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Assessment of Carbon Storage and Sequestration Potential of Heritage Trees in Chennai City, India

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ABSTRACT

Trees in the urban environment offer valuable ecosystem services through carbon sequestration. Historically, Chennai (formerly known as Madras) enjoyed the patronage of several pioneering doctor-turned plant enthusiasts. The formation of the Agri-Horticultural Society in the year 1835 evoked interest in botanical studies. To date, this has flagged the way for planting a wide variety of native and exotics tree species in institutional campuses, places of worship, public precinct, private gardens, and public parks in Chennai. Today, these species are classified under "Heritage Trees" as they stand testimony to the cultural and historical events of this 400 years old city. In this paper, Girth is measured at breast height and the overall Height and compute each tree's carbon stock through a non-destructive method—MS-Excel software for correlation and regression analysis of 34 heritage tree species. Correlation matrix for carbon stocks, GBH, the tree's overall Height, and wood density carried out. The study reveals a linear positive correlation and regression with an R2 value of 0.68 for GBH and carbon stock. Height and wood density also show a positive linear correlation with an R2 value of 0.50 and 0.43, respectively. The results showed that the carbon stocks for *Tamarindusindica* maximum and *CycasCircinalis*were at a minimum of 28.85 and 0.28 total carbon stock, respectively. The results reveal planting trees with large Girth with high wood specific density in an urban environment plays a significant role in carbon storage and sequestration potential in mitigating climate change in the city.

Keywords
Heritage trees, Girth at breast height, Biomass, Carbon stock

INTRODUCTION

The Anthropocene Epoch has a significant impact on Earth's climate and ecosystem. Anthropogenic activities of burning fossil fuel and rapid land-use changes [13] contribute to an annual emission of 9 Gt C (33 Gt Co2). The terrestrial and oceanic system absorbs 3 and 2 Gt C of this anthropogenic carbon release, respectively. Still, the remaining 4 Gt, remains in the atmosphere [10] [8], which has resulted in the Green House Gas (GHG), mainly Co^2 [9]. Due to the industrial revolution, Co^2 concentration in the atmosphere has been rising alarmingly. Before the industrial revolution, the Co^2 attention was around 270 ppm, which increased to 372 ppm in 2005 [10] [18]. Scientist hypothesizes that this rising level of Co2 is one of the causative factors for global warming at 0.2 degrees centigrade per decade with an estimated average rise in global temperature of 3.0 degrees centigrade by 2100 [4] [17] [7] [11] [3]. Co2 is among the most important anthropogenic greenhouse gases [6]. Estimates reveal that managing the World's vegetation could turn the terrestrial biosphere from a source of carbon (0.1-4.2 Pg carbon per year) to a carbon sink (1.3 -3.0 Pg carbon per year) [12]. Urban trees are fifteen times more critical in reducing Co2 build-up than rural trees [1]. In the year 2012, Ontario Urban Forest Council has identified heritage trees are an integral part of urban trees that provide a legacy of genetic materials, they are spotted and assessed based on their age, size, appearance, and, most importantly, their cultural and historical significance. The above statement clarifies that heritage trees are matured and robust, informing the individual tree species' right carbon storage and sequestration potential. Pauline. R, (2012) [14] has identified 34 Heritage Tree species at various locations within the Chennai city, stating its family and binomial name, morphological

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parameters, and historical significance. Have left a data gap unidentified on the overall Height and Girth at breast height (GBH) for a few trees, vital to quantify trees' carbon storage capacity. The location of 34 heritage trees shown in Figure 1. This paper aims to measure the morphological traits such as Girth at breast height (GBH), overall Height and compute the carbon storage and sequestration potential. They use the non-destructive method, which uses bio-statistical tools to identify the maximum and minimum values of the 34 heritage tree species' carbon stock. "If we can control what plants do with carbon, the fate of the carbon in the atmosphere is in our hands," a statement from Freeman Dyson.

Figure 1: Location map of 34 heritage trees in Chennai city

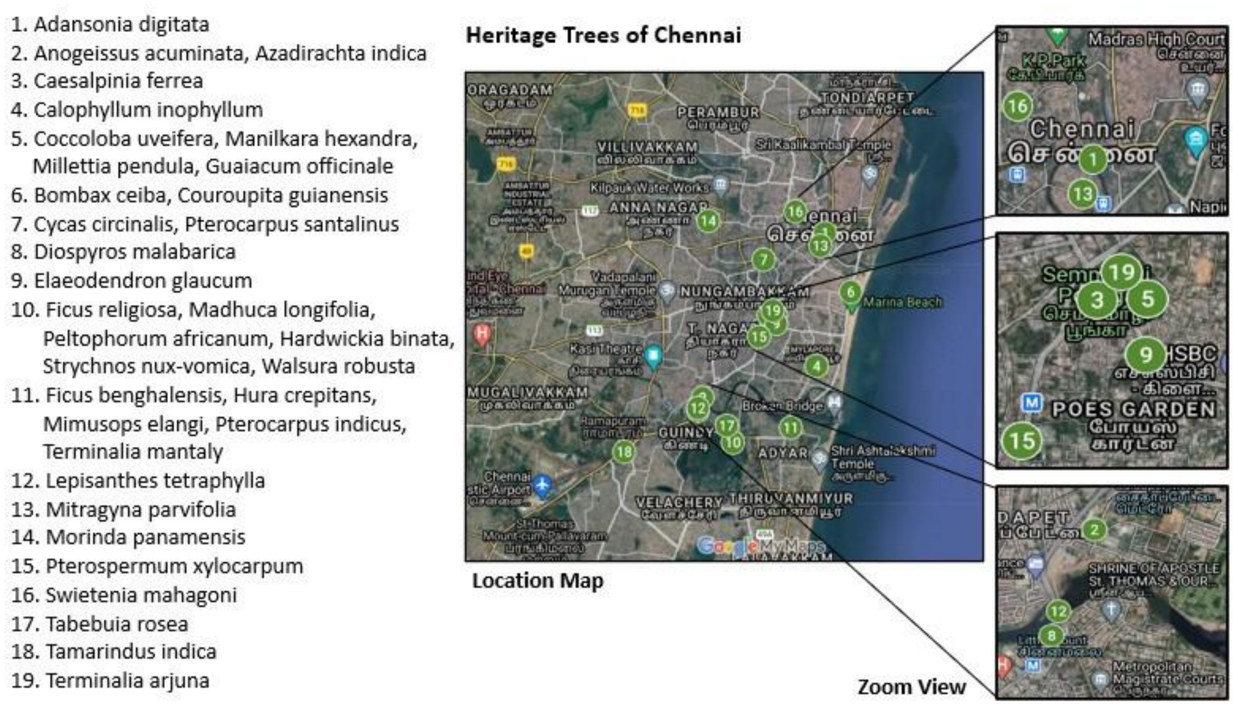

__Figure 1.__ Location map of 34 heritage trees in Chennai city
Source: Authors, (www.maps.google.com)

METHODOLOGY

Heritage Tree locations sites and data collection

Site visits made to the various location in November - December 2019 to measure the missing tree morphological parameters using the following instruments:

i) The GBH and canopy diameter was measured using a fiberglass measuring tape.
ii) Tree height measured using a digital altimeter.

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Table 1: Location, Family, Binomial Name, GBH and Overall Height of 34 heritage trees

S No	Location	Family	Binomial Name	Girth at Breast Height (m)	Overall Height (m)
1	Madras Medical College	Malvaceae	Adansoniadi gitata	11.00	21.00
2	Teacher Training College, Saidapet	Combretaceae	Anogeissusa cuminata	5.00	30.00
3	Teacher Training College, Saidapet	Meliaceae	Azadirachtai ndica	5.00	18.00
4	Madras Presidency College	Malvaceae	Bombaxceib a	3.00	25.00
5	SemmozhiPoonga	Fabaceae	Caesalpiniaf errea	3.00	26.00
6	Mylapore Temple	Calophyllaceae	Calophyllum inophyllum	2.60	20.00
7	Agri-Horticultural Society	Polygonaceae	Coccolobauv eifera	3.00	15.00
8	Madras Presidency College	Lecythidaceae	Couroupitag uianensis	3.00	25.00
9	Women's Christian College	Cycadaceae	CycasCircin alis	2.40	03.20
10	Saidapet	Ebenaceae	Diospyrosm alabarica	3.00	32.00
11	Stella Maris College	Celastraceae	Elaeodendro nglaucum	5.00	30.00
12	Theosophical Society	Lecythidaceae	Ficusbengha lensis	4.50	25.00
13	Guindy National Park	Moraceae	Ficusreligios a	6.00	28.00
14	Agri-Horticultural Society	Zygophyllaceae	Guaiacum officinale	2.00	10.00
15	Guindy National Park	Fabaceae	Hardwickiab inata	3.00	15.00
16	Theosophical Society	Euphorbiaceae	Huracrepitan s	2.50	12.00
17	Saidapet Bridge	Sapindaceae	Lepisanthest etraphylla	3.00	15.00
18	Guindy National Park	Sapotaceae	Madhucalon gifolia	3.50	12.00
19	Agri-Horticultural Society	Sapotaceae	Manilkarahe xandra	2.00	10.00

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20	Agri-Horticultural Society	Fabaceae	Millettiapen dula	2.00	20.00
21	Theosophical Society	Sapotaceae	Mimusopsel angi	3.50	12.00
22	Chintadripet Temple	Rubiaceae	Mitragynapa rvifolia	2.00	12.00
23	KilpaukCemetry	Rubiaceae	Morindapan amensis	3.00	15.00
24	Guindy National Park	Fabaceae	Peltophorum africanum	2.50	12.00
25	Theosophical Society	Fabaceae	Pterocarpusi ndicus	3.50	15.00
26	Women Christian College	Fabaceae	Pterocarpuss antalinus	2.50	15.00
27	YMCA, Nadanam	Malvaceae	Pterospermu mxylocarpu m	4.00	12.00
28	St.Matthias Church	Meliaceae	Swieteniama hagoni	2.00	23.00
29	Guindy National Park	Loganiaceae	Strychnosnu x-vomica	3.00	10.00
30	Anna University campus	Bignoniaceae	Tabebuiaros ea	3.00	16.00
31	St.Thomas Mount Post Office	Fabaceae	Tamarindusi ndica	7.00	18.00
32	St.George's Cathedral	Combretaceae	Terminaliaar juna	6.00	12.00
33	Theosophical Society	Combretaceae	Terminaliam antaly	1.50	10.00
34	Guindy National Park	Meliaceae	Walsurarobu sta	1.50	15.00

COMPUTATION OF CARBON STORAGE

Literature reveals that there are two methods of carbon storage computation of tree species: i) Destructive method and ii) Non-destructive Method.As this research paper focused on the computation of the carbon storage of Heritage Trees, the Non-destructive Method was found appropriate to adopt. The computation procedure is as follows:Firstly, each Tree morphological parameter data, the Girth at Breast Height (GBH), (a standard practice to measure at 1.32 m above ground surface) used to calculate the Diameter (D), (i.e.) GBH was divided by π (3.14) to give diameter (D) [2].Biomass is computed for all 34 heritage trees by application of bio-statistics based allometric equations. Above Ground Biomass (AGB) is computed by multiplying the bio-volume to each tree species' wood density. Tree bio-volume (TBV) value established by multiplying the diameter (D) and Height (H) of each tree species to the factor 0.40

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Bio-volume (TBV) = 0.40x(D)^2xH ………….Equation :1
AGB = Wood Density x TBV ………….Equation :2

Where,
D = (GBH/π), diameter (m) calculated from GBH, assuming the trunk to be cylindrical, H = Height (m),

Wood Density oven-dry mass/fresh volume (gm/Cm^3) obtained from Global Wood Density Database [20].The standard average density of 0.60 gm/Cm^3 is applied wherever the density value is not available for the tree species in the Wood Density database.

Below Ground Biomass (BGB) is computed by multiplying the Above Ground Biomass (ABG) by 0.26 factors as the root: shoot ratio established.[5]

BGB = AGB x 0.26 ………….Equation :3

Total biomass is the sum of Above Ground Biomass (AGB) and Below Ground Biomass (BGB).[19]

Total Biomass (TB) = AGB + BGB ………….Equation :4

Carbon Estimation is generally for any tree species because 50 % of the Total Biomass (TB) is considered carbon.[15]

Carbon Storage = Total Biomass x 50% ………….Equation :5

Table 2: AGB, BGB, TB, and tC values of 34 Heritage Trees of Chennai City

S No	Binomial Name	Wood density (gm/Cm ^3), oven dry mass/fresh volume*	Girth at Breast Height (m)	Over all Height (m)	Diameter (m)	Bio-Volume (TBV) Cu.m	AGB (Kg)	BGB (Kg)	TB (Kg)	tC (Kg)
1	Adansoniadigitata	0.275	11.00	21.00	3.50	103.09	28.35	7.37	35.72	17.86
2	Anogeissusacuminata	0.880	5.00	30.00	1.59	30.43	26.78	6.96	33.74	16.87
3	Azadirachtaindica	0.660	5.00	18.00	1.59	18.26	12.05	3.13	15.18	7.59
4	Bombaxceiba	0.350	3.00	25.00	0.96	9.13	3.19	0.83	4.03	2.01
5	Caesalpiniaferrea	1.170	3.00	26.00	0.96	9.49	11.11	2.89	14.00	7.00

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6	Calophyllu minophyllu m	0.600	2.60	20.00	0.83	5.49	3.29	0.86	4.15	2.07
7	Coccolobau veifera	0.700	3.00	15.00	0.96	5.48	3.83	1.00	4.83	2.42
8	Couroupitag uianensis	0.450	3.00	25.00	0.96	9.13	4.11	1.07	5.18	2.59
9	CycasCircin alis	0.600	2.40	03.20	0.76	0.75	0.45	0.12	0.57	0.28
10	Diospyrosm alabarica	0.720	3.00	32.00	0.96	11.68	8.41	2.19	10.60	5.30
11	Elaeodendro nglaucum	0.800	5.00	30.00	1.59	30.43	24.34	6.33	30.67	15.34
12	Ficus benghalensi s	0.590	4.50	25.00	1.91	36.51	21.54	5.60	27.14	13.57
13	Ficusreligio sa	0.443	6.00	28.00	1.11	13.92	6.16	1.60	7.77	3.88
14	Guaiacum officinale	1.250	2.00	10.00	0.64	1.62	2.03	0.53	2.56	1.28
15	Hardwickia binata	0.730	3.00	15.00	0.96	5.48	4.00	1.04	5.04	2.52
16	Huracrepita ns	0.440	2.50	12.00	0.80	3.04	1.34	0.35	1.69	0.84
17	Lepisanthest etraphylla	0.960	3.00	15.00	0.96	5.48	5.26	1.37	6.62	3.31
18	Madhucalon gifolia	0.990	3.50	12.00	1.11	5.96	5.90	1.54	7.44	3.72
19	Manilkarahe xandra	1.060	2.00	10.00	0.64	1.62	1.72	0.45	2.17	1.08
20	Millettiapen dula	0.870	2.00	20.00	0.64	3.25	2.82	0.73	3.56	1.78
21	Mimusopsel angi	0.960	3.50	12.00	1.11	5.96	5.73	1.49	7.21	3.61
22	Mitragynapa rvifolia	0.640	2.00	12.00	0.64	1.95	1.25	0.32	1.57	0.79
23	Morindapan amensis	0.490	3.00	15.00	0.96	5.48	2.68	0.70	3.38	1.69
24	Peltophoru mafricanum	0.594	2.50	12.00	0.80	3.04	1.81	0.47	2.28	1.14
25	Pterocarpusi ndicus	0.960	3.50	15.00	1.11	7.45	7.16	1.86	9.02	4.51
26	Pterocarpuss antalinus	0.970	2.50	15.00	0.80	3.80	3.69	0.96	4.65	2.32

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27	Pterospermumxylocarpum	0.600	4.00	12.00	1.27	7.79	4.67	1.22	5.89	2.94
28	Swieteniamahagoni	0.510	2.00	23.00	0.64	3.73	1.90	0.49	2.40	1.20
29	Strychnosnux-vomica	0.860	3.00	10.00	0.96	3.65	3.14	0.82	3.96	1.98
30	Tabebuiarosea	0.540	3.00	16.00	0.96	5.84	3.15	0.82	3.97	1.99
31	Tamarindusindica	1.280	7.00	18.00	2.23	35.78	45.80	11.91	57.71	28.85
32	Terminaliaarjuna	0.940	6.00	12.00	1.91	17.53	16.47	4.28	20.76	10.38
33	Terminalia mantaly	0.548	1.50	10.00	0.48	0.91	0.50	0.13	0.63	0.32
34	Walsurarobusta	0.868	1.50	15.00	0.48	1.37	1.19	0.31	1.50	0.75

RESULTS AND DISCUSSION

Data analysed for correlation and regression analysis using MS-Excel software. All 34 heritage trees measured morphological data and carbon storage computed, compared for the girth class with carbon storage (tC), height (m), and canopy diameter (m) to each girth class. The scattered graph plotted shows a linear positive correlation and regression of R^2 = 0.68 linear and predicted linear for GBH Vs. As the same trendline, Carbon Storage, Height Vs. Carbon Storage of R^2 = 0.50 indicated linear trendlines steeper than linear. Wood density Vs. Carbon Storage of R^2 = 0.43 predicted linear trendline steeper than linear. Thus, it reveals a lesser correlation between height and wood density parameters. However, all of the above parameters positively correlated with carbon storage. As the Girth increases, the results show that a tree's Height and canopy also increase, resulting in a simultaneous increase in the tree's carbon storage amount. Similar work and results found a strong correlation (R^2 =0.70) for the overall Height, crown diameter, and leaf area with GBH (Peper et al.,2001). Table 4 and Figure 7 above reveal the total carbon storage (tC) of the 34 Heritage tree species is 173.78 tC. The maximum of carbon stock value 28.85 (tC), found in *Tamarindusindica*, which has GBH of 7.00 m, a height of 18.00 m, and a minimum of carbon stock value 0.28 (tC) in *CycasCircinalis* has GBH of 2.40 m, Height of 3.20 m despite both being the same age. The Girth at Breast Height (GBH) of tree species increases its biomass and carbon storage capacity, thus sequencing more carbon dioxide from the atmosphere.Trees like *Tamarindusindica, Adansoniadigitata, Anogeissusacuminata, Elaeodendronglaucum, Ficusbenghalensis, Terminaliaarjuna, Azadirachtaindica, Caesalpiniaferrea, Diospyrosmalabarica* reported having high carbon sequestration potential, with 80% of carbon stock in above-ground biomass (AGB).

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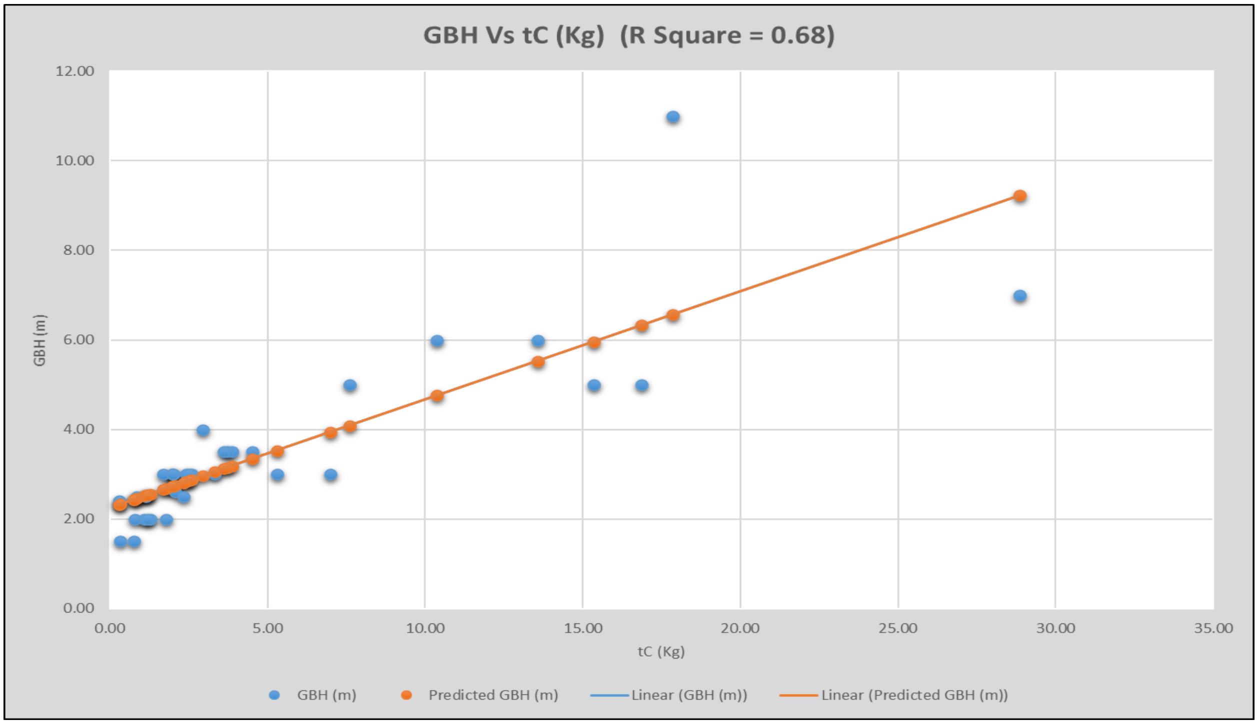

Figure 2. GBH (Girth at Breast Height in meters) Vs. Carbon Storage (Kg)

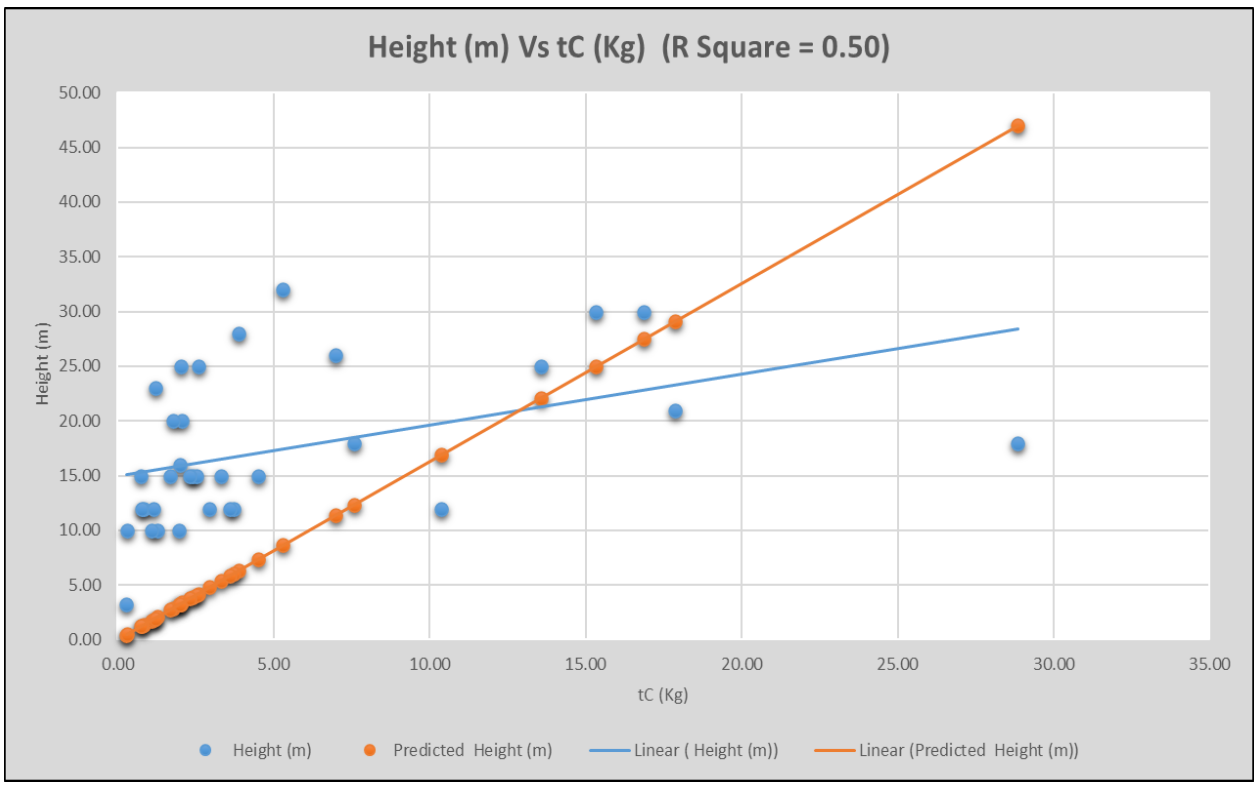

Figure 3. Height (m) Vs. Carbon Storage (Kg)

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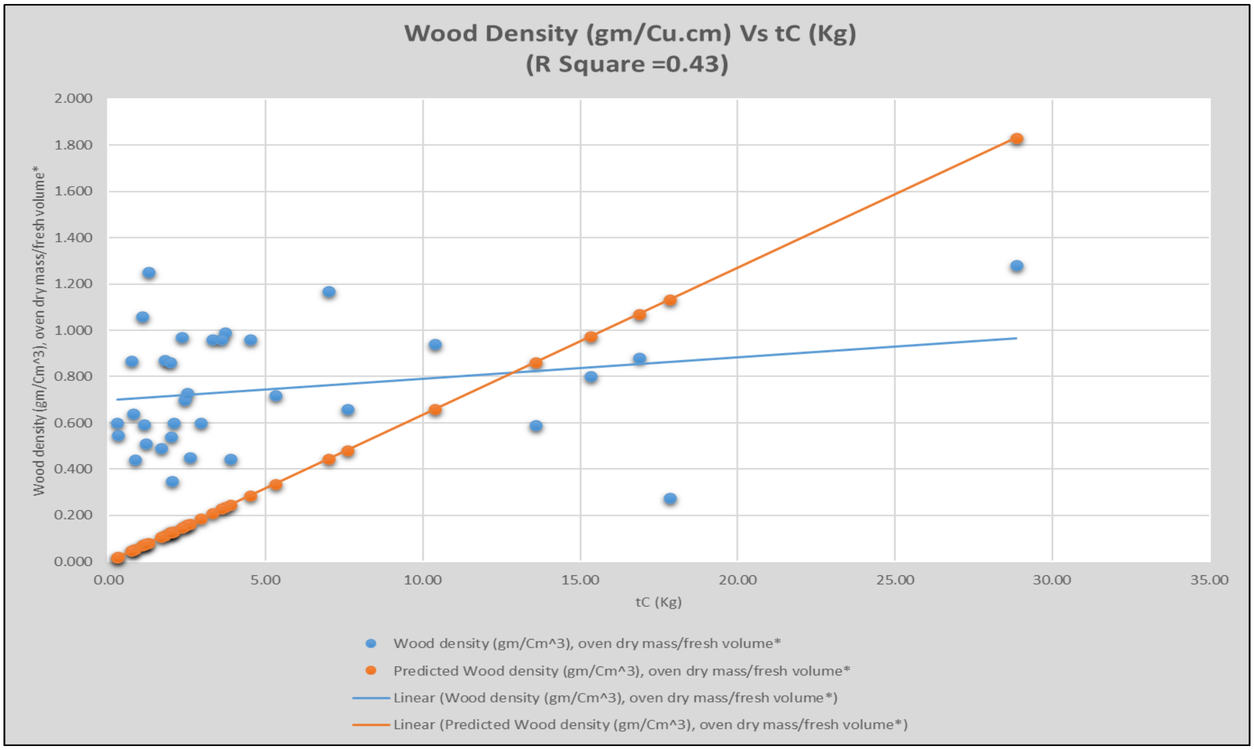

Figure 4. Wood Density (gm/Cu.cm) Vs Carbon Storage (Kg)

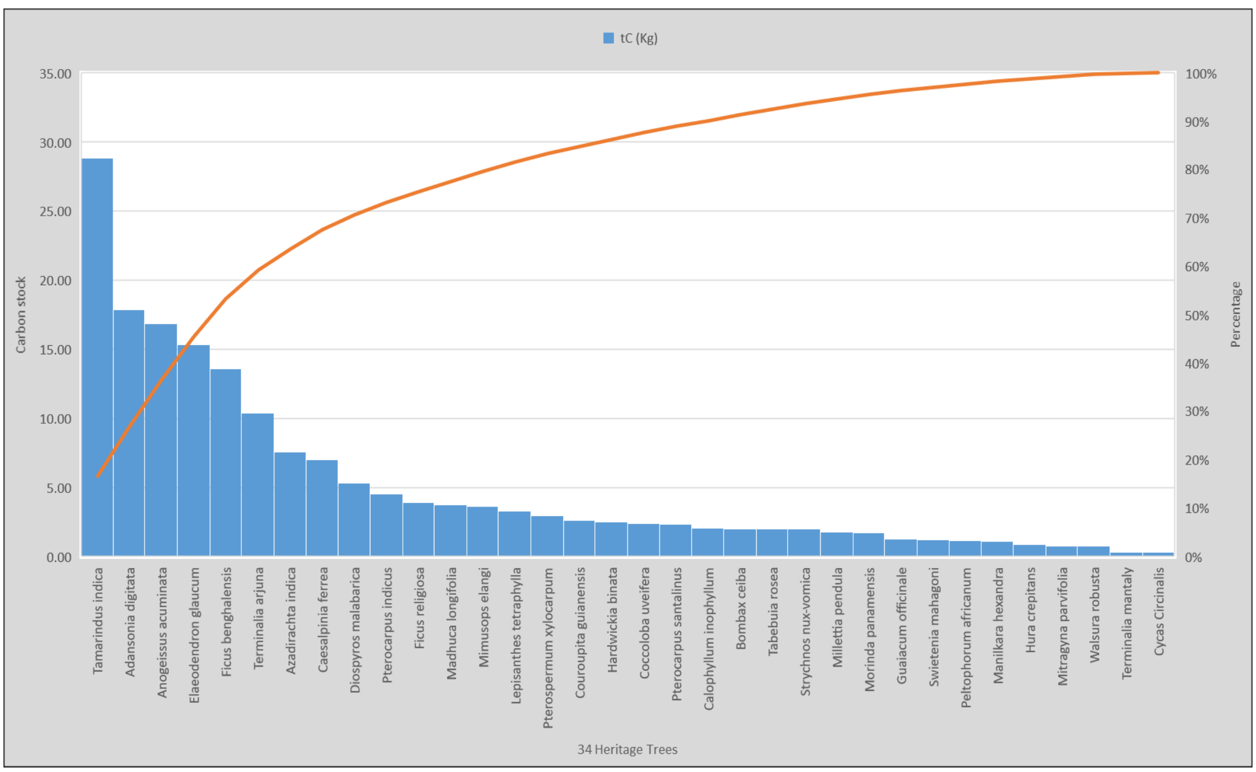

Figure 5. Carbon stock (tC) of 34 Heritage Trees, Chennai City

Trees like *CycasCircinalis*,*Terminaliamantaly*, *Walsurarobusta*, and *Huracrepitans* reported low carbon sequestration potential with 50% of carbon stock in above-ground biomass (AGB). The correlation of overall tree height with the high carbon stock potential of trees reports being positive (R^2=0.50) in *Anogeissusacuminata, Adansoniadigitata, Elaeodendronglaucum, Ficusbenghalensis, Terminaliaarjuna, Tamarindusindica* except for *Azadirachtaindica*,*Caesalpiniaferrea, Diospyrosmalabarica*. Reveals that the tree's overall Height to the carbon stock may not be similarly significant for all tree species as other tree functional traits, climatic and edaphic factors of the locality, influence carbon storage and sequestration potential.

CONCLUSION

The carbon storage and sequestration capacity of a tree species depend on its age, girth size, wood density, and growth rate are important parameters. Carbon stock computed for 34 heritage tree species shows that trees *Tamarindusindica, Adansoniadigitata, Anogeissusacuminata, Elaeodendronglaucum*,*Ficusbenghalensis, Terminaliaarjuna*,*Azadirachtaindica*,*Caesalpiniaferrea, Diospyrosmalabarica* have the maximum carbon storage and sequestration capacity.Thus, to conclude large Girth and high wood density trees plays a significant role in carbon sequestration. Hence, appropriate tree planting and maintaining them healthy from pests, vandalism in an urban environment will harness high carbon storage and sequestration, an economical way to mitigate climate change at the city level.

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