

Understanding the Ecosystem Services of Urban Forests: Implications for Climate Change Mitigation in the case of Adama City of Oromiya Region Sate, Ethiopia

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Abstract

Background

this study was conducted to explore the ecosystem services of urban forests in Adama city, central Ethiopia. Attempts were made to quantify the carbon storage and sequestration, air pollution removal and hydrological benefits of urban trees. The urban forest structure and composition of the city was surveyed and analyzed. The i-Tree Eco Model was employed to analyze the ecosystem services based on the current urban forests structure of the city.

Results

the result revealed that the urban trees of the Adama city stored a total of 116,000 tons of carbon. The tree species identified with higher CO₂ sequestration per year were *Melia azedarach* (15%), *Eucalyptus globulus* (8%), *Carica papaya* (7%), and *Delonix regia* (6%). Approximately 22, 12, 10 and 4% of carbon were stored by *Eucalyptus globulus*, *Melia azedarach*, *Carica papaya* and *Delonix regia* tree species respectively. Moreover, trees and shrubs spp. in the city removed about 188 thousand tons of air pollutants caused by O₃, CO, NO₂, PM2.5 and SO₂ per year. In Adama, 35% of the urban trees' VOC emissions were from *Eucalyptus cinerea* and *Eucalyptus globulus*. The monetary value of Adama urban forest in terms of carbon storage, carbon sequestration, and pollution removal was estimated to 43,781, 3,121 yr⁻¹ and 320,915,596 USD yr⁻¹, respectively.

Conclusions

it was concluded that significant quantity of CO₂ and air pollutants were found being removed by the exotic tree and shrub species. However, every plant species found in the city does not mean ecologically important due their VOC emitting nature. Thus, proper planning and inventories of urban forests should be put in place by the key stakeholders such as government, urban foresters and city dwellers as urban trees mitigate climate changes and essential to alleviate urban pollution besides the trees add esthetic value to the city.

Introduction

Human population growth and urbanization of the world have threatening the environment in various forms, such as elevated temperatures, increases air pollution and stormwater quantity, and decreases in stormwater quality, which pose major environmental and public health problems in cities (Rydin et al. 2012; Seto and Shepherd, 2009). In this regard, urban forest ecosystem plays an important role in providing multiple service and environmental benefits to urban environment (Forrest et al. 1999 ; Strohbach and Haase, 2012).

Ethiopia's urban centers have been urbanizing at rapid rate with a rate of about 4 to 5%, and its urban population is expected to increase from time to time (Girma et al., 2019). The current phenomenon in Ethiopia has been associated with environmental problems in most cities. The major problems are urban sprawl, solid and liquid waste management; water, air, and noise pollution; illegal settlements and the degradation of open green areas (Mpofu, 2013). Developing countries like Ethiopia are experiencing the effects of climate change such as an increase in average temperature and change in rainfall patterns.

Urban green space is considered a mitigate interference for urban heat. While increasing the urban green space coverage is expected to reduce the urban heat, studies on the effects of urban green space formation have produced inconsistent results (Terfa et al., 2020). Quantification of ecosystem services provision by urban trees can be used to assess the actual and potential role of urban forests in providing environmental, social and economic benefits. Assessment of ecosystem services provided by the green spaces of Adama city is quite scanty. The EU FP7 Climate change and Urban Vulnerability in Africa (CLUVA) project (www.cluva.eu) provided a foundation for the assessment of ecosystem services by the green spaces of the

city. Apart from the above study, quantitative assessment of individual ecosystem services provided by urban forests of Adama city is generally lacking. As a result, information on ecosystem services from urban forests and green spaces are not available for use in the urban planning activities of the city.

There are several techniques and models that have been developed to quantify ecosystem services. These models include i-tree eco and i-tree streets (i-tree, 2010). In this work, i-tree eco suite was used for the analysis. The i-tree Eco is designed to use standardized field data from randomly located plots, as well as local hourly air pollution and meteorological data, to quantify urban forest structure, ecological function, and the associated value (Nowak et al. 2008; McPherson 2010).

Such application of technologies to explore the ecosystem services of urban forests is extraordinary in Ethiopia. So far, there is no any i-tree Eco based ecosystem services assessment study conducted in Ethiopia. Thus, the main aim of this study was to assess the ecosystem service of urban forest of Adama city interms of climate change mitigation. More specifically, the study was intended i) to assess carbon storage and sequestration potential of adama city trees ii) to estimate the oxyigen production and pollution removal by different species of adama city trees and iii) assess the hydrological and functional values of trees in Adama city.

Research Methods

Study Area

This study was conducted in Adama city of Oromiya National Regional State, Central Ethiopia. Adama city is geographically situated between 8° 32' 24" N, latitude and 39° 16' 12" E longitude within the altitudinal range of 1,712 meter a.s.l. (Fig. 1). The total area of the city was about 13,366.5 ha and it is situated at about 99 km distance from Addis Ababa the capital city of Ethiopia. The annual average minimum and maximum temperature of the study area was 13 and 27⁰c, respectively. The annual average rainfall is 837-1005.7 mm and its climate varies due to the great variation in altitude (Central Statistical Authority, 2007). The total population of Adama was about 303,569 of which 150,228 are males and 153,341 are females.

Figure 1: Location map of the study area.

Research Design and Sampling

The reconessance survey was conducted (from October to December, 2018) by a team of 5 people. The site assessment has done to observe the general plot information used to identify the plots and its general characteristics. In this work, trees and shrub information were used to estimate trees and shrubs leaf area/biomass, pollution removal, and volatile organic compound (VOC) emissions. Finally, tree informations used to estimate forest ecosystem value, carbon storage, carbon sequestration and hydrological functions of Adama city urban forest.

In this study, a total of 214 sample plots have established by using a simple random sampling method. As a general rule, 200 plots (one-tenth acre each) will yield a standard error of about 10% for an estimate of the entire city. As the number of plots increases, the standard error will be decrease; and therefore we were more confident to estimate for the population. With regard to the sample plot size, the standard plot size for an Eco analysis is a 0.1-acre circular plot with a radius of 11.16 m or 0.0407 hectares. The samples of plots were created directly in the Eco application using the random plots generator via the Google Maps function (Fig. 2).

The diameters of all identified trees and shrubs were measured at breast height (1.3 m above ground) using a diameter tape (5 m length). Diameter of individual trees were recorded to calculate basal area and relative basal area of plant species. Height of all sampling trees and shrubs were measured by silva hypsometer.

The field data collection crews were typically located field plots using maps to indicate plot location. Aerial photographs and digital maps were used in order to locate plots and features. During random plots distribution in the city, the researchers faced a challenge of miss place placement of some plots; for example, some plot center has fallen in buildings, private land and the

border of different land ownerships and land-use types; as a result the researchers professional skills were used to shift the plot center into appropriate locations.

Figure 2: Sample plots (highlighted yellow) distribution randomly within the project site based on the standard of the i-tree eco Model

Data collection and analysis

In this study, the data was collected from sample plots which have an area of 0.0407 ha (1/10 ac) that randomly laid in city areas of states and data was analyzed using the i-tree Eco (formerly Urban Forest Effects (UFORE)) model (Nowak et al., 2008). The state plots were based on Forest Inventory Analysis national program plot design and data were collected as part of pilot projects testing FIA data collection in urban areas (Steenberg et al., 2016). For each tree found in the sample plots carbon storage, annual sequestration, oxygen production, pollutant removal and hydrological functions were estimated using biomass and growth equations. In order to carry out in national estimates of carbon storage and sequestration, the carbon data was standardized per unit of tree cover.

Results

Structure of tree species of Adama city

Trees covered about 20% of Adama city and provided 8.871 square miles of leaf area. Indeed, total leaf area is greatest in urban areas. In Adama urban trees, the most dominant species in terms of canopy cover and leaf area were *Acacia albida*, *Casimiroa edulis*, and *Eucalyptus cinerea*. The attributes of 20 tree species are presented in (Table 1).

Table 1
The measurements and condition of some twenty common tree species

Species	Frequency	DBH	Height	Canopy Cover (ft ²)	Tree condition	Leaf area/ac	Leaf biomass(lb)	Leaf area index	Basal area(ft ²)
<i>Persia americana</i>	31	4.27	18.67	87.82	Good	318.48	4.887	3.635	0.12
<i>Eucalyptus globulus</i>	28	17.05	48.74	102.02	Good	521	13.82	4.51	3.11
<i>Citrus medica</i>	16	8.16	22.77	134.6	Excellent	649.72	17.94	4.23	0.48
<i>Podocarpus falcatus</i>	24	7.46	33.66	88.525	Good	528.7	8.1	5.06	0.43
<i>Eucalyptus camaldulensis</i>	24	7.87	86.05	77.43	Excellent	378.58	10.04	4.94	0.55
<i>Olea europea</i>	11	5.1	16.4	26.4	Poor	104	1.6	3.9	0.1
<i>Acacia abyssinica</i>	40	7.09	17.39	98.36	Fair	403.56	19.97	3.88	0.58
<i>Eucalyptus grandis</i>	14	7.91	36.53	110.62	Fair	754.04	17.85	6.35	0.47
<i>Cordia africana</i>	16	7.42	18.7	120.45	Good	554.11	8.50	3.77	0.38
<i>Mangifera indica</i>	32	5.88	18.88	66.06	Good	250.85	3.84	3.75	0.23
<i>Melia azedarach</i>	119	8.11	18.39	57.28	Good	247.23	3.78	3.88	0.57
<i>Citrus sinensis</i>	20	4.04	13.61	45.6	Good	194.765	4.97	4.225	0.115
<i>Carica papaya</i>	55	9.10	17.71	41.25	Good	160.02	2.44	3.83	0.89
<i>Delonix regia</i>	33	10.44	36.13	150.65	Excellent	610.06	9.35	4.23	0.71
<i>Grevillea robusta</i>	28	7.07	28.85	80.328	Good	493.57	12.3	5.38	0.46
<i>Eucalyptus cinerea</i>		8.37	75.68	179.28	Good	849.59	22.51	4.7	0.45
<i>Acacia tortilis</i>	38		16.97	146.07	Fair	536.09	26.54	3.48	0.27
<i>Leucaena leucocephala</i>	35	4.62	18.05	50.10	Excellent	182.08	2.78	4.26	0.14
<i>Casimiroa edulis</i>	15	9.12	30.66	272.33	Good	1272.71	19.51	5	0.54
<i>Acacia albida</i>		14.42	31.02	270.53	Good	1366.97	67.67	4.78	1.53
Total		153.57	604.93	2205.85		10376.2	278.46	87.82	12.18

Carbon Storage and Sequestration

Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new growth every year. The gross carbon sequestration of Adama city trees was about 8,291 thousand tons of carbon per year with an associated value of 31,134 USD. Net carbon sequestration in the urban forest was about 7,474 thousand tons. The most common species that are known

for the greater share of carbon sequestration in the study area forest are listed in Table 2. In particular, the tree species such as *Melia azedarach*, *Eucalyptus globulus*, *Carica papaya* and *Delonix regia* sequestered the most percentage of carbon which were approximately 15, 8, 7 and 6% of all annually sequestered carbon respectively (Fig. 3).

Figure 3: Estimated annual gross carbon sequestration (points) and value (bars) by urban tree species of Adama city

Trees in Adama urban forests were estimated to store 116,000 tons of carbon (437,994.7 USD). Of the species sampled, *Eucalyptus globulus*, *Melia azedarach*, *Carica papaya* and *Delonix regia* stored the most approximately 22, 12, 10 and 4% of all stored carbon respectively (Table 2).

Table 2
Carbon storage and sequestration potential of common woody species of Adama urban forest.

Species	No of trees	Carbon storage (ton/yr)	Co2 equivalent(ton)	Carbon sequestratoin (ton/yr)	Co2 equivalent(ton)
<i>Acacia abyssinica</i>	26099	6086.6	22319.6	321.3	1178.22
<i>Acacia albida</i>	5872	3147.7	11542.6	251.39	921.84
<i>Melia azedarach</i>	77643	14273.62	52341.4	1220.63	4476.04
<i>Casuarina cunninghamiana</i>	5220	5544.41	20331.4	51.27	188.02
<i>Carica papaya</i>	35886	11018.11	40403.4	607.28	2226.91
<i>Delonix regia</i>	21531	4844.54	17764.9	518.38	1900.9
<i>Eucalyptus cinerea</i>	13702	2260.97	8291	232.21	851.51
<i>Eucalyptus globulus</i>	18269	25676.41	94155.4	612.23	2245.04
<i>Ficus sur</i>	1957	986.93	3619.1	47.36	173.66
<i>Ficus sycomorus</i>	3915	2892.47	10606.7	243.8	894.03
<i>Ficus vasta</i>	652	5001.59	18340.8	14.98	54.95
<i>Grevillea robusta</i>	18269	2670.2	1176.82	320.92	1176.82
<i>Podocarpus falcatus</i>	15659	2114.66	952.95	259.87	952.95
<i>Acacia tortilis</i>	24794	1854.2	6799.2	277.86	1018.91
<i>Casimiroa edulis</i>	9787	1572.1	5765	217.06	795.96
<i>Citrus medica</i>	10439	1640.8	6016.8	179.74	659.12
<i>Ficus elastica</i>	4567	1996.3	7320.3	169.2	620.46
<i>Persea americana</i>	20226	663.5	2433.1	138.63	508.34
Total	314487	94245.11	330180.47	5684.11	20843.68

Air Pollution Removal by Urban Trees

Urban pollution removal capacities of each urban tree species are presented in (Fig. 4). It is estimated that trees and shrubs removed 188 thousand tons of air pollution (ozone (O₃), carbon monoxide (CO), nitrogen dioxide (NO₂), particulate matter less than 2.5 microns (PM_{2.5}), and sulfur dioxide (SO₂)) per year with an associated value of 686,519,156.80 USD.

Figure 4: Annual pollution removal (points) and value (bars) by urban trees of Adama city

Volatile Organic Compound Emission

In 2018, trees in Adama city emitted about 51 tons of volatile organic compounds (VOCs) per year of which 34 tons was isoprene and 18 tons was monoterpenes. The amount of emissions from the trees varied based on species characteristics (e.g. some genera such as *Grevillia robusta* was high isoprene emitter) and amount of leaf biomass. In Adama city, 35% of the urban trees' VOC emissions was by *Eucalyptus cinerea* and *Eucalyptus globulus*. These VOCs are precursor chemicals to ozone formation (Table 3).

Table 3
Estimates of VOC removal by common woody species of Adama city, central Ethiopia.

Species Name	Monoterpene (lb/yr.)	Isoprene (lb/yr.)	Total VOCs (lb/yr.)
<i>Persea americana</i>	210.00	7.50	217.50
<i>Eucalyptus globulus</i>	2681.90	13430.50	16112.50
<i>Schinus molle</i>	714.10	0.00	714.10
<i>Acacia torulosa</i>	1132.00	8.10	1140.10
<i>Eucalyptus camaldulensis</i>	1670.40	8364.80	10035.20
<i>Acacia abyssinica</i>	5540.80	39.60	5580.50
<i>Eucalyptus grandis</i>	1733.20	8679.40	10412.60
<i>Mangifera indica</i>	643.10	0.00	643.10
<i>Pinus patula</i>	384.70	2.80	387.50
<i>Citrus sinensis</i>	298.70	4.90	303.70
<i>Acacia seyal</i>	489.90	3.50	493.40
<i>Ficus elastica</i>	289.60	7117.60	7407.30
<i>Grevillea robusta</i>	159.10	17.10	176.20
<i>Eucalyptus cinerea</i>	3280.00	16425.80	19705.80
<i>Acacia tortuosa</i>	772.00	5.50	777.60
<i>Acacia tortilis</i>	6992.40	50.00	7042.50
<i>Acacia albida</i>	4222.90	30.20	4253.10
<i>Casimiroa edulis</i>	981.20	14.50	995.70
<i>Eucalyptus globoidea</i>	996.40	4989.70	5986.10
Total	34055.50	59205.70	93261.80

Hydrological benefits of urban trees

Urban forests as a whole have important roles throughout the hydrological cycle. Tree crowns intercept rain and reduce the amount of water reaching the pervious or impervious surfaces below. This can increase evapotranspiration and transpiration of urban forests. The total leaf area of adama urban forest was 2,298 hectarea. The potential evapotranspiration of Adama urban forest was about 187,655,094 ft³ per year, whereas the transpiration potential was estimated to 48,441,686 ft³ per year. In (Table 4) presents the hydrological benefits of 18 tree species of Adama city.

Table 4
Hydrological benefits of 18 tree species of Adama city

Species Name	Number of Trees	Leaf Area	Potential Evapotranspiration	Transpiration
<i>Ficus sur</i>	1957	35.90	1186695.64	306336.14
<i>Ficus vasta</i>	652	2.64	87181.81	22505.30
<i>Citrus medica</i>	10439	155.71	5146853.39	1328619.70
<i>Podocarpus falcatus</i>	15659	190.06	6282314.47	1621730.05
<i>Eucalyptus cinerea</i>	13702	267.24	8833401.02	2280272.96
<i>Casimiroa edulis</i>	9787	285.95	9451862.27	2439923.87
<i>Acacia tortilis</i>	24794	305.14	10085969.15	2603613.57
<i>Acacia abyssinica</i>	26099	241.79	7992174.74	2063117.02
<i>Azadirachta indica</i>	77643	440.68	14566266.32	3760167.03
<i>Carica papaya</i>	35886	131.83	4357542.49	1124865.31
<i>Eucalyptus globulus</i>	18269	218.51	7222632.76	1864465.81
<i>Grevillea robusta</i>	18269	207.00	6842149.76	1766247.12
<i>Persea americana</i>	20226	147.88	4888111.40	1261827.49
<i>Delonix regia</i>	21531	301.55	9967327.43	2572987.15
<i>Acacia albida</i>	5872	184.28	6091170.63	1572387.77
<i>Casuarina cunninghamiana</i>	5220	24.65	814877.96	210354.33
<i>Ficus elastica</i>	4567	611.96	20227693.99	5221620.04
<i>Ficus sycomorus</i>	3915	225.14	7441674.13	1921009.62
Total	14487	3977.91	1485899.36	33942050

Eco benefit of Adama urban trees

The summary of ecosystem value that include number of trees, carbon storage and sequestration, pollution removal, and structural value of woody species of Adama urban forest were estimated and summarized in (Table 5).

Table 5
The summary of monetary value of Adama urban trees

Trees		Carbon Storage			Gross Carbon Sequestration			Pollution Removal	
No	SE	Ton	SE	USD	Ton/yr.	SE	USD/yr.	Ton/yr.	USD/yr.
525235	± 43,558	116280	± 33,049	437,691	8291	± 845	31,209	89445	320,915,596
SE: Standard Error, USD: US Dollar yr.: year									

Carbon storage and gross carbon sequestration values were calculated based on the price of 3.76 USD per ton. Also, the pollution removal value was calculated based on the prices of 1,041.15 USD per ton (CO), 7,330.42 USD per ton (O₃), 7,330.42 USD per ton (NO₂), 1,794.60 USD per ton (SO₂), 4,894.18 USD per ton (PM2.5).

Discussions

This study estimated the quantity of the C stored and sequestered by urban trees in Adama city of central Ethiopia. The result of carbon sequestration and storage of Adama city was appeared higher than carbon assessment work conducted in cities such as Padua, Bolzano and Florence, Lisbon, Portugal, Zurich Switzerland (Crema 2008; Paoletti et al. 2011; Wälchli 2012). In the results current study the amount of carbon stored and sequestered in Adama urban trees was higher than result indicated in the study of Pace (Pace et al., 2018) regarding ecosystem services modeling for urban trees in Munich city of Germany; which was estimated to be 6225 ton and 214 tons per year respectively. Further more, the carbon storage and sequestration indicated in the current study were also compared with the study results presented for three cities of North America. Accordingly, the carbon storage and sequestration estimates of cities such as New York, Chicago and Jersey City were 1,225,200 and 38,400 ton C^{-yr} , 854,800 and 40,100 ton C^{-yr} and 19,300 and 800 ton C^{-yr} respectively (Nowak and Crane, 2002). This comparison showed that the annual carbon storage and sequestration of the cities were higher than that of Adama city of Ethiopia except the annual carbon sequestration of Jersey city which was less than Adama city.

The carbon storage and sequestration results from this study were difficult to assess in terms of accuracy and to compare with other studies because of the use of different estimation methodologies, climatic condition, different species composition, and urban forest structures (Jo and McPherson 1995; Strohbach and Haase 2012).

The pollution removal indicated in this study was lower than the result reported from city of Baton Rouge which was 860 tons/year. In the work of Nowak et al. (2014) recently analyzed the effects of urban forests on air quality and human health in the United States, they found that in highly vegetated areas, trees can improve air quality by as much as 16% (Kroeger et al. 2014). Baumgardner et al. (2012) pointed out that around 2% of the ambient PM10 in Mexico city is removed from the study area. In a study carried out in the city of Barcelona (Spain), Barò et al. (2014) reported that urban forest services reduce PM10 air pollution by 2.66%. Moreover, in the Mediterranean city of Tel-Aviv, Cohen et al. (2014) observed that an urban park significantly mitigated nitrogen oxides (NOx) and PM10 concentrations, with a greater removal rate being observed in winter, and increased tropospheric ozone levels during summer.

In this result, the amount of annual Volatile Organic Carbon (VOC) removal was lower than the report of study conducted in Scotlandville's trees which yearly produce 8.91 tons of monoterpene, 125.53 tons of isoprene, and produce 134.43 tons of volatile organic compounds (VOCs); that may contribute to ozone formation. (Nowak and Dwyer 2007; Nowak et al. 2014).

In Adama urban forest trees such as *Acacia tortilis*, *Melia azedarach* and *Ficus elastica* have higher potential evapotranspiration and transpiration (Table 4). Similarly, Xiao and McPherson (2016) reported that trees in urban areas can increase the return of runoff to the atmosphere through transpiration, providing associated air cooling benefits. Furthermore, according to the study of Gwynns Falls watershed in Baltimore indicated that heavily forested areas can reduce total runoff by as much as 26% and increase low-flow runoff by up to 13% compared with non-tree areas in existing land cover and land use conditions (Neville, 1996). Studies have also reported that tree cover over pervious surfaces reduced total runoff by as much as 40%; while tree canopy cover over impervious surfaces had a limited effect on runoff.

The Adama urban forest in terms of monetary value have presented in the result section (Table 5). The outcome of current study was compared with the study conducted in city of Baton Rouge the annual monetary value of urban forest service were lower, in terms of Carbon storage (\$6.2 million/year), Carbon sequestration (\$41.0 million) and pollution removal (\$1.1 million/year).

In general, this work has tried to quantify the ecosystem service value of Adama city of Ethiopia which will help for further urban forest development work and government intervention in terms of policy and awareness creation. Further researches should be conducted to assess and evaluate the ecosystem service value of urban trees in several urban green infrastructures and comparing with different cities in the country. This will sensitize cities to learn and compute in urban forest development to enhance the ecosystem value of trees.

Conclusions

Urban trees and forests have positive effect on human health and well-being through improving air quality and reducing greenhouse gases, mainly through lowering air temperatures and energy use and through direct pollution removal and carbon sequestration. Although the current greening coverage and management practice is contributing significant amount of CO₂ sequestration and pollutant removal, further greenery expansion in the city would help to have sustainable urbanization trend in the city and its outskirts. The incorporation of adequate tree coverage into the built-up environment and proper management practices would be expected to increase the pollutants and carbon absorption.

Understanding the value of an urban forest can give decision makers a better understanding of urban tree management. Exotic tree and shrub species are the predominant vegetation of the Adama city. As a result, the higher carbon sequestration and pollutant removal were found with most introduced ornamental trees and shrubs. However, all trees and shrubs species are not positively contribute to the environmental remedy. Some species were found diversely affecting the environment due to the fact that significant amount of VOC emission and formation of pollutants.

These results provide baseline information for management recommendations to maximize the ecological benefits provided by trees. By understanding the effects of trees and forests on the atmospheric environment, urban forest managers and policy makers can decide on the policy and strategic planning of urban greening. Subsequently, it will help for designing appropriate and healthy vegetation structure in cities to improve air quality and consequently human health and well-being for current and future generations.

Abbreviations

SE: Standard Error; USD: US Dollar; yr: year; VOC: Volatile Organic Carbon; lb: pound (a unit of mass or weight); CO₂: Carbon dioxide; ft²: Feet Square; DBH: Diameter at Breast Height; SO₂: Sulfur dioxide; O₃: Ozone; CO: Carbon mono oxide; NO₂: Nitrogen dioxide; PM_{2.5}: Particulate Matter less than 2.5 microns.

Declarations

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Author's Contributions

Mr. Hingabu Hordofa: Contributed in designing the research idea, data collection, report writing and data analysis and guiding the overall paper work:

Mr. Ararsa Derese: Participated in data analysis, interpretation and report writing:

Mr. Tikabo Gebreyesus: Participated in data interpretation and edited language:

Dr. Fekadu Fufa: Participated in designing method and structuring report:

Prof. Shaoxian Song: Participated in designing method, structuring report and guiding the overall paper work.

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Availability of data and materials

The data set generated for the study area is available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The subject has no ethical risk.

Consent for publication

The subject matter has no ethical risk.

Computing interest

The authors declares that they have no competing interests.

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Figures

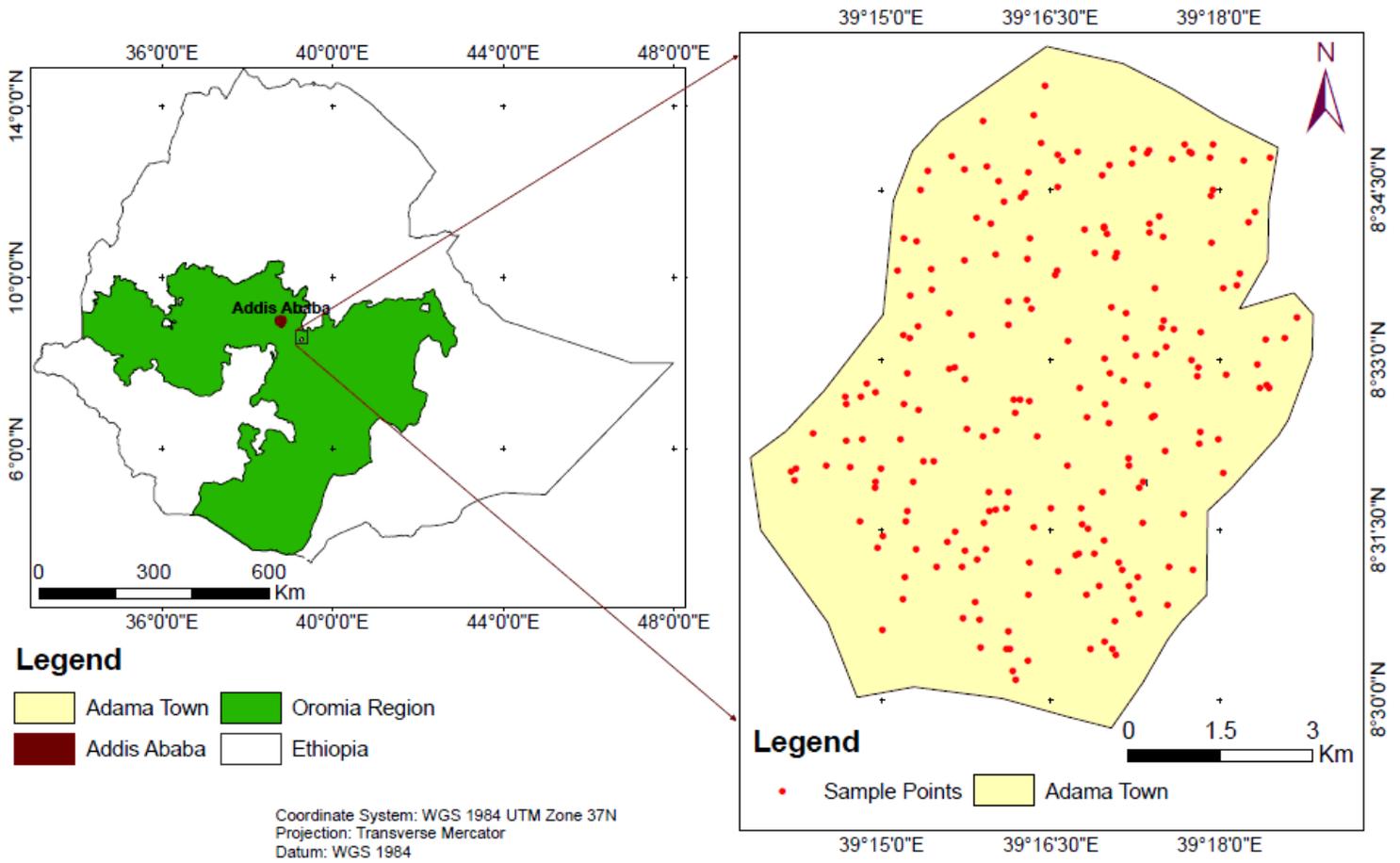


Figure 1

Location map of the study area.

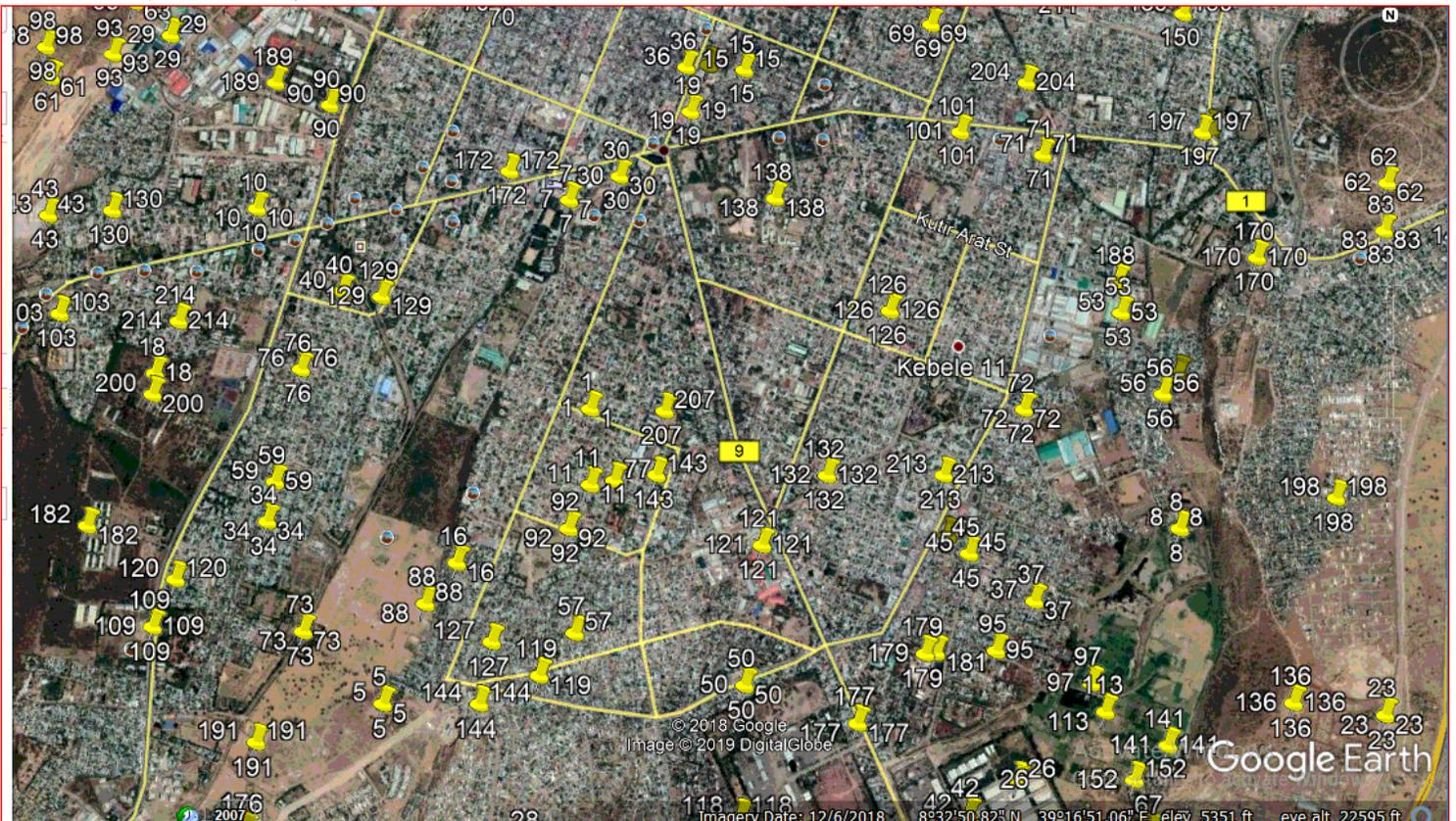


Figure 2

Sample plots (highlighted yellow) distribution randomly within the project site based on the standard of the i-tree eco Model

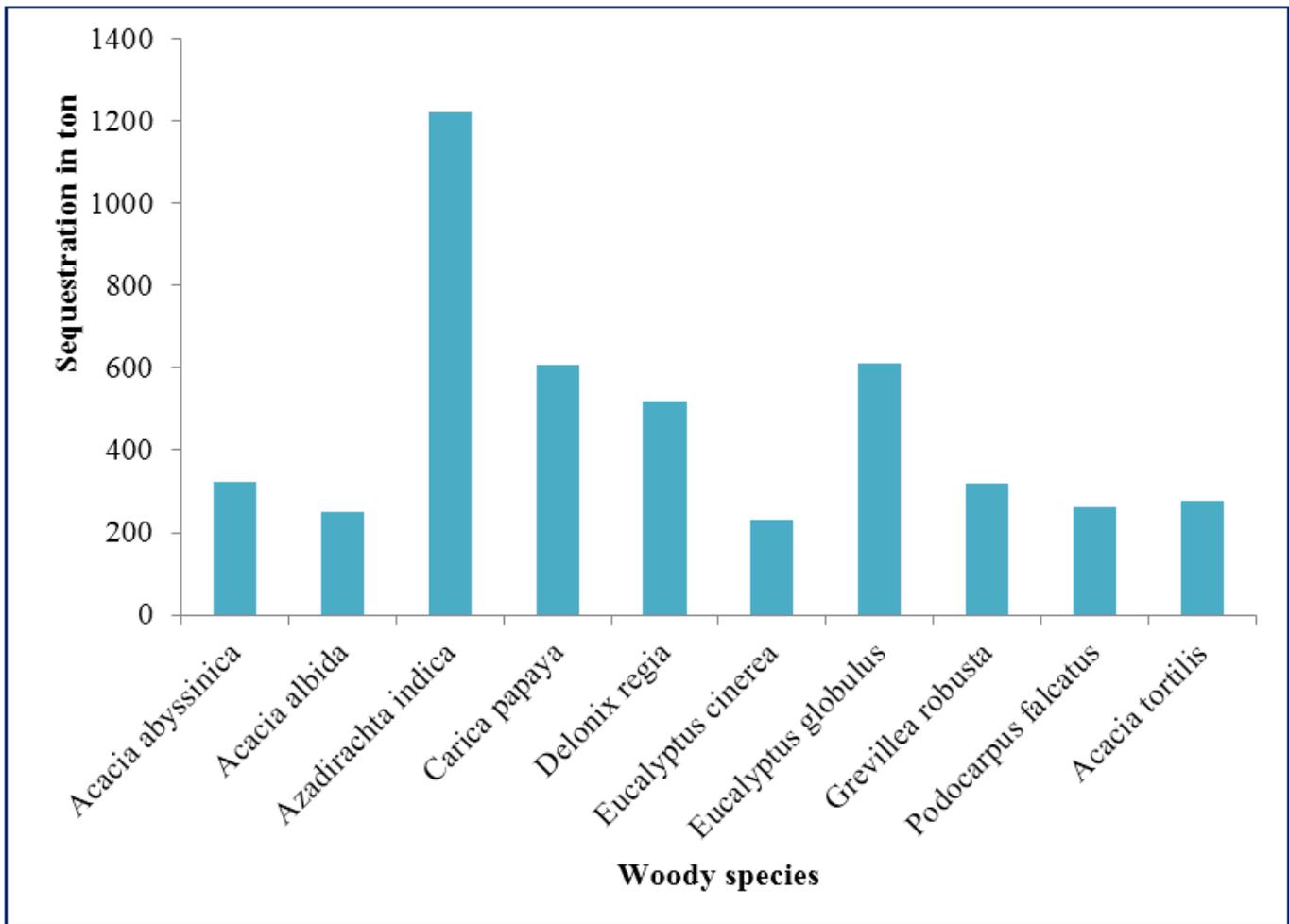


Figure 3

Estimated annual gross carbon sequestration (points) and value (bars) by urban tree species of Adama city

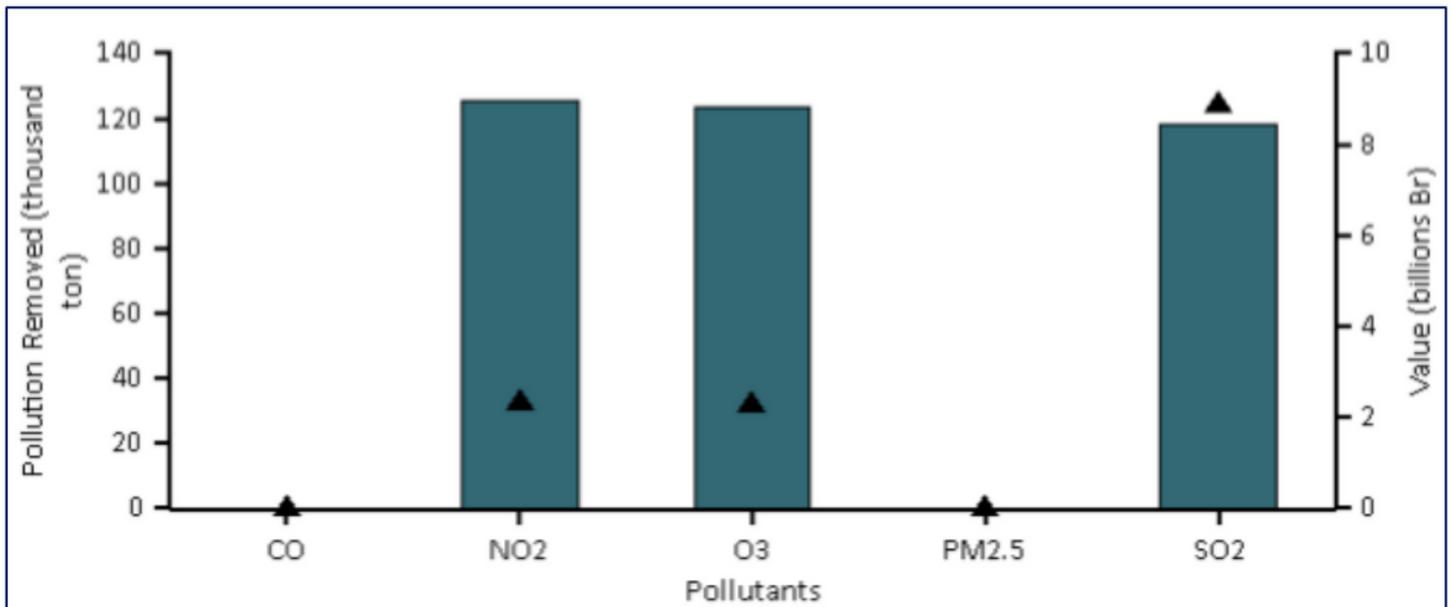


Figure 4

Annual pollution removal (points) and value (bars) by urban trees of Adama city