5.23 t ha^{-1} minimum litter carbons were recorded in Gulele botanical garden and in church forests respectively (Table 4 and Figure 2). The minimum litter carbon was 1.15 t ha^{-1} in study of selected urban parks.

Table 4: SOC and LC of selected sites.

No	Study site	No of study sites	Total Area (ha)	Reference
1	Church forest	135.94	4.95	[1]
2	Church forest	108.9	3.282	[2]
3	Public parks	113.55	5.17	[3]
4	Public parks	93.93	1.15	[4]
5	Public parks	69.2	10.5	[5]
6	Botanical garden	223.56	18.64	[6]
7	Yeka forest	144.75	2.01	[7]
8	Yerer forest	78.33	4.97	[8]
	Average	121.02	6.33	

Forest vegetation (species, age, and density), climate, and the comparatively fast decomposition rate in the tropics can all influence the amount of litter fall and the forest's carbon storage. In most parks dead litter was not accessible since it is collected for fuel purpose and also considered as waste which decrease the beauty of the park. The average carbon stock in litter biomass of urban forest was 6.33 t ha^{-1} which ranges from 1.15 to 18.64 t ha^{-1} [12].

The mean dead litter value of urban forest is higher than the values cited in IPCC, while carbon in dead litter pool was 2.1 t ha^{-1} for tropical dry forests and 49 t ha^{-1} for moist boreal broad leaf forests. It is also in the range of tropical and sub-tropical forests in Puerto Rico that ranged between 3.1-8.61 t ha^{-1}. In a similar study Singh and Singh, dead litter fall ranged from 4.88 to 6.71 t ha^{-1} in a dry forest in India, and from 3 to 10 t ha^{-1} for a variety of dry tropical forests.

The litter carbon content found in urban forest was also relatively greater than the values recorded in some other studies conducted in Ethiopia. For instance the average carbon stock in the litter biomass was 3.4 t ha^{-1} in Egdu Forest, 0.9 t ha^{-1} in Tara Gedam Forest and 0.019 t ha^{-1} in forests of Semien Mountain National Park [13].

As shown on the above graph there is variation of LC in different urban forests. Highest LC was shown on botanical gardens and the lowest was recorded in church forests. The litter quantity and quality varies with tree species, forest types and age.

The lowest carbon stock in litter pool could due to small amount of litter fall. According to this study the carbon in the dead litter plays a significant role in lowering carbon emissions in urban forests.

The average carbon stock sequestered in the above ground biomass was 110.84 t ha^{-1}. This shown significance of urban forests for climate change mitigation role in addition to other ecosystem services.

Conclusion

This review paper confirms that urban forests in Addis Ababa have significant role for lowering carbon emissions and climate change mitigation by storing total Carbon of 262.33 t ha^{-1}. The largest carbon stock was found in the soil organic carbon 121.02 t ha^{-1} followed by the aboveground biomass of 110.84 t ha^{-1}. Urban forests have the ability to reduce carbon dioxide concentrations in the atmosphere [14].

Differences in policy and institutions, age, existing forest conditions could have contributions to the difference observed patterns in urban forests. The conservation of urban trees must be prioritized in order to increase carbon sequestration capacity and mitigate climate change. Furthermore the practice of managing and conserving urban forests as an inherent component of urban greening should be scaled up [15].

References

1. Liu C, X Li (2012) Carbon storage and sequestration by urban forests in Shenyang, China. Urban For Urban Green 11: 121-128.
2. Mc Carthy M, M Best, Betts R (2010) Climate change in cities due to global warming and urban effects. Geophys Res Lett 37.
3. Surya P (2020) Urban Forests and their Role in Carbon Sequestration: A Review. Int J For Res 16: 23-29.
4. Dubbale D, Tsutsumi J, Michael B (2010) Urban environmental challenges in developing cities: the case of Ethiopian capital Addis Ababa. Int J Environ Eng 4: 164-169.
5. Strohbach ME, Arnold, Haase D (2012) The carbon footprint of urban green space-A life cycle approach. Landsc Urban Plan 104: 220-229.
6. Woldegerima T, Yeshitela K, Lindley S (2017) Characterizing the urban environment through Urban Morphology Types (UMTs) mapping and land surface cover analysis: The case of Addis Ababa, Ethiopia. Urban Ecosyst 20: 245-263.
7. Kuchelmeister G (2000) Trees for the urban millennium: urban forestry update. UNASYLVA-FAO 49-55.
8. Habtamu M, Argaw M (2019) Carbon Stock Estimation of Urban Forests in Selected Public Parks of Addis Ababa and Its Contribution to Climate Change Mitigation. Int J For Soil Eros 9: 14-21.
9. Marshet T, Teshome S (2015) Carbon stock potentials of woody plant species in Biheretsige and Central Closed Public Parks of Addis Ababa and its contribution to climate change mitigation. J Environ Earth Sci Res 5: 1-14.
10. Woldegerima TK, Yeshitela, Lindley S (2017) Ecosystem services assessment of the urban forests of Addis Ababa, Ethiopia. Urban Ecosyst 20: 683-699.
11. Teferi E, Abraha H (2017) Urban heat island effect of Addis Ababa City: Implications of urban green spaces for climate change adaptation, in Climate Change Adaptation in Africa 539-552.
12. Gudina L, Dons K, Meilby H (2014) Efficiency of parks in mitigating urban heat island effect: An example from Addis Ababa. Landsc Urban Plan 123: 87-95.
13. MacDicken KG (1997) A guide to monitoring carbon storage in forestry and agroforestry projects.
14. Brown S, Gillespie AJ, Lugo AEJFs (1989) Biomass estimation methods for tropical forests with applications to forest inventory data. For Sci 35: 881-902.
15. Yohannes H, Soromessa T, Argaw M (2015) Carbon stock analysis along altitudinal gradient in gedo forest: Implications for forest management and climate change mitigation. Am J Environ Prot 4: 237-244.