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Carbon Storage and Sequestration by Trees in and Around University Campus of Aurangabad City, Maharashtra.

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ABSTRACT: Trees assimilate the atmospheric carbon through the process of photosynthesis that stores a tremendous CO₂ from the atmosphere in the form of biomass. Therefore urban trees play potential role for the accumulation of atmospheric CO₂ in the form of biomass. The study was carried out in and around university area of Aurangabad city to know the CO₂ sequestration from selected ten tree species. Selected tree species were *Ficus benghalensis*, *Eucalyptus citriodora*, *Mangifera indica*, *Delonix regia*, *Azadirachta indica*, *Ficus racemosa*, *Embllica officinalis*, *Acacia nilotica*, *Dalbergia sissoo* and *Annona squamosa*. It is found that *Ficus benghalensis* has a great potential to store the carbon and carbon dioxide whereas *Annona squamosa* has least potential of carbon sequestration from selected tree species. Present study shows that total tree count of species from the study area was 6360, total above ground biomass is 2963.114 kg, total below ground biomass 770.412 kg, total biomass 3733.535 kg, total carbon is 1866.768 and total CO₂ sequestered 6844.131 kgs. Total CO₂ sequestered from all trees are 4161.203 tons. To protect the developing world from adverse effects of climate change and global warming, the sustainable management of urban trees with the objectives of carbon sequestration is the need of the time.

KEYWORDS: CO₂ Trees, sequestration, potential, biomass, nondestructive method

I. INTRODUCTION

Carbon is found in all living organisms and is the vital building block for the life on planet. Carbon found in various forms, mostly occur as plant biomass and organic matter in soil with as the gaseous carbon dioxide in the troposphere and in the form of dissolved water in oceans (William H., 1999). In terms of atmospheric CO₂ decrease, trees in urban areas gives the maximum advantage of direct carbon accumulation and the avoidance of carbon dioxide generation by different fossil fuel power plants by energy conservation from trees (Nowak, 1993). These trees capture CO₂ by fixing carbon during photosynthesis process and accumulating extra carbon as biomass. Plant grows through the natural process of photosynthesis, in which carbon dioxide is captured and stored in cells of plants with growth. One of the most burning issue in the modern era is the problem of change in climatic conditions and harmful role of greenhouse gases play in the changing temperatures at the international level. Anthropogenic causes of warming in the globe have become a biggest topic of concern in front of the world because of the life threatening changes that could result from increase in global heat and temperature. Even if planets average temperature increased by 2.0°C could be very harmful to environment, and some of the models which are predicting change of up to 5.0°C which is more warmer than average temperatures of history (IPCC,

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2007). The ever increasing temperatures at the global level will lead to various changes including increase in atmospheric gaseous form of water, different losses from forests and alteration in vegetation occurrence and composition, increased ocean acidification, extreme flooding, an increase in weather events, and ever altering ecosystems that will potentially alter biological diversity (King, 2005). The gas of most concern is CO₂. Although CO₂ is not a so harmful greenhouse gas, it is discharged in the very large amounts from artificial processes. Many different manmade activities of global climate change which have been recognized. These include change in land-use, deforestation, and discharge of various greenhouse gases that strengthen the greenhouse gas effect (Mannion, 1998). Some of the key sources of carbon dioxide include manufacturing of cement, iron and production of steel, various natural gas systems and most importantly municipal solid waste combustion (U.S. EPA, 2011).

II. MATERIALS AND METHODS

Location

Aurangabad District is located mainly in the Godavari river basin and partly in the Tapi river basin. The district is from 19 to 20 degrees north longitude and 74 to 76 degrees east latitude. Aurangabad city is situated on the bank of river Kham a tributary of the Godavari river. The entire city is situated at the latitude of 19°53'50" N and longitude of 75°22'46" E. It is located 512 meters above Sea Level. The city is surrounded by hills of the Vindhya ranges and the river Kham passes through it. The study area comprises of 500 hectares of area mainly B.A.M. University campus and Jaisingpura, Pahadsingpura etc. In this study, the amounts of biomass and CO₂ in standing woody biomass of selective ten tree species were calculated.

Measurement of tree height and diameter at breast height (DBH):

To estimate biomass of different trees, non-destructive method was used. The biomass of tree was estimated on the basis of DBH and tree height. DBH can be determined by measuring tree Girth at Breast Height (GBH), approximately 1.3 meter above the ground. The GBH of trees having diameter greater than 10 cm were measured directly by measuring tape (Hangarge et al., 2012). The tree height measured by theodolite instrument.

Above ground biomass (AGB) of trees:

The above ground biomass of tree includes the whole shoot, branches, leaves, flowers, and fruits. It is calculated using the following formula. (Bandana and Sanjay, 2014)

AGB kg = volume of tree (m³) x wood density Kg/m³

$$V = \pi r^2 H$$

Where V = volume of the cylindrical shaped tree in m³, r = radius of the tree in meter, H = Height of the tree in meter, Radius of the tree is calculated from GBH of tree. The wood densities were obtained from the website www.worldagroforestrycentre.org/sea/products/AFDbases/WD. Height is measured with the help of the instrument Theodolite. Wood density is used from Global wood density database. The standard average density of 0.6 gm / cm is applied wherever the density value is not available for tree species.

Estimation of Below Ground Biomass (BGB)

The Below Ground Biomass (BGB) includes all biomass of live roots excluding fine roots having < 2 mm diameter. The BGB has been calculated by multiplying AGB by 0.26 factors as the root: shoot ratio. BGB is calculated by following formula (MacDicken, K.G. 1997, Hangarge et al., 2012)

$$BGB \text{ (Kg/tree)} = AGB \text{ (Kg/tree)} \text{ or } (\text{ton/tree}) \times 0.26$$

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Table 1: Wood densities of tree species

Sr. No.	Tree Species (Scientific Name)	Local name	Wood density in g/cm ³
1	<i>Ficus benghalensis</i>	Wad	0.4902
2	<i>Eucalyptus citriodora</i>	Nilgiri	0.8297
3	<i>Mangifera indica</i>	Mango	0.5977
4	<i>Delonix regia</i>	Gulmohar	0.6
5	<i>Azadirachta indica</i>	Neem	0.7275
6	<i>Ficus racemosa</i>	Umbar	0.3758
7	<i>Embllica officinalis</i>	Awala	0.7288
8	<i>Acacia nilotica</i>	Black babul	0.7629
9	<i>Delbergia sissoo</i>	Shisam	0.6934
10	<i>Annonasquamosa</i>	Sitaphal	0.6135

Estimation of total biomass

Total Biomass is the sum of the above and below ground biomass. (Sheikh et al., 2011).

Total Biomass (TB) = Above ground biomass + Below ground biomass (kg/tree)

Estimation of Carbon

Generally, for any plant species 50% of its biomass is considered as carbon (Pearson et al., 2005) i.e., Carbon Storage = Biomass x 50% or Biomass/2 (kg/tree).

Determination of the weight of carbon dioxide (CO₂) sequestered in the tree

CO₂ is composed of one molecule of carbon and 2 molecules of oxygen. The atomic weight of carbon is 12.001115, the atomic weight of oxygen is 15.9994, the weight of CO₂ is C+2*O=43.999915, The ratio of CO₂ to C is 43.999915/12.001115=3.6663. Therefore, to determine the weight of carbon dioxide sequestered in the tree, multiply the weight of carbon in the tree by 3.6663.

III. RESULTS AND DISCUSSION

The tree can survive in the urban environment polluted with traffic-related contaminants (Raju et al., 1995) and it may be one of the important green region in urban and industrial sectors. Carbon capture rates vary by species, soil, climate, topography and most important is management practice (EPA, 2010). Most of the researchers revealed that above ground biomass is more strongly correlated with DBH (Clark et al., 2001). Also, it is accepted by many experts in this field that simple models with only diameters as input is one of the good estimator of AGB (Djomoa et al., 2010). Scientific proofs suggests that enhanced atmospheric carbon dioxide could have some good effects like improvement in plant productivity (Keutgen and Chen, 2001). The study was conducted in the Aurangabad city to estimate the carbon sequestration in the ten selected tree species based on estimation of carbon and carbon dioxide. According to descending order of CO₂ sequestering potential of individual trees have been discussed below.

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Ficus benghalensis has sequestered 1333.44 kg/tree of CO₂ which is highest compared to other tree species from the study area. It is due to highest DBH of tree i.e. 0.4268 meters. At the same time volume, AGB, BGB, total biomass, carbon is also highest in the *Ficus benghalensis*.

Total tree count is 195 and total CO₂ sequestered 260.021 tonnes. *Eucalyptus citriodora* has the highest height i.e. 13.142 meters compared to other tree species but DBH has only 0.257 meters. This is second highest tree species in terms of CO₂ sequestered per tree i.e. 1307.961 kg.

Mangifera indica sequestered 1805.271 tonnes of CO₂ which is highest and second highest in average DBH compared to other tree species. Due to high DBH and highest number of trees *Mangifera indica* sequestered maximum CO₂. *Azadirachta indica* is the second highest species which sequestered 584.281 tonnes of CO₂ followed by *Mangifera indica* and having 763 individual trees. *Ficus racemosa* has only 12 tree individuals and sequestered very low amount of CO₂ i.e. 4.037 tonnes. *Annona squamosa* has only 0.159 meters DBH which is lowest but shows 1462 tree individual species which is second highest followed by *Mangifera indica*. Therefore present study shows that total tree count of selected species from the study area were 6360. Total above ground biomass is 2963.114 kg, total below ground biomass 770.412 kg, total biomass 3733.535 kg, total biomass is 1866.768 and total CO₂ sequestered 6844.131 kgs. Total CO₂ sequestered from the study area is 4161.203 tons. The maximum biomass storage in *Dalbergiasissoo species* might be due to its maximum energy conversion potential, photosynthetic rate (Srivastava and Ram 2009) and maximum number of nodules generation in the roots as compared to the other species (Kimothi et al., 1983). Similar results were also obtained by Kok et al., (1973) and Kok et al., (1976). A research study shown that lowest and highest values of CO₂ assimilated from the atmosphere were 0.019 tonnes (with 4 cm DBH and 2 metre height) and 4.041 tonnes (with 50 cm dbh and 25 metre height) per tree respectively. Trees of urban area are transplanted from the nurseries and managed for the aesthetic value, when cutting eliminates accumulated carbon. Openly grown trees typically are smaller but often have biggest crowns with more branches than woodland grown trees. Assessment of carbon accumulations and stock alterations in tree biomass which are relevant to deal with UNFCC and report of Kyoto Protocol (Gill et al., 2007).

Several studies have found that growing trees to capture carbon could provide moderately low-cost net discharge reductions for a many countries. In relation to C capture, results have shown that species choice can make a very large difference in the services as well as in the future storages of carbon in the living biomass with that the substitution of present exotic plantations by plantations of local species in this region has the greatest efficiency for increasing carbon capture.

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Table 2: Total carbon and CO₂ sequestered by trees.

Sr. No.	Tree Species (Scientific Name)	Common name	Avg DBH in meter	Avg Height in meter	Volume (m ³)	Above ground biomass (kg/tree)	Below ground biomass (kg/tree)	Total biomass (kg/tree)	Carbon (kg/tree)	CO ₂ sequesterd (kg/tree)	Tree count	CO ₂ sequesterd of all trees in tonnes
1	<i>Ficus benghalensis</i>	Wad	0.42	8.23	1.17	577.30	150.09	727.40	363.70	1333.44	195	260.021
2	<i>Eucalyptus citriodora</i>	Nilgiri	0.25	13.14	0.68	566.27	147.23	713.50	356.75	1307.96	278	363.613
3	<i>Mangifera indica</i>	Mango	0.34	7.53	0.68	409.63	106.50	516.13	258.06	946.15	1908	1805.271
4	<i>Delonix regia</i>	Gulmohar	0.32	7.96	0.65	390.24	101.46	491.70	245.85	901.37	322	290.243
5	<i>Azadirachta indica</i>	Neem	0.25	9.15	0.45	331.53	86.19	417.73	208.86	765.76	763	584.281
6	<i>Ficus racemosa</i>	Umbar	0.24	7.91	0.38	145.65	37.87	183.52	91.763	336.43	12	4.037
7	<i>Emblica officinalis</i>	Awala	0.24	5.83	0.27	203.95	53.027	256.98	128.49	471.08	1130	532.327
8	<i>Acacia nilotica</i>	Black babul	0.18	7.84	0.20	159.07	41.35	200.43	100.21	367.42	55	20.208
9	<i>Dalbergia sissoo</i>	Shisam	0.18	5.785	0.15	107.53	27.96	135.49	67.74	248.39	235	58.3720
10	<i>Annona squamosa</i>	Sitaphal	0.15	5.87	0.11	71.90	18.69	90.60	45.30	166.09	1462	242.828



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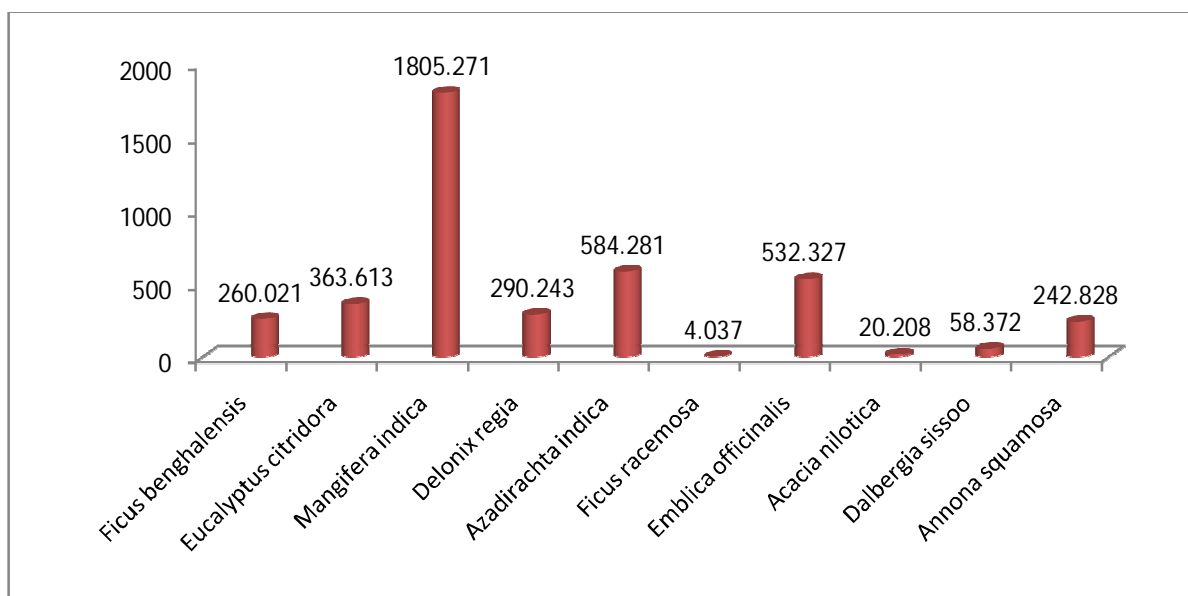
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Large healthy trees more than 77 cm in diameter capture approximately 90 times more carbon as compared to small healthy trees which have diameter less than 8 cm (Nowak, 1994). Large trees also preserve approximately 1000 times maximum carbon than smaller trees (Nowak, 1994). More research work is required on the overall effects of trees, soils and its proper management in the urban areas (e.g., Pataki et al., 2006). Carbon storage by tree species in woodlands at national level was 20.2 billion tonnes in 2008 (Heath et al., 2011).



Graph Showing Carbon dioxide captured by trees (in Tonnes)

As urban areas discharge large amount of emissions of carbon, tree creates an impact carbon emissions through changing in climates at micro level, albedo, use of energy, and maintenance of emissions require to be added with tree storage and capture estimates to improve a more complete evaluation of the role of trees of urban area on climate change (Nowak et al., 2013).

IV. REGRESSION ANALYSIS

To estimate the closeness and relationships various parameters a regression analysis was performed with the help of SPSS 16.0 software.

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Tables 3: - Regression of DBH, Height and Volume of tree species

Model Summary

Model	R (correlation coefficient)	R Square	Adjusted R Square	Std. Error of the Estimate
1	.980 ^a	.960	.949	.0184293

a. Predictors: (Constant), Volume, Height

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t (statistics)	Significant.
		B (regression coefficient)	Std. Error	Beta		
1	(Constant)	.212	.023		9.096	.000
	Height	-.010	.003	-.267	-3.122	.017
	Volume	.270	.021	1.080	12.609	.000

a. Dependent Variable: DBH
Where,

R= Multiple correlation coefficient; R² and adjusted R² = Coefficient determination of variables
B= Regression coefficient; t = Statistics

Above table shows that shows strong correlation coefficient between the DBH with volume and height whereas adjusted R² shows 94% variability between DBH with height and volume. From above table regression equation can be written as follows.

$$DBH = 0.212 - 0.010 * \text{height} + 0.270 * \text{volume}$$

The relationship between DBH and height with volume is nearly linear in all major tree species. In other words maximum DBH have highest carbon stock. The regression models developed for the prediction of carbon and carbon dioxide from the trees to avoid the requirement of destructive sampling frequency. In this range maximum tree species have linear relationships in terms of DBH and carbon availability. Above table shows that volume is significant with DBH. As increase in DBH its metabolic and growth necessities would also increase. (Jaiswal et al., 2014)

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V. CONCLUSION

Urban forests can play a significant role in helping to reduce atmospheric carbon dioxide levels. The carbon stock determined for *Ficus benghalensis*, *Eucalyptus citriodora*, *Mangifera indica*, *Delonix regia*, *Azadirachta indica*, *Ficus racemosa*, *Embllica officinalis*, *Acacia nilotica*, *Dalbergia sissoo* and *Annona squamosa* species in and around university campus of Aurangabad city which shows that *Ficus benghalensis* has the better carbon sequestration potential. While on the basis of the girth class, the capacity to absorb carbon is the highest in the girth class more than average diameter 11 inches i.e. of *Azadirachta indica* and *Mangifera indica* compared to less average diameters of other species. On the basis of this study calculation of carbon sequestration was done by non-destructive method where theodolite instrument was used for measurement. Wood densities were obtained from World Agroforestry Centre for the measurement of above ground biomass. To protect the world from climate change and global warming, the sustainable management of trees from urban areas with the objectives of carbon sequestration is the need of the time. Before applying the approach of sustainable urban tree management it will be helpful to quantify of organic carbon and organic carbon sequestration potential by nondestructive method.

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