ASSESSMENT OF BENEFITS OF BIODIVERSITY CONSERVATION AND CLIMATE MITIGATION FROM URBAN TREE PLANTING

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Thesis submitted to

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In partial fulfilment of the requirements

for the award degree of

MASTER OF SCIENCE (Agriculture)

in

ENVIRONMENTAL SCIENCES

BENGALURU **JANUARY, 2018**

Affectionately dedicated to

My Parents

Sri. Rangaswamy H C

Smt. Vijayalakshmi M K

& My Brother

Niranjan R V

DEPARTMENT OF FORESTRY AND ENVIRONMENTAL SCIENCES
UNIVERSITY OF AGRICULTURAL SCIENCES
BENGALURU – 65

CERTIFICATE

This is to certify that the thesis entitled **"ASSESSMENT OF BENEFITS OF BIODIVERSITY CONSERVATION AND CLIMATE MITIGATION FROM URBAN TREE PLANTING"** submitted in partial fulfilments of the requirement for the degree of **MASTER OF SCIENCE (Agriculture)** in **ENVIRONMENTAL SCIENCE** of the University of Agriculture Sciences, Bengaluru is a bonafide record of research work carried out by **Mr. LOHITH, R. V. ID No. PALB 5214** during the period of his study in the University under my guidance and supervision, no part of the thesis has been submitted for the award of any degree, diploma, associate ship, fellowship or other similar titles.

Bengaluru,
January, 2018

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Bengaluru
January, 2018 **Lohith. R. V.**

ASSESSMENT OF BENEFITS OF BIODIVERSITY CONSERVATION AND CLIMATE MITIGATION FROM URBAN TREE PLANTING

LOHITH R V

THESIS ABSTRACT

Urban trees provide many useful functions such as climate stabilization through carbon sequestration, air quality improvement, biodiversity conservation. They also have aesthetic, socio-religious and recreational value in urban context. In spite of these benefits trees have not received much attention. This study investigates the diversity, density, carbon sequestration and other benefits by tree species grow along the road-side, parks and around the lake in Ward no. 4 Yelahanka of Bengaluru, Karnataka. The total area of this ward is 4.9 km^2. In the present study 46 tree species belonging to 25 families with 7854 trees were found. Species richness is found to be higher in park followed by avenue trees. *Pongamia pinnata* is most dominant tree species. Total carbon content accumulated by the trees is 3144 tons and total CO_2 sequestered is 11538 tons and 2.51 tons of oxygen is added to the air from trees present in all the three landscapes. *Ficus benghalensis, Ficus religiosa* and *Enterlobium saman* were found to accumulate highest biomass, basal area and canopy size. A total area of 0.82 Km^2 is area covered by the tree leaf canopy, which accounts for 16.7 Per cent of the total area. Out of these 46 species *Michelia champaca, Santalum album* were found which are considered to be vulnerable and *Saraca asoca* is also found which is considered to be endangered in Karnataka region according to IUCN red list of tree species. Thus growing trees in urban areas help in conserving biodiversity and help in providing healthy atmosphere.

January-2018

Department of Forestry and Environmental science

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Dr. A. S. Devakumar

(Major Advisor)

ನಗರ ಪ್ರದೇಶಗಳಲ್ಲಿ ಬೆಳೆಯುತ್ತಿರುವ ಮರಗಳಿಂದ ಜೀವವೈವಿಧ್ಯ ಸಂರಕ್ಷಣೆ ಮತು ಹವಮಾನ ಮಿತಿಗೊಳಿಸುವಿಕೆಯ ಪ್ರಯೋಜನಗಳ ನಿರ್ಧರಿಸುವಿಕೆ

ಲೋಹಿತ್. ಆರ್. ವಿ

ಪ್ರಬಂಧ ಸಾರಾಂಶ

ನಗರ ಪ್ರದೇಶದ ಮರಗಳು ಇಂಗಾಲದ ಅನುಕ್ರಮಣಿಕೆ, ವಾಯು ಗುಣಮಟ್ಟದ ಸುಧಾರಣೆ ಜೀವವೈವಿಧ್ಯ ಸಂರಕ್ಷಣೆಯ ಮೂಲಕ ಹವಮಾನ ಸ್ಥಿರೀಕರಣದಂತಹ ಅನೇಕ ಉಪಯುಕ್ತ ಕಾರ್ಯಗಳನ್ನು ಒದಗಿಸುತ್ತದೆ ಹಾಗೂ ಈ ಮರಗಳು ಪ್ರಕೃತಿ ಸೌಂದರ್ಯ, ಸಾಮಾಜಿಕ-ಧಾರ್ಮಿಕ ಮತ್ತು ಮನರಂಜನಾ ಮೌಲ್ಯವನ್ನು ಕೂಡಾ ಹೊಂದಿರುತ್ತದೆ. ಈ ಅನೇಕ ಪ್ರಯೋಜನೆಗಳ ಹೊರತಾಗಿಯೂ ನಗರ ಪ್ರದೇಶದಲ್ಲಿ ಮರಗಳನ್ನು ಬೆಳೆಸುವ ಕಾರ್ಯ ಹೆಚ್ಚು ಗಮನ ಸೆಳೆದಿಲ್ಲ ಈ ನಿಟ್ಟಿನಲ್ಲಿ ಪ್ರಸ್ತುತ ಅಧ್ಯಯನವನ್ನು ನಡದಸಿದ್ದು ಇದರಲ್ಲಿ ಮರಗಳ ವೈವಿಧ್ಯತೆ, ಸಾಂದ್ರತೆ, ಇಂಗಾಲದ ಅನುಕ್ರಮಣಿಕೆ ಹಾಗೂ ಇತರ ಪ್ರಯೋಜನೆಗಳನ್ನು ಸಮೀಕ್ಷಿಸಲಾಗಿದೆ. ರಸ್ತೆಬದಿ, ಉದ್ಯಾನಗಳಲ್ಲಿ ಮತ್ತು ಸರೋವರದ ಸುತ್ತಲೂ ಬೆಳೆದಿರುವ ವಿವಿಧ ಜಾತಿಯ ಮರಗಳ ಕುರಿತು ತನಿಖೆಯನ್ನು, ಬೆಂಗಳೂರು ಜಿಲ್ಲೆಯ ಯಲಹಂಕ ವಾರ್ಡ ನಂ. ೪ ರಲ್ಲಿ ನೆಡೆಸಲಾಗಿದೆ. ಈ ವಾರ್ಡಿನ ಒಟ್ಟು ವಿಸ್ತೀರ್ಣವು ೪.೯ ಚದುರ ಕಿ.ಮೀ. ಪ್ರಸ್ತುತ ಅಧ್ಯಯನದಲ್ಲಿ ಒಟ್ಟು ೪೬ ಜಾತಿಯ ೭೮೫೪ ಮರಗಳಿದ್ದು, ಇವು ೨೫ ಕುಟುಂಬಗಳಿಗೆ ಸೇರಿರುತ್ತವೆ. ಜಾತಿಗಳ ಶ್ರೀಮಂತಿಕೆ ಉದ್ಯಾನಗಳಲ್ಲಿ ಹೆಚ್ಚಾಗಿದ್ದು ರಸ್ತೆಬದಿಯಲ್ಲಿ ಉದ್ಯಾನಕ್ಕಿಂತ ಕಡಿಮೆ ಕಂಡುಬಂದಿದೆ. ಹೊಂಗೆ ಮರವು ಅತ್ಯಂತ ಪ್ರಬಲವಾಗಿ ಕಂಡುಬಂದಿದೆ. ಮರಗಳು ಸಂಗ್ರಹಿಸಿದ ಒಟ್ಟು ಇಂಗಾಲದ ಅಂಶವು ೩೧೪೪ ಟನ್ ಮತ್ತು ಇಂಗಾಲದ ಡೈಆಕ್ಸೈಡ್ ೧೧೫೩.೮ ಟನ್ ಆಗಿದ್ದು, ೨.೫೧ ಟನ್ ಗಳಷ್ಟು ಆಮ್ಲಜನಕ ಗಾಳಿಗೆ ಬಿಡಗಡೆಯಾಗುತ್ತಿದೆ. ಮರದ ವಿವಿಧ ತಳಿಗಳ ಪೈಕಿ ಆಲದ ಮರ, ಅರಳಿ ಮರ ಮತ್ತು ಮಳೆ ಮರಗಳು ಅತ್ಯಧಿಕ ಜೀವರಾಶಿ, ತಳದ ಪ್ರದೇಶ ಮತ್ತು ಮೇಲಾವರಣ ಗಾತ್ರವನ್ನು ಹೊಂದಿರುತ್ತದೆ. ಒಟ್ಟು ೦.೮೨ ಚದುರ ಕಿ.ಮೀ. ವಿಸ್ತೀರ್ಣವು ಮರದ ಎಲೆಯ ಮೇಲಾವರಣದಿಂದ ಆವೃತವಾಗಿರುವ ಪ್ರದೇಶವಾಗಿದೆ ಎಂದು ಅಧ್ಯಯನವು ಸೂಚಿಸುತ್ತದೆ. ಒಟ್ಟು ೧೬.೭ ರಷ್ಟು ಪ್ರದೇಶ ಇದರ ಭಾಗವಾಗಿದೆ. ಈ ೪೬ ಜಾತಿಯ ಮರಗಳಲ್ಲಿ ಐ.ಯು.ಸಿ.ಎನ್. ಕೆಂಪು ಪಟ್ಟಿಯ ಪ್ರಕಾರ ಕರ್ನಾಟಕದ ಪ್ರದೇಶದಲ್ಲಿ ಸಂಪಿಗೆ ಮತ್ತು ಗಂಧದ ಮರಗಳನ್ನು ದುರ್ಬಲ ಎಂದು ಪರಿಗಣಿಸಲಾಗಿದೆ ಮತ್ತು ಅಶೋಕ ಮರವನ್ನು ಅಪಾಯದಲ್ಲಿದೆ ಎಂದು ಪರಿಗಣಿಸಲಾಗಿದೆ. ಹೀಗಾಗಿ ನಗರ ಪ್ರದೇಶಗಳಲ್ಲಿ ಬೆಳೆಯುತ್ತಿರುವ ಮರಗಳಿಂದ ಜೀವವೈವಿಧ್ಯತೆಯನ್ನು ಸಂರಕ್ಷಿಸುವಲ್ಲಿಯೂ ಸಹಾಯವಾಗುತ್ತದೆ ಮತ್ತು ಆರೋಗ್ಯಕರ ವಾತವರಣವನ್ನು ಒದಗಿಸುವಲ್ಲಿ ಸಹಾಕಾರಿಯಾಗಿದೆ.

ಜನವರಿ ೨೦೧೮
ಅರಣ್ಯಶಾಸ್ತ್ರ ಮತ್ತು ಪರಿಸರ ವಿಜ್ಞಾನ ವಿಭಾಗ
ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾನಿಲಯ, ಜಿ.ಕೆ.ವಿ.ಕೆ, ಬೆಂಗಳೂರು

ಡಾ॥ ಎ ಎಸ್ ದೇವಕುಮಾರ್
ಪ್ರಧಾನ ಸಲಹೆಗಾರರು

Biodiversity conservation and carbon sequestration from trees in urban landscapes

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Introduction

- India is considered to be one of the fast growing economies in the world. Economic progress of the country has seen a wide range of developmental activities especially across the major cities in India. However this has lead to large scale urbanization resulting in considerable reduction of green cover. Such land scape changes can have serious implication on local environment and human health in the long run.
- Global climate change is predicted to have serious implication especially in tropical countries. In the urban areas built up areas replace the vegetation cover, increase the vehicular number and movement.
- All these activities are likely to increase the release of pollutants and green house gases leading to change in air quality and atmospheric temperature.
- The trees act as major CO_2 sink which reduce carbon from the atmosphere and also help in trapping pollutants and particulate matter.
- Therefore deliberately growing trees in urban areas can contribute not only towards reducing atmospheric CO_2 concentration but also help in conserving biological biodiversity and aesthetic qualities.
- Trees with large evergreen canopies and thick cuticle and plumose structures help in accumulation of particulate pollutants.
- In this background current study is conducted in part of Bangalore, which is one of the fastest growing cities in the world with the following objectives.

Objectives

1. To assess the biodiversity existing in different urban landscapes.
2. To assess the carbon stock in the standing tree in different urban landscapes.

Materials and Methods

- **Study site:** Study was conducted in parts of Ward 4, Yelahanka New town, Bangalore, Karnataka. The tree planted on road side, in the parks and around the Allasandra Lake were considered as three land use systems.
- **Tree diversity:** Tree species planted in this area will be identified to species level as per taxonomic classification and diversity in the tree species present in the road side; parks and water bodies will be assessed.
- **Carbon sequestration assessment:** This will be assessed by deriving the standing tree biomass by measuring girth, height and carbon content of the trees.
- **Measurement of girth of the tree:** The girth of the tree is measured using measuring tape graduated to measure a minimum of 1 mm.(Plate -1)
- **Measurement of height of the tree:** The height of tree is measured with the help of Blume Leiss altimeter. (Plate-2)
- **Calculation of volume of the tree(m^3)** = $\pi r^2 h$
- **Estimation of biomass from the volume and density (Kg) =** volume × wood density of the species.
- **Carbon content of the biomass (Kg) =** Standing Biomass × 0.45.
- **Calculation of Alpha Diversity index:** Shannon Diversity index(H) = $- \sum (P_i * \ln P_i)$
- **Calculation of Beta Diversity Index:** Jaccard Diversity Index(C_j)=j/(a+b-j)

Results

Table 1-List of tree Species, Number of Individuals in Avenue, Parks and lake

Sl.No.	Name of the species	Number of Individuals			Total
		Avenue	Parks	Lakes	
1	*Albizia lebbeck*	9	9	0	18
2	*Alstonia scholaris*	51	47	0	98
3	*Anthocephalus cadamba*	71	100	0	171
4	*Araucaria columnaris*	9	22	0	31
5	*Artocarpus heterophyllus*	26	15	5	46
6	*Azadirachta indica*	132	119	0	251
7	*Bauhinia purpurea*	439	198	4	641
8	*Bixa ornella*	12	29	0	41
9	*Callistemon lanceolatus*	12	30	0	42
10	*Cassia spectabilis*	25	96	3	124
11	*Coccos nucifera*	182	63	6	251
12	*Couroupita guianensis*	52	119	0	171
13	*Dalbergia sissoo*	28	61	0	89
14	*Delonix regia*	29	118	0	147
15	*Dolichandrone platycalyx*	309	185	0	494
16	*Eucalyptus globulus*	13	0	15	28
17	*Ficus benghalensis*	2	2	1	5
18	*Ficus racemosa*	11	28	7	46
19	*Ficus religiosa*	5	7	2	14
20	*Grevillea robusta*	31	71	0	102
21	*Hyophorbe lagenicaulis*	0	0	115	115
22	*Jacaranda mimosifolia*	47	81	0	128
23	*Kigelia pinnata*	9	28	2	39
24	*Lagerstroemia flosreginae*	163	169	0	332
25	*Mangifera indica*	44	48	0	92
26	*Michelia champaca*	177	139	5	321
27	*Millingtonia hortensis*	29	63	0	92
28	*Muntingia calabura*	107	114	3	224
29	*Peltophorum pterocarpum*	248	135	3	386
30	*Phyllanthus emblica*	13	24	0	37
31	*Plumeria alba*	12	28	48	88
32	*Polyalthia longifolia*	54	56	0	110
33	*Pongamia pinnata*	745	430	122	1297
34	*Enterolobium saman*	68	55	0	123
35	*Santalum album*	0	6	0	6
36	*Saraca asoca*	20	32	0	52
37	*Schefflera actinophylla*	0	22	0	22
38	*Spathodea companulata*	172	139	0	311
39	*Swietenia mahagoni*	326	110	3	439
40	*Syzygium cumini*	45	58	6	109
41	*Tabebuia argentea*	27	42	0	69
42	*Tabebuia avellanedae*	226	77	2	305
43	*Tabebuia rosea*	9	34	0	43
44	*Tamarindus indica*	4	0	0	4
45	*Terminalia catappa*	81	41	6	128
46	*Thespesia populnea*	87	85	0	172
	Total	4161	3335	358	7854

Table 2 - Shannon Weiner Alpha Diversity index

Sl No.	Land use system	Alpha Diversity Index
1	Avenue Trees	3.03
2	Parks	3.41
3	Lake	1.84

Table 3. Jaccard Beta Diversity index

Sl No.	Land use system	Avenue Trees	Parks	Lake
1	Avenue Trees	******	*****	*****
2	Parks	0.911	*****	*****
3	Lake	0.409	0.377	*****

Table 4- carbon stocks in the above ground biomass of Standing tree.

Sl. No	Land use system	Tons of Cabon
1	Avenue Trees	1703
2	Parks	1414
3	Lake	27
	Total	3144

Plate-1

Plate-2

Discussion

- There are 46 tree species found in the study area belonging to 25 different families. The total number of trees found in the study area was 7854 of which 4161 were found as road side planting, 3335 were planted in 14 parks and 358 trees were found all along the Allasandra lake.
- From the alpha diversity Index it is observed that the diversity of trees on the road side as well as parks there was no much different, while the diversity of the trees on lake bund was less. This mainly because of the number of trees in these three land use systems. It is also because of the purpose with which the trees are planted in these locations. The trees planted on road side is done mainly with the intention of providing shade and to absorb the pollutants. While trees planted in the parks and on the lake bunds are of aesthetic importance. The diversity values were 3.03, 3.41 and 1.84 for road side planting, parks and lake respectively (Table 2).
- Beta Diversity Index was calculated comparing each landscapes by Jaccard Diversity Index method. The index value between avenue and parks is 0.911, avenue and lake is 0.409, park and lake is 0.377 (Table 3). This indicate the uniqueness of the tree species in the three land use systems studied.
- The total carbon stock was estimated from the biomass of standing tree in three land use systems (Table 4). The total carbon accumulated in the biomass of avenue trees is 1703 tons, parks is 1414 tons and lake is 27 tons. From this a total of 11,538 tons of CO_2 from the atmosphere has been sequestered in to trees.

Summary

One of the important issues under the rapid rate of urbanization is pollution of the atmosphere that has severely affected human health and also cause loss of biodiversity. Trees grown in the urban area has helped in removing 11,538 tons of CO_2 and other pollutants released from the vehicular emissions. From this study it is found that forty five different tree species belonging to 25 different families have been used. Growing trees have not only helped in providing clean atmosphere but also help in conserving the tree diversity which is an important concern under the current climate scenario.

Advisory Committee

1) Dr. A.S. Devakumar (Chairperson)
2) Dr. K.T. Prasanna (Member)
3) Dr. Nagaraju (Member)
4) Dr. C.T. Subbarayappa (Member)

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I. INTRODUCTION

India is considered to be one of the fast growing economies in the world. Economic progress of the country has seen a wide range of developmental activities especially centered towards the cities in most part of the world and so also in India. This has led to large scale urbanization leading to considerable reduction of green cover due to reduction of agricultural land and forest cover. Such land scape changes can have serious implication on the local environment and human health in the long run. These land use changes are clearly shown to create imbalances in the natural ecosystem and contribute for global climate change (Prentice *et al.* 2001). Further global climate change is predicted to have serious implications especially in tropical countries in terms of uncertainties of rainfall and other natural perturbations that severely influence food security as well as health.

Deteriorating quality of urban ecosystems is a major concern of urban planners and managers. Environmental problems such as air and water stress and pollution are more rampant in urban areas which currently account for 78 per cent of global carbon emissions, 60 per cent of water going for domestic use (Shivanand *et al.* 2010). It is therefore essential to take steps to redesign the urban ecosystems to address these environmental problems and to sustain clean air, water and other ecosystem services needed for healthy urban living. In the urbanization process built up areas replace the vegetation cover and also increase in vehicle movement. These activities are likely to increase the release of pollutants and greenhouse gases resulting in increased atmospheric temperature, decreased air quality and increased levels of stress for trees (Saini, 2017). Trees act as major CO_2 sink which captures carbon from the atmosphere and stores the same in the form of biomass in the growth process while releasing oxygen to the air through photosynthesis (Watson *et al.* 2000). Conservation and restoration of urban green spaces comprising of “urban trees” is therefore an important approach to improve the environmental quality of urban areas.

The term ‘urban trees’ refers to trees, both within the built environment and in the avenues and other public places. They play a very significant role in the urban environment and provide many important ecosystem services to urban inhabitants, such as climate change mitigation by carbon sequestration, air quality improvement by air pollution abatement, oxygen generation, noise reduction, mitigation of urban heat-island effects, microclimate regulation, stabilization of soil, ground water recharge, prevention of soil erosion and biodiversity conservation. They also have aesthetic, socio-religious and recreational values.

In nature, forest ecosystem act as a reservoir of carbon. They store substantial amount of carbon and regulate the carbon cycle by absorbing CO_2 from the atmosphere. Forest ecosystem is one of the most important carbon sinks of the terrestrial ecosystem that plays an important role in the global carbon cycle by sequestering carbon dioxide from the atmosphere (Vashum and Jay Kumar, 2012; Chavan and Rasal, 2012; Gorte, 2009; IPCC, 2003, Chavan and Rasal, 2010). In the global carbon cycle biomass is an important building block, and is useful in quantifying pools and changes of Green House Gases from the terrestrial biosphere to the atmosphere associated with land-use and land cover changes (Cairns *et al.* 2003). The efficiency of trees to sequester carbon depends on both carbon assimilation capacity of the individual species and also the favorable growing conditions in which the tees would grow. Considering the stress the trees would experience under urban environment (Saini, 2017), it is important to choose species that have ability to perform under higher levels of moisture stress.

Biodiversity influences climate at local, regional and global levels, yet most climate models do not take biodiversity into consideration because its variables and effects are too diverse and complex to compute. The loss of biodiversity is of critical concern. Increasing amount of research indicates that diversity plays an important role in long-term ecosystem functioning (Savard *et al.* 2000). Many factors are contributing to biodiversity loss including habitat modification through urbanization, competition from introduced species, human demand for certain species and products, and rapid environmental changes such as climactic fluctuations (Groombridge and Jenkins, 2002). In order to sustain the biodiversity and its environmental benefits it is important to increase the vegetation cover under all possible landscapes and more specifically in urban landscapes.

Tree canopy is the upper portion of the trees with actively photosynthesizing leaves. Each species of tree has its own unique shape, size, and color, but all of them contribute to the overall tree canopy–benefiting wildlife and people, alike. Some of the benefits that trees and their canopy provide to humans include, producing oxygen, clean drinking water, moderating atmosphere temperature and microclimate, trapping pollutants and purifying the air in particular. Particulate pollutants are captured on surfaces of the leaves and bark and retaining them, thereby reducing it in the air. A large, healthy tree and its canopy removes almost 70 times more air pollutants each year than a small or newly-planted tree with a smaller canopy (Dwyer *et al.* 2000). The urban forest, which includes vegetation along urban streets and in urban parks, woodlots, abandoned sites, and residential areas, contribute significant percentage of nation's tree canopy. In the contiguous USA, trees in urban counties account for nearly 25 per cent of the nation's total tree canopy cover (Dwyer *et al.* 2000).

The variation of dust deposition in different plants is possible due to different morphological characters such as phyllotaxy, leaf shape, plant height, leaf texture, presence or absence of hairs, etc. Stomatal frequencies are also related to the efficiency of dust collecting capacity of plants (Das and Pattanayak, 1977) on upper and lower surfaces of the leaf.

In this background present study is an attempt to assess the diversity of tree species among the different landscapes in the urban areas and their contribution towards ameliorating the urban environment with the following objectives.

1. To assess the biodiversity existing in different urban landscapes.
2. To assess the carbon stock in the standing tree in different urban landscapes.
3. To assess the climate amelioration from the vegetation in the urban landscapes.

II. REVIEW OF LITERATURE

In the present study assessment of tree diversity, carbon stock and climate mitigation from the tree species have been studied. The literature relevant to identification of trees, species richness, evenness and similarity between the ecosystems, tree carbon stock, oxygen release to atmosphere, Canopy cover, leaf area and wax content of leaf to the trap pollutants have been reviewed and presented in this chapter.

2.1 Biodiversity in urban landscapes

The urban forest, which includes vegetation along urban streets and in urban parks, woodlots, abandoned sites, and residential areas, can comprise a significant percentage of a nation's tree canopy. In the contiguous United States, trees in urban counties account for nearly 25 per cent of the nation's total tree canopy cover (Dwyer *et al.* 2000).

Rapid loss of biodiversity is a global phenomenon. It is estimated that possibly half or more of all current species could be at risk of extinction in the foreseeable future (Myers, 1996; Sax and Gaines, 2003).

Nowak *et al.* (1996) reported that measurement of city tree cover can aid in urban vegetation planning, management, and research by revealing characteristics of vegetation across a city. Two important factors that affect the amount of urban tree cover are the natural environment and land use. Urban tree cover is highest in cities that developed in naturally forested areas (31 per cent), followed by grassland cities (19 per cent) and desert cities (10 per cent), but showed wide variation based on individual city characteristics. Tree cover ranged from 15 to 55 per cent for cities in forested areas, 5 to 39 per cent for those in grassland areas, and 0.4 to 26 per cent for cities developed in desert regions. Park and residential lands along with vacant lands in forested areas generally have the highest tree cover among different land uses.

Savard *et al.* (2000) reported that the association of biodiversity and urban ecosystems has usually concerned the impact of urbanization on biodiversity. However, biodiversity concepts can easily be applied to the urban ecosystem itself. As more and more people live in cities, restoration, preservation and enhancement of biodiversity in urban areas become important. Concepts related to biodiversity management such as scale, hierarchy, species identity, species values, and fragmentation, global approaches can be used to manage urban biodiversity. Application of these concepts in such artificial ecosystems may yield important insights for the management of natural ecosystems. Enhancement of biodiversity in urban ecosystems can have a positive impact on the quality of life and education of urban dwellers and thus facilitate the preservation of biodiversity in natural ecosystems.

The loss of biodiversity is of critical concern, an increasing amount of research indicates that diversity plays an important role in long-term ecosystem functioning. Many factors are contributing to biodiversity loss including habitat modification, competition from introduced species, human demand for certain species and products, and rapid environmental changes such as climactic fluctuations (Groombridge and Jenkins, 2002).

Cornelis and Hermy (2004) reported that urban and suburban parks can play an important role in the conservation of biodiversity, especially in a strongly urbanized region like Flanders (Belgium). A method developed for monitoring biodiversity applied to 15 parks in Flanders. This method took both habitat and species diversity into account and resulted in 13 biodiversity indicators. The results show that urban and suburban parks can have high species richness, especially if they consist of different, more or less semi-natural habitats. Park area was the main factor explaining the variation in biodiversity indicators, so larger parks could contribute more to the conservation of biodiversity than small ones. A biodiversity score based on habitat diversity and species richness was proposed to summarize and evaluate the biodiversity.

Biodiversity research on a broader landscape scale has also revealed that urban areas can contain a relatively high level of biodiversity. Kuhn *et al.* (2004) examined the landscape of Germany by dividing the country into city and non-city grid cells. Non-native as well as native plant species richness was significantly higher in the city grid cells. They suggest that this may be due to geological diversity. Both the location of German cities and the locations of high native plant diversity positively correlated with locations that were geologically diverse. The authors concluded that cities may be disproportionately situated in areas of naturally occurring high biodiversity.

Due to the current rapid rate of global urbanization, the percentage and value of urban forests will increase. Nowak and Walton (2005) reported that, "expanding urbanization increases the importance of urban forests in terms of their extent and the critical ecosystem services they provide to sustain human health and environmental quality in and around urban areas."

Alvey (2006) reported that efforts for mitigating global biodiversity loss have often focused on preserving large, intact natural habitats. However, preserving biodiversity should also be an important goal in the urban environment, especially in highly urbanized areas where little natural habitat remains. Researchers at the city scale as well as at the landscape scale reveal that urban areas can contain relatively high levels of biodiversity. Important percentages of species found in the surrounding natural habitat, including endangered species, have been found in the urban forest. This contribution concisely highlights some examples of urban biodiversity research from various areas of the world. The potential for urban areas to harbor considerable amounts of biodiversity needs to be recognized by city planners and urban foresters so that management practices that preserve and promote that diversity can be pursued. Management options should focus on increasing biodiversity in all aspects of the urban forest, from street trees to urban parks and woodlots.

Goddard *et al.* (2010) reported that as the urbanization increases globally and the natural environment becomes increasingly fragmented, the importance of urban green spaces for biodiversity conservation grows higher. In many countries, private gardens are a major component of urban green space and can provide considerable biodiversity benefits. Gardens and adjacent habitats form interconnected networks and a landscape ecology framework is necessary to understand the relationship between the spatial configuration of garden patches and their constituent biodiversity. They suggest mechanisms for encouraging 'wildlife-friendly' management of collections of gardens across scales from the neighborhood to the city.

Tree dominated areas in the name of parks, gardens, avenue trees, landscapes, within historic monuments, university premises and open spaces because of their proximity to generation of vehicular emissions are important in reducing atmospheric carbon. These tree laden green areas are recognized for their social, cultural, recreational and aesthetic values apart from conserving the biodiversity, of the region (Chaudhary *et al*. 2011) and performing carbon storage and sequestration activity (Ugle *et al.* 2010).

Roy *et al.* (2012) reported that urban trees can potentially mitigate environmental degradation accompanying rapid urbanization via a range of tree benefits and services. Few researchers have systematically assessed how urban tree benefits and costs vary across different cities, geographic scales and climates. Researchers published findings in 33 journals from diverse disciplines including: forestry, land use planning, ecology, and economics. Research has been geographically concentrated (64 per cent of studies were conducted in North America). Nearly all studies (91.3 per cent) used quantitative research, and most studies (60 per cent) employed natural science methods. Demonstrated tree benefits include: economic, social, health, visual and aesthetic benefits; identified ecosystem services include: carbon sequestration, air quality improvement, storm water attenuation, and energy conservation.

2.2 Biodiversity assessment

Biodiversity is assessed in terms of numbers of species, number of individuals of each species as well as the variation of these two between the different ecosystems. Different indices are used to assess the biodiversity such as, Shannon, Menhinick, Simpson, Shannon evenness (Magurran, 1988). The Shannon diversity index and Shannon evenness index assume that all species within land-use type or city have been sampled. The first is mainly an indicator of species richness (α biodiversity) while the second is an indicator of species evenness. Both have a moderate sensitivity to sample size and therefore land-uses and/or cities may not be comparable. β diversity is the variation in species composition between areas of diversity and the easiest way to assess it is by using similarity coefficients between pairs of ecosystems. In order to assess β diversity, the most widely used indices are Jacquard and Sorensen (Southwood, 1978; Janson and Vegelius, 1981).

The assessment of alpha (α) and beta (β) vegetation diversity in the 36 metropolitan boroughs and analyze the relationship of the assessed biodiversity using indices of richness, dominance and evenness, to social and economic levels (high, middle, and low income). These three levels conform to different microclimatic conditions related to the different structural materials within the urban environment and affect the amount and arrangement of vegetation (Quattrochi and Rowntree, 1988).

2.3 Carbon stock of standing tree in urban landscapes.

Total carbon storage and annual carbon sequestration by trees can also be estimated using tree cover and tree diameter distribution data (Rowntree and Nowak, 1991).

Current international researcher on carbon stock estimation in urban green space mainly focus on carbon stock of trees. Few consider the carbon stock of shrubs and herbs. Shrubs and herbs are also important contributors to urban green space (Jo and McPherson, 1995).

Interacting with atmospheric processes through photosynthesis and respiration, forest ecosystems play dominant roles in regulating global carbon cycle (Fang *et al.*1996) because they are responsible for about more than 86% of overall vegetation carbon sink and about 73 per cent for overall soil carbon sink on Earth (Lv *et al.* 2008).

Tree, shrub, soil and sea water play crucial role in absorbing atmospheric carbon dioxide. The trees act as major CO_2 sink which captures carbon from the atmosphere and acts as sink, stores the same in the form of fixed biomass during the growth process. Therefore growing trees in urban areas can be a potential contributor in reducing the concentration of CO_2 in atmosphere by its accumulation in the form of biomass (Ravindranath *et al*. 1997).

Guan *et al.* (1998) estimated green space carbon stock in the dense urban areas of Guangzhou city, and indicated that the roles of urban vegetation in the balance of carbon and oxygen would be increased greatly if it could be conserved and improved in some way.

McPherson, (1998) quantified the benefits of the urban forests in Sacramento, USA in offsetting carbon emissions from human energy consumption, and presented guidelines of urban forest management to improve these benefits.

As trees grow and their biomass increases, they absorb carbon from the atmosphere and store it in the plant tissues (Mathews *et al*. 2000) resulting in growth of different parts. Active absorption of CO_2 from the atmosphere in photosynthetic process and its subsequent storage in the biomass of growing trees or plants is the carbon storage (Baes *et al*. 1977). In terms of atmospheric carbon reduction, trees in urban areas offer the double benefit of direct carbon storage and stability of natural ecosystem with increased recycling of nutrient along with maintenance of climatic conditions by the biogeochemical processes.

Most terrestrial carbon storage is in tree trunks, branches, foliage, and roots which is often called biomass. Terrestrial vegetation important sources and sink of atmospheric carbon (Watson *et al.* 2000), with land use change accounting for 24 per cent of net annual anthropogenic emission of GHGs to the atmosphere (Prentice *et al.* 2001). Trees act as a sink for CO_2 by fixing carbon during photosynthesis and storing excess carbon as biomass.

In their study they have made an attempt to explore ecological conservation values of such areas in urban ecosystem. The study constitutes an assessment of standing biomass, carbon sequestration potential of tree flora in and around Pune City, with inventories on indigenous and exotic tree species. Such green areas or pockets act as Hot Spot in urban biodiversity (Kulkarni *et al.* 2001).

Vegetation in urban green space can absorb CO_2 in the atmosphere through photosynthesis and store excessive carbon as biomass (Nowak and Crane, 2002). Therefore, the quantification of carbon stock in urban green space can help better understand its function in reducing CO_2 emission in the global carbon cycle and provide a theoretical basis for the planning and management of urban green space.

Generally, for any plant species 45% of its biomass is considered as carbon (Pearson *et al.* 2005) i.e., Carbon Storage = Biomass x 45%.

Compared with other methods of mitigating CO_2 emission under the background of global climate change, urban forests have their own specific advantages, such as lower cost and higher efficiency (Huang, 2008).

To estimate biomass from selective tree species, it is not advisable to cut them. The biomass can be measured by mathematical models by measuring diameter at breast height (DBH) directly and the girth at DBH. Girth considered is the DBH (Chavan and Rasal, 2010).

Zhao *et al.* (2010) evaluated the influence of the urban forests in Hangzhou city on reducing carbon emissions from industrial energy use, and showed that urban forests could play a key role in offsetting urban carbon emissions.

Jayakumar and vashum, (2012) reported that the above-ground biomass constitutes the major portion of the carbon pool estimating the amount of forest biomass is very crucial for monitoring and estimating the amount of carbon that is lost or emitted during deforestation, and it will also give us an idea of the forest's potential to sequester and store carbon in the forest ecosystem. Estimations of forest carbon stocks are based upon the estimation of forest biomass. Forest's carbon stocks are generally not measured directly; however, many authors assume the carbon concentration of tree parts to be 50% or 45% of the dry biomass.

Liu and Li, (2012) reported that the quantification of Carbon storage and sequestration by urban forests in Shenyang was estimated by biomass equations, using field survey data and urban forests data derived from high-resolution Quick Bird images. Results indicated that the Carbon storage and sequestration rate varied among urban forest types with different species composition and age structure. These results can be used to help assess the actual and potential role of urban forests in reducing atmospheric CO_2 in Shenyang.

Strohbach and haase, (2012) reported that estimation of the above-ground carbon storage in trees in the central European city of Leipzig. They used stratified random sampling across 19 land cover classes using 190 sample plots to measure carbon storage. In addition, they derived canopy cover from color-infrared ortho photos using an object-oriented approach and Random Forest machine learning. They also applied an error assessment method that includes sampling error, but also uncertainty stemming from allometric equations, and that so far has only been applied to rural forests. The total aboveground carbon stock of Leipzig was estimated using both land cover and canopy cover.

The aboveground biomass (AGB) has been calculated by multiplying volume of biomass and wood density the volume was calculated based on diameter and height

(Pandya *et al*. 2013). The wood density value for the species obtained from web (www.worldagroforestry.org) AGB (g) = volume of biomass (cm^3) × wood density (g/ cm^3)

Nowak *et al.* (2013) reported that urban tree field data from 28 cities in 6 states were used to determine the average carbon density per unit of tree cover. These data were applied to state wide urban tree cover measurements to determine total urban forest carbon storage and annual sequestration by state and at nation level.

Pandya *et al.* (2013) reported that trees are carbon reservoir on earth. In nature, photosynthesis is the unique mechanism through which carbon flows in ecosystems and utilized by plants in the form of CO_2. Worldwide, we are losing of trees every year; which leads to the climate change globally. From estimation of carbon storage in 25 species in Gujarat, India it is found that maximum carbon storage was found in *Tamarindus indica* 55.95 t C followed by *Terminalia arjuna* 44.81 t C. The lowest carbon storage value estimated in *Emblica officinalis* 1.77 t C.

Tripathi, (2016) carried out a study evaluating the role of urban trees in carbon mitigation in a non-forested and tree-dominated area of the National Capital Territory (NCR) of Delhi, the world’s second largest urban area facing the menace of carbon emissions (particularly vehicular and industrial) which result from population growth, coupled with urbanization and deforestation. He defined parks, gardens, trees along avenues, natural landscapes, plant life within historic monuments, university premises and open spaces. According to the study, urban trees within Delhi/NCR play a pivotal role in offsetting carbon, despite the acute challenges which a growing tree must face in order to thrive in an urban environment.

2.4. Quantification of climate amelioration from the vegetation in the urban landscapes

The variation of dust deposition in different plants is due to the fact that different plants have acquired different morphological features apart from those factors like phyllotaxy, leaf shape, plant height, leaf texture, presence or absence of hairs, stomatal frequency are also related to the efficiency of dust collecting capacity of plants (Das and pattanayak, 1977). Both upper and lower leaf surfaces accumulate dust.

Urban trees affect air pollution through two major processes: (1) cooling of the ambient temperature and hence slowing the smog formation process and (2) dry deposition by which the airborne pollutants (both gaseous and particles) can be removed from the air. Trees directly remove pollutant gases such as CO, NO_x, O_3, and SO_2 predominantly through leaf stomata (Smith, 1984; Fowler, 1985).

Climate change may pose a serious threat to the environment (Melillo *et al.* 1990; Karl *et al.* 1997) unless measures are investigated to mitigate the rising accumulation of atmospheric CO_2.Urban green space plays an important role in reducing atmospheric CO_2 (Jo and McPherson, 1995; Jo, 2002).

Measurements of tree cover also provide basic structural data used to model urban forest functions such as air pollution mitigation and carbon dioxide sequestration (Rowntree and Nowak, 1991; Nowak, 1994).

Estimates of the effects of trees on atmospheric carbon can be used to assess the effects of urban trees on greenhouse gases, and can provide useful information for the voluntary reporting of greenhouse gases (Anon, 1994).

Tree cover data can also be useful in quantifying air pollution removal by city trees. In the Chicago area (19 per cent tree cover), estimated average hourly improvement (in-leaf season) in air quality owing to trees ranged from 0.002 per cent for carbon monoxide to 0.4 per cent for particulate matter. Maximum hourly improvement for the area was estimated at 1.3 per cent for sulfur dioxide, though localized improvements in air quality can reach 5-10 per cent in areas with relatively high tree cover (Nowak, 1994). By understanding variations in tree cover and associated costs and benefits, city planners and managers can develop strategies, such as increasing tree cover in heavily polluted areas that will improve the urban environment.

Developmental activities and increased transportation activities are increasing the concentration of air pollutants as greenhouse gases, especially CO_2. These are leading to increased atmospheric temperature through the trapping of certain wavelengths of heat radiation in the atmosphere. The increasing carbon emission is of major concerns; it has been well addressed in Kyoto protocol (Ravindranath *et al*. 1997).

Urban forests can reduce the levels of atmospheric CO_2 through sequestration and reducing CO_2 emissions by conserving energy used for heating and cooling (McPherson *et al.* 1999).

The trees, shrubs and other natural vegetation affect urban air contaminant levels, and, by extension, air quality and the overall experience of health and well-being of humans living in urban areas (Bass 2001; Bass and Baskaran 2001).

Globally, the averaged surface air temperature increased 0.5°C in the 20th century. It is estimated that the global average air temperature would further increase by 1.5–4.5°C by the year 2100 (Houghton *et al.* 1996). The increase in air temperature was mainly due to the increasing emissions of greenhouse gases (Lashof and Ahuja, 1990), among which carbon dioxide (CO_2) is the most dominant one, accounting for three quarters of the total emissions (Olivier *et al.* 2005).

Akbari, (2002) reported that urban shade trees offer significant benefits in reducing building air-conditioning demand and improving urban air quality by reducing smog. The savings associated with these benefits vary by climate region and can be up to $200 per tree. Their calculations suggest that urban trees play a major role in sequestering CO_2 and thereby delay global warming. A tree planted in Los Angeles avoids the combustion of 18 kg of carbon annually, even though it sequesters only 4.5–11 kg. In this sense, one shade tree in Los Angeles is equivalent to three to five forest trees.

Climate change has become an important issue mainly due to the greenhouse effect caused by carbon dioxide (CO_2) emission (Jo, 2002; Sivrikaya *et al.* 2013). Nowak *et al.* (2006) reported that urban trees and shrubs offer the ability to remove significant amounts of air pollutants and consequently improve environmental quality and human health. Trees remove gaseous air pollution primarily by uptake via leaf stomata and some gases are removed by the plant surface. Inside the leaf, gases diffuse into intercellular spaces and may be absorbed by water films to form acids or react with inner-leaf surfaces. Trees also remove pollution by intercepting airborne particles. Some particles can be absorbed into the tree, though most particles that are intercepted are retained on the plant surface. The intercepted particle often is re-suspended to the atmosphere, washed off by rain, or dropped to the ground with leaf and twig fall. Thus Urban forests can play an important role in mitigating the impacts of climate change by reducing CO_2 in urban areas (McHale *et al*. 2007).

Particles which are trapped in wax are hydrophobic thus probably contain most harmful organic substances like e.g. aliphatic and aromatic hydrocarbons. Highest rates of particulate matter assayed on leaves of silver birch are probably a result of thick epicuticular wax layer, characteristic for this species. There was over six fold more waxes on birch leaves than on other species. Amount of waxes is important for trapping PM. Probably chemical composition and structures of wax layer, which are a species-specific trait, are also essential. Amounts of particulate matter deposited on leaf surface of five tree species. Although leaves of tested trees demonstrated high effectiveness in capturing airborne particles in view of average concentration in air, some significant differences between species were recorded. Birch, white beam and poplar were most effective, while oak demonstrated lowest levels of PM on leaves. (Dzierzanowski and Gawronski,2009)

Selmi *et al.* (2016) reported that in his study integrates i-Tree Eco model in order to estimate air pollution removal by urban trees in Strasbourg city, France. They applied for the first time in a French city, the model shows that public trees, i.e. trees managed by the city, removed about 88 tons of pollutants during one year period (from July 2012 to June2013): about 1 ton for CO; 14 tons for NO_2; 56 tons for O_3; 12 tons for PM_{10} coarse (particles with diameter ranging from 2.5 to 10µm); 5 tons for $PM_{2.5}$ and 1 ton for SO_2. Air pollution removal varied mainly with the tree cover and the level of air pollutants concentrations. Comparison between simulated pollution removal rates and local emissions shows that public trees of Strasbourg reduce about 7 per cent of the emitted PM_{10} in the city’s atmosphere; however, effect on other air pollutants is small. Thus, there study reveals that urban trees are a significant element to reduce air pollution but are not the only solution to this problem.

III. MATERIAL AND METHODS

The details of the various methodologies followed in this study are explained in this chapter.

3.1. Study site

Study was conducted in parts of Ward 4, i. e. Yelahanka New town, Bangalore, Karnataka. In this new extension of Bengaluru city with a total area of 4.9 km^2. Following are the different areas fall under this location namely; Udaya Layout, Mother Dairy, Soma Nagar, Janata colony, Chikka Bommasandra, Yelahanka Satellite town, ABC quarters, Ambedkar colony, Allalsandra, Allalsandra lake, Judicial Layout, GKV Nagar, Judicial colony. The tree diversity and carbon stocks in avenue trees, parks and lakes were assessed in these area.

Plate 1: Location of Yelahanka (ward 4), Bengaluru.

3.2. Tree diversity

Tree species planted in this area will be identified to species level as per taxonomic classification and diversity in the tree species present in the road side; parks and water bodies are assessed.

3.2.1. Contribution of dominant ten tree species to the tree Density, Biomass and basal area in three landscapes

The contribution of dominant trees with highest number of density, larger basal area and Biomass of ten species were identified.

Tree density is the quantitative measure of tree cover on an area, i.e. the amount of trees material per unit area or space

To estimate a tree basal area uses the tree diameter at breast height DBH in centimeters with the following formula. The result will be in m^2.

$$\textbf{Basal area = pie} \times \textbf{(DBH)}^{2} \textbf{ / (4*10000)}$$

$$\textbf{Basal area = pie} \times \textbf{(DBH)}^{2} \textbf{ / (40000)}$$

$$\textbf{BA=0.00007854} \times \textbf{(DBH)}^{2}$$

Biomass of the tree species calculated using formula

Biomass (Kg) = volume × density of the species

3.2.2. Calculation of Alpha Diversity Index

Alpha diversity index calculated using the Shannon Alpha Diversity index Method. Typical values are generally varied between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon index increases as both the richness and the evenness of the community increase. The fact that the index incorporates both components of biodiversity can be seen as both strength and a weakness. It is strength because it provides a simple, synthetic summary, but it is a weakness because it makes it difficult to compare communities that differ greatly in richness.

$$\mathbf{H = -\sum (P_i * \ln P_i)}$$

Where,

P_i is the proportion of individuals found in species i.

For a well-sampled community, we can estimate this proportion as $P_i = n_i/N$.

$n_i$is the number of individuals in species i.

N is the total number of individuals in the community.

Since by definition the P_iS will all be between zero and one, the natural log makes all of the terms of the summation negative, which is why we take the inverse of the sum.

3.2.3. Calculation of Beta Diversity Index

Jaccard β diversity is the variation in species composition between areas of diversity and the easiest way to assess it is by using similarity coefficients between pairs of sites. The values vary between 0-1 and the values indicate the extent of dis-similarity between the ecosystems.

$$\mathbf{C_j = j/(a+b-j)}$$

Where,

j is the number of species found in both the sites.

a is the number of species in site A.

b is the numbers of species found in site B.

3.3. Carbon sequestration assessment

This will be assessed by deriving the standing tree biomass by measuring girth, height and carbon content of the trees.

3.3.1. Measurement of girth of the tree

The girth of the tree is measured using measuring tape graduated to measure a minimum of one mm.

3.3.2. Measurement of height of the tree

The height of tree is measured with the help of Blume Leiss altimeter. The Blume Leiss altimeter is developed to measure slope and tree height by the trigonometric principle. The device measures the elevation angle between the operator and measured points. Tree heights can directly be read from the device depending on fixed distances of 15 m, 20 m, 30 m and 40 m. For mountainous areas slope correction factors can directly be read from the device depending on the slope.

3.3.2.1. Using BlumeLeiss Altimeter to determine tree height:

1. Select a distance, preferably 15, 20, 30, or 40 meters away from the tree, where the required point on the tree (e.g. tree tip) can be seen. Measure the selected horizontal distance from the base of the tree.
2. Release the pointer by pressing the button on the side of the instrument.
3. Sight at the required point on the tree, wait for a moment for the pointer to settle then pull trigger.
4. Read the height directly from the appropriate scale if you are 15, 20, 30, or 40 meters away from the tree. If you were unable to find a position at one of these distances:
    - If the horizontal distance is a simple fraction of one of the scale distances (e.g. 10 m is half of 20 m), read from the scale distance and multiply by the appropriate fraction.
    - Read from the percent scale and multiply this percentage by the horizontal distance measured in step 1.
5. Site to the base of the tree and repeat steps 2 - 4.
6. Combine the heights from steps 4 and 5 to determine total tree height:
    - Add the 2 heights together if you looked up to the required point in step 3 and down to the base of the tree in step 5.
    - Subtract the height to the base of the tree from the height to the required point if you are on sloping ground and had to look up to both the required point and the base of the tree.

3.3.3. Calculation of volume of the tree:

For calculation of volume of tree we use the formula.

$$\textbf{VOLUME} = \pi r^2 h$$

For getting the value of radius from the girth of the tree

$$C = 2\pi r$$

Where,

C = circumference = girth of the tree

Then,

$$r = C/2\pi.$$

3.3.4. Estimation of biomass from the volume and density

After deriving the total volume of the tree it will be multiplied with the density of specific tree species to derive the biomass.

Biomass (Kg) = volume × density of the species

3.3.5. Carbon content of the biomass

In general the carbon content of the biomass present in different parts of the plant such as leaf, stem and other parts varies between 40-50 per cent of the biomass. On an average 45 per cent of the above ground biomass is considered as carbon content.

Carbon content (Kg) = Standing Biomass × 0.45.

3.3.5.1. CO_2 content of the Biomass.

The CO_2 in the atmosphere is assimilated by trees in the process of photosynthesis. In order to derive the amount of CO_2 converted into carbon and retained in the biomass. The molecular weight relation between carbon and oxygen is used as follows. Atomic weight of carbon is 12 and oxygen is 16

$CO_2 = (12 + (16\times2))/12 = 44/12 = 3.67$.

Thus one molecule of carbon=3.67 molecules of CO_2 or 1 ton of carbon = 3.67 ton of CO_2.

3.3.5.2. Amount of oxygen released to atmosphere.

On an average one mature tree produces nearly 260 pounds of oxygen each year. This is given by Canada's national environmental agency. For one day it is 0.71 pounds which on converting to tons gives 0.00032 tons per day. The product of 0.00032 and number of trees gives the amount of oxygen released to atmosphere expressed in tons.

3.4. Tree canopy spread

The tree canopy cover is measure of physiologically active part of the tree. The width of the canopy is measured from north to south and west to east and average of it is considered as canopy spread and expressed in meters. The total area covered by tree canopy spread by all trees present in the area of 4.9 sq. km is calculated by identifying the radius and area of circle which is multiplied with number of trees gives total canopy spread of all species expressed in m^2. For the sq. km value divide that value by 10^6.

$$\textbf{Area of circle} = \pi r^2$$

3.5. Leaf Area of Tree Species

Leaf area of individual leaf of each tree species is estimated using leaf Area Meter (LI-3100C) expressed in cm^2. 50 leaves from each species was collected and measured in the leaf area meter and average of all 50 leaves gives the leaf area of the species.

3.6. Epicuticular wax content

Extraction was done by dipping the leaves the leaves in chloroform. The duration for which the leaves were immersed in the chloroform was standardized for each species as 15 seconds as maximum wax content was released compared to other time duration expressed in $\mu g/cm^2$.

The detailed procedure was as follows:

- Empty petriplates are washed cleanly without any other residues and kept for oven drying.
- These empty petriplates were weighed in electronic balance and replicated 5 times for each species.
- Sufficient of chloroform is added to the petriplates so as to completely immerse the leaf.
- The leaves of known leaf area after cleaning gently to remove the dust were cut into pieces to dip in the petriplates containing chloroform.
- The leaves were dipped for 15 seconds which allowed the epicuticular wax to dissolve in the chloroform. Then petriplates are kept overnight for drying in a dust free condition.

- After ensuring the complete evaporation of the chloroform petriplates were weighed using an electronic balance (Sortorious, ALC-210.4, and USA).
- The difference in the weight of the empty petriplate and the petriplate with the wax was considered as wax content.

3.7. Statistical Analysis

The Analysis of the Carbon Stock data was done which is obtained from the trees that are existing Yelahanka ward 4, The level of significance used in F-test was at $p = 0.05$. CD was calculated whenever the F-test was found significant.

- Single factor ANOVA- for the Canopy spread, Leaf area and Wax content of leaf of the tree species.
- Correlation between different variables of trees was carried out to know the relation between the variables.

Data processing was performed using Microsoft Office Excel 2010

IV. EXPERIMENTAL RESULTS

The results of the experiments conducted to evaluate the contribution of trees in urban landscapes towards climate amelioration and pollution abatement is presented in this chapter.

This study was conducted in northern parts of Bengaluru urban landscapes. Tree diversity in Avenue Trees, Park and Around the Lakes was assessed. There are 46 tree species found in the study area belonging to 25 different families. The total number of trees found in the study area was 7854 of which 4161 were found in road side planting, 3335 were planted in 14 parks and 358 trees were found all along the Allasandra lake in the ward 4, Yelahanka Newtown (Table 1).

Out of 4161 trees along the roadside, highest number of trees found were *Pongamia pinnata* (745), followed by *Bauhinia purpurea* (439), *Swietenia mahagoni* (326), *Dolichandrone platycalyx* (309), *Peltophorum pterocarpum* (248) and *Tabebuia avellanedae* (226) and least number was seen in the species *Ficus benghalensis* (2), *Tamarindus indica* (4), *Ficus religiosa* (5). The tree species that were not found among the avenue trees out of 46 species are *Hyophorbe lagenicaulis, Santalum album, Schefflera actinophylla.* Similarly in the park landscapes out of the total 3335 trees highest number of trees were found in *Pongamia pinnata* (430) followed by *Bauhinia purpurea* (198), *Dolichandrone platycalyx* (185), *Lagerstroemia flosreginae* (169). The least number of trees found were *Ficus benghalensis* (2) followed by *Santalum album* (6) and *Albizia lebbeck* (9) while no trees of *Eucalyptus globulus*, *Hyophorbe lagenicaulis*, *Tamarindus indica*were found in this landscape. In case of lakes a total of 358 trees came from only 19 different trees species among which 122 trees were of *Pongamia pinnata* and 115 trees belonged to *Hyophorbe lagenicaulis.* The species diversity remained same in avenue and park landscapes where the number of species was found to be 42.

Table 1: List of tree species and their distribution in three urban landscapes

Sl No.	Name of the species	Family	Number of Individuals			Total
			Avenue	Park	Lake	
1	*Albizia lebbeck*	Fabaceae	9	9	0	18
2	*Alstonia scholaris*	Apocynaceae	51	47	0	98
3	*Anthocephalus cadamba*	Rubiaceae	71	100	0	171
4	*Araucaria columnaris*	Araucariaceae	9	22	0	31
5	*Artocarpus heterophyllus*	Moraceae	26	15	5	46
6	*Azadirachta indica*	Meliaceae	132	119	0	250
7	*Bauhinia purpurea*	Fabaceae	439	198	4	641
8	*Bixa orellana*	Bixaceae	12	29	0	41
9	*Callistemon lanceolatus*	Myrtaceae	12	30	0	42
10	*Cassia spectabilis*	Fabaceae	25	96	3	124
11	*Coccos nucifera*	Aracaceae	182	63	6	251
12	*Couroupita guianensis*	Lecythidaceae	52	119	0	171
13	*Dalbergia sissoo*	Fabaceae	28	61	0	89
14	*Delonix regia*	Fabaceae	29	118	0	147
15	*Dolichandrone platycalyx*	Begnoniaceae	309	185	0	494
16	*Eucalyptus globulus*	Myrtaceae	13	0	15	28
17	*Ficus benghalensis*	Moraceae	2	2	1	5
18	*Ficus racemosa*	Moraceae	11	28	7	46
19	*Ficus religiosa*	Moraceae	5	7	2	14
20	*Grevillea robusta*	Proteaceae	31	71	0	102
21	*Hyophorbe lagenicaulis*	Aracaceae	0	0	115	115
22	*Jacaranda mimosifolia*	Bignoniaceae	47	81	0	128
23	*Kigelia pinnata*	Bignoniaceae	9	28	2	39
24	*Lagerstroemia flosreginae*	Lithraceae	163	169	0	332
25	*Mangifera indica*	Anacardiaceae	44	48	0	92
26	*Michelia champaca*	Magniliaceae	177	139	5	321
27	*Millingtonia hortensis*	Bignoniaceae	29	63	0	92
28	*Muntingia calabura*	Muntingiaceae	107	114	3	224
29	*Peltophorum pterocarpum*	Caesalpiniaceae	248	135	3	386
30	*Phyllanthus emblica*	Phyllanthaceae	13	24	0	37
31	*Plumeria alba*	Apocynaceae	12	28	48	88
32	*Polyalthia longifolia*	Annonaceae	54	56	0	110
33	*Pongamia pinnata*	Fabaceae	745	430	122	1297
34	*Enterolobium saman*	Fabaceae	68	55	0	123
35	*Santalum album*	Santalaceae	0	6	0	6
36	*Saraca asoca*	Fabaceae	20	32	0	52
37	*Schefflera actinophylla*	Araliaceae	0	22	0	22

Sl No.	Name of the species	Family	Number of Individuals			Total
			Avenue	Park	Lake	
38	*Spathodea companulata*	Bignoniaceae	172	139	0	311
39	*Swietenia mahagoni*	Meliaceae	326	110	3	439
40	*Syzygium cumini*	Myrtaceae	45	58	6	109
41	*Tabebuia argentea*	Bignoniaceae	27	42	0	69
42	*Tabebuia avellanedae*	Bignoniaceae	226	77	2	305
43	*Tabebuia rosea*	Bignoniaeae	9	34	0	43
44	*Tamarindus indica*	Fabaceae	4	0	0	4
45	*Terminalia catappa*	Combretaceae	81	41	6	128
46	*Thespesia populnea*	Malvaceae	87	85	0	172
			4161	3335	358	7854

The contribution of dominant tree species were listed with respect to tree density, biomass and basal area in three landscapes studied. It is generally expressed in terms of top ten species out of total number of species in each landscape.

Tree density of dominant ten species in the Avenue trees is found to 2987 out of 4161 total trees present in this landscape. Around 71 per cent of the total number of trees has come from only 10 out of 43 species found in this landscape. Similarly in the parks around 52 per cent of the total number of trees has come from only 10 out of 43 species found in this landscape. In case of lake around 93 per cent of the total number of trees has come from only 10 out of 18 species found in this landscape. (Table 2)

Tree biomass of dominant ten species in the Avenue trees is 58325 Kg out of 78621 Kg total biomass of trees present in this landscape. The contribution of top ten tree species to total tree biomass in this landscape is 74 per cent. Similarly in the park 35741 Kg of biomass found in top ten tree species out of 52191 Kg accounting for 68 per cent of biomass is from top ten species. In case of Lake 15913 Kg biomass of trees out of 16865 Kg, with 94 per cent of tree biomass is from top ten species present in the ecosystem. (Table 3)

Tree basal area for the dominant ten species in the Avenue trees is found to 5.07 m^2 out of 7.33 m^2 of total tree basal area present in this landscape. The contribution of top ten tree species basal area to total tree basal area in this landscape is 69 percent. Similarly in the park ecosystem 3.44 m^2 basal area came from top ten tree species out of 5.8 m^2 with 61 percent of basal area is from top ten species. In case of Lake 1.47 m^2 basal area of trees out of 1.63 m^2 with 90 per cent of tree basal area are in top ten species present in the ecosystem. (Table 4)

Table 2: Contribution of dominant ten tree species to the tree density in three landscapes

Sl. No.	Avenue Trees		Parks		Lake	
	Name of the Species	**Density**	**Name of the Species**	**Density**	**Name of the Species**	**Density**
1	*Pongamia pinnata*	745	*Pongamia pinnata*	430	*Pongamia pinnata*	122
2	*Bauhinia purpurea*	439	*Bauhinia purpurea*	198	*Hyophorbe lagenicaulis*	115
3	*Swietenia mahagoni*	326	*Dolichandrone platycalyx*	185	*Plumeria alba*	48
4	*Dolichandrone platycalyx*	309	*Lagerstroemia flosreginae*	169	*Eucalyptus globulus*	15
5	*Peltophorum pterocarpum*	248	*Michelia champaca*	139	*Ficus racemosa*	7
6	*Tabebuia avellanedae*	226	*Spathodea companulata*	139	*Cocos nucifera*	6
7	*Cocos nucifera*	182	*Peltophorum pterocarpum*	135	*Syzygium cumini*	6
8	*Michelia champaca*	177	*Azadirachta indica*	119	*Terminalia catappa*	6
9	*Spathodea companulata*	172	*Couroupita guianensis*	119	*Artocarpus heterophyllus*	5
10	*Lagerstroemia flosreginae*	163	*Delonix regia*	118	*Michelia champaca*	5
Total		**2987(71%)**		**1751(52%)**		**335(93%)**
Total number of trees		**4161**		**3335**		**358**

Table 3: Contribution of dominant ten tree species to the tree biomass in three landscapes

Sl. No.	**Avenue Trees**		**Parks**		**Lake**	
	Name of the Species	**Biomass(Kg)**	**Name of the Species**	**Biomass(Kg)**	**Name of the Species**	**Biomass(Kg)**
1	*Ficus benghalensis*	21797	*Ficus benghalensis*	8299	*Ficus benghalensis*	11343
2	*Ficus religiosa*	7705	*Enterolobium saman*	6168	*Eucalyptus globulus*	1422
3	*Enterolobium saman*	7599	*Ficus religiosa*	4450	*Cocos nucifera*	566
4	*Albizia lebbeck*	4791	*Albizia lebbeck*	3182	*Peltophorum pterocarpum*	542
5	*Eucalyptus globulus*	2886	*Dalbergia sissoo*	2934	*Syzygium cumini*	492
6	*Tamarindus indica*	2869	*Grevillea robusta*	2376	*Kigelia pinnata*	453
7	*Dalbergia sissoo*	2866	*Couroupita guianensis*	2343	*Terminalia catappa*	306
8	*Kigelia pinnata*	2722	*Peltophorum pterocarpum*	2216	*Cassia spectabilis*	283
9	*Delonix regia*	2573	*Delonix regia*	2049	*Artocarpus heterophyllus*	258
10	*Grevillea robusta*	2517	*Spathodea companulata*	1725	*Michelia champaca*	248
Total		**58325(74%)**		**35741(68%)**		**15913(94%)**
Total biomass		**78621**		**52191**		**16865**

Table 4: Contribution of dominant ten tree species to the tree basal area in three landscapes.

Sl. No.	Avenue Trees		Parks		Lake	
	Name of the Species	**Basal area (m^2)**	**Name of the Species**	**Basal area (m^2)**	**Name of the Species**	**Basal area (m^2)**
1	*Ficus benghalensis*	1.55	*Ficus benghalensis*	0.65	*Ficus benghalensis*	0.93
2	*Ficus religiosa*	0.89	*Enterolobium saman*	0.61	*Eucalyptus globulus*	0.11
3	*Enterolobium saman*	0.65	*Ficus religiosa*	0.49	*Cocos nucifera*	0.07
4	*Albizia lebbeck*	0.46	*Albizia lebbeck*	0.32	*Kigelia pinnata*	0.07
5	*Ficus racemosa*	0.33	*Spathodea companulata*	0.31	*Peltophorum pterocarpum*	0.07
6	*Kigelia pinnata*	0.31	*Couroupita guianensis*	0.26	*Syzygium cumini*	0.05
7	*Schefflera actinophylla*	0.3	*Delonix regia*	0.26	*Cassia spectabilis*	0.05
8	*Delonix regia*	0.26	*Dalbergia sissoo*	0.21	*Artocarpus heterophyllus*	0.04
9	*Couroupita guianensis*	0.2	*Peltophorum pterocarpum*	0.19	*Bauhinia purpurea*	0.04
10	*Jacaranda mimosifolia*	0.12	*Anthocephalus cadamba*	0.14	*Ficus racemosa*	0.04
Total		**5.07(69%)**		**3.44(61%)**		**1.47(90%)**
Total Basal area		**7.33**		**5.8**		**1.63**

Shannon alpha diversity index was calculated for the study site to know the richness and evenness of the diverse trees present in three different landscapes. Typical values vary between 1.5 and 3.5 in most ecological studies. The index value for Avenue trees varied from 1.84 in lake to 3.41 in parks (Table 5).

Table 5: Shannon alpha diversity index.

Sl No.	Land use system	Diversity Index
1	Avenue Trees	3.03
2	Parks	3.41
3	Lake	1.84

Jaccard beta diversity index avenue trees and parks were found to be 0.911 which suggest that there is about 91.1 per cent similarity between these two landscapes while a value of 0.409 between lake and avenue landscapes indicates about 41 per cent similar species or 59 per cent of the species are unique to these two landscapes. Similarly between the lake and park landscapes 61.4 per cent species were unique to these two ecosystems (Table 6).

Table 6: Jaccard beta diversity index.

Sl No.	Land use system	Avenue Trees	Parks	Lake
1	Avenue Trees	--	--	--
2	Parks	0.911	--	--
3	Lake	0.409	0.377	--

The total amount of carbon stocked in three landscapes varied from 1703 tons in avenue trees followed by 1414 tons in parks and the least of 27 tons was found in the trees around the lake. From these entire three ecosystems a total of 3144 tons of carbon is stored in standing biomass of trees which is equal to 11538 tons of carbon dioxide sequestered from atmosphere over years (Table 7).

Table 7: Carbon stocks and CO_2 in the above ground biomass of standing tree

Sl. No	Land use system	Carbon (tons)	Tons of CO_2
1	Avenue Trees	1703	6250
2	Parks	1414	5189
3	Lake	27	99
	Total	3144	11538

The mean carbon accumulated in avenue trees found highest in *Ficus benghalensis* (9809 kg) followed by *Ficus religiosa* (3467 kg), *Enterolobium saman* (3420 kg), *Albizia lebbeck* (2156 kg), *Eucalyptus globulus* (1299 kg) and the least values were found in *Muntingia calabura* (24 kg)followed by *Saraca asoca* (25 kg), *Tabebuia rosea* (28 kg), *Lagerstroemia flosreginae* (34 kg). Similarly in case of park ecosystem the mean carbon stock was found to be highest in *Ficus benghalensis* (3735 kg) followed by *Ficus religiosa* (2002 kg), *Enterolobium saman* (2776 kg), *Albizia lebbeck* (1432 kg), *Dalbergia sissoo* (1320 kg) and the least mean carbon stock found in *Muntingia calabura* (21 kg) followed by *Saraca asoca* (24 kg), *Santalum album* (25 kg), *Plumeria alba* (27 kg). In case of Lake landscape the mean carbon stock was found to be highest *Ficus religiosa* (5104 kg), *Eucalyptus globulus* (639 kg), *Cocos nucifera* (255 kg), *Peltophorum pterocarpum* (244 kg) and the least was found in *Muntingia calabura* (7 kg) followed by *Pongamia pinnata* (7 kg), *Hyophorbe lagenicaulis* (24 kg), *Plumeria alba* (24 kg) (Table 8).

In order to quantify the carbon stocks among the tree species the total amount of carbon sequestered from each species varied as follows. Out of the total amount of 3144 tons *Peltophorum pterocarpum* has contributed 401 tons followed by *Enterolobium saman* (385 tons), *Swietenia mahagoni* (295 tons), *Spathodea companulata* (248 tons), *Pongamia pinnata* (210 tons). Among the species the least carbon accumulated species found to be in *Santalum album* (0.15 ton) followed by *Saraca asoca* (1.26 tons), *Tabebuia rosea* (1.29 tons).

Table 8:Carbon stock of each species in different landscapes

Sl No.	Name of the species	Carbon stock (tons)			Total (tons)
		Avenue	Park	Lake	
1	*Albizia lebbeck*	2.16 ± 1.26	1.43 ± 0.52		32
2	*Alstonia scholaris*	0.22 ± 0.18	0.29 ± 0.18		25
3	*Anthocephalus cadamba*	0.29 ± 0.35	0.43 ± 0.44		63
4	*Araucaria columnaris*	0.05 ± 0.05	0.08 ± 0.12		2
5	*Artocarpus heterophyllus*	0.20 ± 0.17	0.44 ± 0.51	0.12 ± 0.046	12
6	*Azadirachta indica*	0.22 ± 0.31	0.25 ± 0.32		59
7	*Bauhinia purpurea*	0.20 ± 0.35	0.17 ± 0.17	0.11 ± 0.053	122
8	*Bixa ornella*	0.04 ± 0.02	0.04 ± 0.02		3
9	*Callistemon lanceolatus*	0.04 ± 0.05	0.08 ± 0.11		19
10	*Cassia spectabilis*	0.22 ± 0.36	0.14 ± 0.21	0.13 ± 0.045	102
11	*Cocos nucifera*	0.36 ± 0.23	0.57 ± 0.28	0.25 ± 0.057	3
12	*Couroupita guianensis*	0.77 ± 0.88	1.05 ± 0.75		166
13	*Dalbergia sissoo*	1.29 ± 1.30	1.32 ± 1.08		117
14	*Delonix regia*	1.16 ± 0.72	0.92 ± 0.49		142
15	*Dolichandrone platycalyx*	0.14 ± 0.23	0.28 ± 0.33		95
16	*Eucalyptus globulus*	1.30 ± 0.82		0.64 ± 0.177	26
17	*Ficus benghalensis*	9.81 ± 0.71	3.73 ± 1.70	5.10 ± 3.61	32
18	*Ficus racemosa*	0.89 ± 0.75	0.65 ± 0.32	0.07 ± 0.015	28
19	*Ficus religiosa*	3.47 ± 1.62	2.00 ± 1.24	0.09 ± 0.011	31
20	*Grevillea robusta*	1.13 ± 0.97	1.07 ± 0.97		111
21	*Hyophorbe lagenicaulis*			0.02 ± 0.016	3
22	*Jacaranda mimosifolia*	0.50 ± 0.62	0.49 ± 0.44		64

23	*Kigelia pinnata*	1.22 ± 0.97	0.53 ± 0.31	0.20 ± 0.027	26
24	*Lagerstroemia flosreginae*	0.03 ± 0.05	0.04 ± 0.05		11
25	*Mangifera indica*	0.21 ± 0.27	0.26 ± 0.25		21
26	*Michelia champaca*	0.14 ± 0.17	0.12 ± 0.12	0.11 ± 0.042	42
27	*Millingtonia hortensis*	0.19 ± 0.21	0.21 ± 0.19		19
28	*Muntingia calabura*	0.02 ± 0.02	0.02 ± 0.03	0.01 ± 0.002	5
29	*Peltophorum pterocarpum*	1.07 ± 0.94	1.00 ± 0.92	0.24 ± 0.024	401
30	*Phyllanthus emblica*	0.06 ± 0.05	0.03 ± 0.03		2
31	*Plumeria alba*	0.04 ± 0.03	0.03 ± 0.02	0.02 ± 0.056	2
32	*Polyalthia longifolia*	0.17 ± 0.17	0.18 ± 0.17		19
33	*Pongamia glabra*	0.15 ± 0.25	0.24 ± 0.32	0.01 ± 0.002	211
34	*Enterolobium saman*	3.42 ± 2.30	2.78 ± 1.87		385
35	*Santalum album*		0.02 ± 0.02		0.2
36	*Saraca asoca*	0.02 ± 0.02	0.02 ± 0.02		1
37	*Schefflera actinophylla*		0.09 ± 0.04		2
38	*Spathodea companulata*	0.82 ± 0.81	0.78 ± 0.70		248
39	*Swietenia mahogany*	0.54 ± 0.85	0.45 ± 0.50	0.04 ± 0.009	296
40	*Syzygium cumini*	0.53 ± 0.55	0.49 ± 0.49	0.22 ± 0.039	53
41	*Tabebuia argentea*	0.09 ± 0.12	0.07 ± 0.10		5
42	*Tabebuia avellanedae*	0.29 ± 0.49	0.29 ± 0.54	0.06 ± 0.018	87
43	*Tabebuia rosea*	0.03 ± 0.02	0.03 ± 0.02		1
44	*Tamarindus indica*	1.29 ± 0.54			5
45	*Terminalia catappa*	0.20 ± 0.24	0.33 ± 0.32	0.14 ± 0.113	30
46	*Thespesia populnea*	0.07 ± 0.10	0.07 ± 0.08		12
					3144

The canopy spread of different tree species is significantly different from each other. *Ficus benghalensis* has highest canopy size of 17.97 m^2 followed by *Ficus religiosa* (17.71 m^2) *Enterolobium saman* (16.62 m^2) and *Spathodea companulata* (16.39 m^2). While trees that had smallest canopy spread were *Muntingia calabura* (5.2 m^2), *Plumeria alba* (5.2m^2) *and Bixa orellana* (5.53m^2) (Table 9).

Leaf area of individual leaflet was found to vary significantly among all the tree species. Among the species *Hyophorbe lagenicaulis* which is found in Lake Ecosystem has largest leaf area (266.77 cm^2) followed by *Terminalia catappa* (234.02 m^2), *Schefflera actinophylla* (233.58 cm^2), *Cocos nucifera* (224.54 cm^2). Among the species *Tamarindus indica* (0.15 cm^2), *Peltophorum pterocarpum* (0.41cm^2) and*Callistemon lanceolatus* (1.67cm^2) (Table 10).

Wax content of leaves was estimated the values found to vary significantly among all the tree species. *Muntingia calabura* found to contain highest wax (339.34 µg/cm^2) followed by *Plumeria alba* (222.67 µg/cm^2), *Tamarindus indica* (214.67 µg/cm^2), *Schefflera actinophylla* (204.67 µg/cm^2). The least was found in *Couroupita guianensis* (32.66 µg/cm^2) *Swietenia mahagoni* (47.34 µg/cm^2) and *Bauhinia purpurea* (48 µg/cm^2) (Table 11).

Table 9: Canopy spread of all the tree species found in the study.

Sl.No.	Name of the Species	Canopy spread (m^2)	Sl.No.	Name of the Species	Canopy spread (m^2)
1	*Albizia lebbeck*	13.62 ± 1.70	24	*Lagerstroemia flosreginae*	6.66 ± 0.45
2	*Alstonia scholaris*	9.15 ± 1.35	25	*Mangifera indica*	9.57 ± 0.51
3	*Anthocephalus cadamba*	13.23 ± 2.74	26	*Michelia champaca*	10.07 ± 1.20
4	*Araucaria columnaris*	7.29 ± 1.02	27	*Millingtonia hortensis*	10.33 ± 1.44
5	*Artocarpus heterophyllus*	14.29 ± 2.28	28	*Muntingia calabura*	5.2 ± 0.29
6	*Azadirachta indica*	9.28 ± 2.24	29	*Peltophorum pterocarpum*	14.6 ± 0.78
7	*Bauhinia purpurea*	9.56 ± 2.54	30	*Phyllanthus emblica*	5.76 ± 0.93
8	*Bixa orellana*	5.53 ± 0.33	31	*Plumeria alba*	5.2 ± 1.58
9	*Callistemon lanceolatus*	6.51 ± 0.70	32	*Polyalthia longifolia*	6.07 ± 0.63
10	*Cassia spectabilis*	12.19 ± 2.46	33	*Pongamia pinnata*	10.1 ± 0.63
11	*Cocos nucifera*	12.66 ± 1.86	34	*Enterolobium saman*	16.62 ± 1.28
12	*Couroupita guianensis*	15.16 ± 0.61	35	*Santalum album*	7.84 ± 1.82
13	*Dalbergia sissoo*	14.3 ± 0.80	36	*Saraca asoca*	6.11 ± 0.18
14	*Delonix regia*	15.51 ± 0.52	37	*Schefflera actinophylla*	9.77 ± 0.47
15	*Dolichandrone platycalyx*	10.77 ± 0.54	38	*Spathodea companulata*	16.39 ± 0.86
16	*Eucalyptus globulus*	11.81 ± 2.03	39	*Swietenia mahagoni*	15.75 ± 0.51
17	*Ficus benghalensis*	17.966 ± 0.78	40	*Syzygium cumini*	15.05 ± 0.61
18	*Ficus racemosa*	14.94 ± 1.13	41	*Tabebuia argentea*	6.11 ± 0.62
19	*Ficus religiosa*	17.71 ± 0.63	42	*Tabebuia avellanedae*	11.76 ± 1.51
20	*Grevillea robusta*	6.54 ± 0.92	43	*Tabebuia rosea*	6.49 ± 0.42
21	*Hyophorbe lagenicaulis*	6.13 ± 0.16	44	*Tamarindus indica*	16.04 ± 1.50
22	*Jacaranda mimosaefolia*	13.96 ± 2.19	45	*Terminalia catappa*	13.61 ± 0.99
23	*Kigelia pinnata*	13.69 ± 1.46	46	*Thespesia populnea*	7.95 ± 1.63
	Total				511.3(0.82km^2-16.7%)

F_{cal}=44.32; F_{table}=1.44; SEM=5.55; CD=11.18

Table 10: Leaf area of all the tree species found in the study area.

Sl.No.	Name of the Species	Leaf Area(cm^2)	Sl.No.	Name of the Species	Leaf Area(cm^2)
1	*Albizia lebbeck*	4.21 ± 1.93	24	*Lagerstroemia flosreginae*	149.09 ± 62.86
2	*Alstonia scholaris*	146.03 ± 39.94	25	*Mangifera indica*	80.12 ± 17.7
3	*Anthocephalus cadamba*	182.21 ± 15.22	26	*Michelia champaca*	44.15 ± 4.43
4	*Araucaria columnaris*	6.22 ± 0.73	27	*Millingtonia hortensis*	5.23 ± 2.45
5	*Artocarpus heterophyllus*	48.37 ± 7.63	28	*Muntingia calabura*	45.36 ± 2.01
6	*Azadirachta indica*	3.55 ± 0.96	29	*Peltophorum pterocarpum*	0.41 ± 0.13
7	*Bauhinia purpurea*	90.07 ± 19.71	30	*Phyllanthus emblica*	11.41 ± 3.25
8	*Bixa orellana*	18.31 ± 3.17	31	*Plumeria alba*	75.93 ± 22.9
9	*Callistemon lanceolatus*	1.67 ± 0.85	32	*Polyalthia longifolia*	69.12 ± 15.72
10	*Cassia spectabilis*	10.66 ± 1.13	33	*Pongamia pinnata*	35.36 ± 8.85
11	*Cocos nucifera*	224.54 ± 36.63	34	*Enterolobium saman*	8.55 ± 2.82
12	*Couroupita guianensis*	89.98 ± 79.49	35	*Santalum album*	43.61 ± 6.46
13	*Dalbergia sissoo*	19.02 ± 5.69	36	*Saraca asoca*	62.62 ± 13.32
14	*Delonix regia*	4.97 ± 1.77	37	*Schefflera actinophylla*	233.58 ± 41.49
15	*Dolichandrone platycalyx*	153.2 ± 50.25	38	*Spathodea companulata*	45.57 ± 17.1
16	*Eucalyptus globulus*	41.16 ± 9.59	39	*Swietenia mahagoni*	53.55 ± 8.16
17	*Ficus benghalensis*	87.21 ± 23.1	40	*Syzygium cumini*	76.46 ± 4.75
18	*Ficus racemosa*	38.55 ± 17.95	41	*Tabebuia argentea*	41.56 ± 28.66
19	*Ficus religiosa*	110.14 ± 31.91	42	*Tabebuia avellanedae*	32.26 ± 11
20	*Grevillea robusta*	77.54 ± 33.59	43	*Tabebuia rosea*	44.32 ± 12.6
21	*Hyophorbe lagenicaulis*	266.77 ± 25.17	44	*Tamarindus indica*	0.15 ± 0.1
22	*Jacaranda mimosaefolia*	2.45 ± 0.95	45	*Terminalia catappa*	234.02 ± 55.47
23	*Kigelia pinnata*	45.09 ± 8.52	46	*Thespesia populnea*	42.28 ± 22.79

F_{cal}=38.98; F_{table}=1.44; SEM=98.28; CD=197.95.

Table 11: Wax content of leaf in all the tree species found in the study area.

Sl. No.	Name of the Species	Wax content (µg/cm^2)	Sl. No.	Name of the Species	Wax content(µg/cm^2)
1	*Albizia lebbeck*	66 ± 12.34	24	*Lagerstroemia flosreginae*	190 ± 36.51
2	*Alstonia scholaris*	187.33 ± 22.9	25	*Mangifera indica*	133.34 ± 10.27
3	*Anthocephalus cadamba*	194 ± 34.27	26	*Michelia champaca*	167.34 ± 22.9
4	*Araucaria columnaris*	151.33 ± 80.82	27	*Millingtonia hortensis*	150.67 ± 38.4
5	*Artocarpus heterophyllus*	76.66 ± 14.91	28	*Muntingia calabura*	339.34 ± 39.19
6	*Azadirachta indica*	118.66 ± 47.99	29	*Peltophorum pterocarpum*	180 ± 60.83
7	*Bauhinia purpurea*	48 ± 11.45	30	*Phyllanthus emblica*	140.67 ± 26.5
8	*Bixa orellana*	102.66 ± 12.56	31	*Plumeria alba*	222.67 ± 132.57
9	*Callistemon lanceolatus*	82 ± 13.04	32	*Polyalthia longifolia*	55.34 ± 17.42
10	*Cassia spectabilis*	64 ± 30.4	33	*Pongamia pinnata*	168.67 ± 26.31
11	*Cocos nucifera*	123.33 ± 155.49	34	*Enterolobium saman*	54 ± 26.85
12	*Couroupita guianensis*	32.66 ± 10.11	35	*Santalum album*	66 ± 12.34
13	*Dalbergia sissoo*	158.66 ± 79.81	36	*Saraca asoca*	79.34 ± 11.40
14	*Delonix regia*	168 ± 75.37	37	*Schefflera actinophylla*	204.67 ± 45.68
15	*Dolichandrone platycalyx*	89.33 ± 26.18	38	*Spathodea companulata*	122.67 ± 48.50
16	*Eucalyptus globulus*	153.33 ± 48.02	39	*Swietenia mahagoni*	47.34 ± 4.35
17	*Ficus benghalensis*	168 ± 87.64	40	*Syzygium cumini*	128 ± 35.64
18	*Ficus racemosa*	69.33 ± 34.83	41	*Tabebuia argentea*	72.67 ± 1.49
19	*Ficus religiosa*	66.67 ± 9.13	42	*Tabebuia avellanedae*	50 ± 15.09
20	*Grevillea robusta*	53.34 ± 19.58	43	*Tabebuia rosea*	150 ± 78.33
21	*Hyophorbe lagenicaulis*	84.67 ± 12.16	44	*Tamarindus indica*	214.67 ± 61.90
22	*Jacaranda mimosaefolia*	118.67 ± 12.82	45	*Terminalia catappa*	176.67 ± 83.9
23	*Kigelia pinnata*	166 ± 71.55	46	*Thespesia populnea*	199.34 ± 45.18

F_{cal}=7.56; F_{table}=1.44; SEM=88.89; CD=179.05.

Correlation was carried out for different variables of the avenue trees in urban ecosystem. All the variables are found to be highly correlated. With increase in one variable other variable also increases (Table 12).

Table 12: Correlation between different growth characters of Avenue trees.

	Biomass	Girth	Height	Canopy Size	Carbon
Biomass	1				
Girth	0.893131	1			
Height	0.657856	0.813587	1		
Canopy Size	0.534653	0.737866	0.665072	1	
Carbon	0.99975	0.892648	0.655186	0.532395	1

Correlation was carried out for different variables of the trees present in parks in urban ecosystem. All the variables are found to be highly correlated. With increase in one variable other variable also increases (Table 13).

Table 13: Correlation between growth characters of trees in Park ecosystem

	Biomass	Girth	Height	Canopy Size	Carbon
Biomass	1				
Girth	0.917563	1			
Height	0.728208	0.836846	1		
Canopy Size	0.67185	0.814568	0.687321	1	
Carbon	1	0.917548	0.728267	0.67184	1

Correlation was carried out for different variables of the trees along the lake in urban ecosystem. All the variables found to be highly correlated. With increase in one variable other variable also increases (Table 14).

Table 14: Correlation between growth characters of trees in Lake Ecosystem

	Biomass	Girth	Height	Canopy Size	Carbon
Biomass	1				
Girth	0.9614	1			
Height	0.481505	0.627228	1		
Canopy Size	0.396217	0.519336	0.753548	1	
Carbon	1	0.961382	0.481446	0.396227	1

V. DISCUSSION

Bangalore is popularly known as garden city and it has earned this name in this synonym because of its large areas of vegetation in the form of parks, botanical gardens and avenue trees that in turn moderated weather conditions to provide a pleasant atmosphere all through the year. With the signing of GATT agreement, the Indian economy was opened up for global markets that attracted investors across the globe. These investments were largely concentrated in major cities, among which Bangalore is one of the most preferred cities. Among the various considerations while choosing a city in India what attracted most investors to Bangalore is its pleasant weather. However, over the past few decades such investments have increased industrialization and thereby urbanization. Rapid growth rates of city has brought in tremendous changes in the land and land use pattern in and around Bangalore, where many of the agricultural lands and forest areas have been converted into various urban facilities. Currently Bangalore is 67th among the fastest growing cities in the world and 14th among the cities in India, with an annual growth rate of 2.7 per cent (Anon. 2017). The disadvantages of such fast growth is rapid increase in the urban population and the households, vehicle numbers leading to higher emission levels, decrease in the tree cover and loss of water bodies. Urbanization has resulted in deteriorating air and water quality, increased atmospheric pollution levels over years. In order to sustain healthy environment of the city, for which Bangalore is known for, it is essential to take appropriate measures especially to contain the pollution levels in expanding city. The situations are similar across the world in most developing countries where urbanization is increasing in the process of achieving economic growth. This is in fact driving the global climate change. Carbon dioxide is the main greenhouse gas responsible for global warming whose emission is increasing due to urbanization and needs to be addressed in tandem with economic growth. One of the important cost effective steps to address this issue is to increase tree cover, because trees have the ability to absorb CO_2 and other pollutants as well as increase the oxygen levels in the air. Growing trees also contribute in conserving the biological diversity which is one of the major causes of concern under deteriorating climate. Present study is an attempt to assess the benefits of presence of trees in urban areas with an emphasis to understand the reduction of atmospheric CO_2

concentration and conservation of biological diversity that can be achieved through tree planting in urban landscapes.

In the present study a total of 7854 trees were found in the study area across three landscapes, spread over an area of 4.9 km^2 in ward 4 of Yelahanka, Bangalore. The tree population is constituted by 46 different tree species belonging to 25 families (Table 1). Among the three landscapes studied, 53 per cent of the tree population is found in the avenue trees, 42 per cent were found in fourteen parks spread over the area and 5 per cent is seen around the only lake (Allasandra lake) in the area. The type of species as well as the density of species across the landscapes varied. Among the three landscapes studied more number of species was found in parks followed by avenue trees but it was least in lake (Table 1). Most dominant species was *pongamia pinnata* followed by *Bauhinia purpurea* and *Swietenia mahagoni* in the avenue trees (Table 2) while in park ecosystem, it was *pongamia pinnata* followed by *Bauhinia purpurea*, *Dolichandrone platycalyx* were more in numbers. In Lake ecosystem too *Pongamia pinnata* is most abundant followed by *Hyophorbe lagenicaulis* (which is an ornamental tree), and *Plumeria alba*. These landscapes being man made ecosystems the species composition is highly regulated. *Pongamia pinnata* is found to be most preferred species which constitute about 16 per cent of the total population from all the three landscapes. This could be due to following reasons. Urban environment is highly stressful in terms of insufficient or excess light exposure, high temperatures (urban heat island), air pollution, soil nutrient deficiency, water stress, water logging, restricted root spacing, etc. (Kiran and Kinnary, 2011). Pongamia is leguminous in nature that has ability to assimilate atmospheric nitrogen and thus it helps in reducing the nutrient deficiency. Higher population is indicative of higher survival rate and therefore suggests that it has higher stress tolerance. The morphological features of *Pongamia pinnata* such as moderate height, medium size leaflet, lush green canopy (Bohre *et al.* 2014) make them suitable for growing as avenue trees, in parks and lake side. It is also important to note that presence of 46 different tree species established in the urban landscape over 20-25 years (approximate age of the trees) is a general indication of stress tolerance of these species. Most of the species used here are indigenous in nature. As they are tropical in origin it is not too hypothetical to expect them to exhibit higher stress tolerance.

The composition of tree species varied considerably among the three landscapes. From the population of each species in these three landscapes, it was found that most of the population has come from only few species and it varied with the landscapes. About 71 per cent of the total population is contributed by ten out of 43 species found in Avenue trees, while 52 per cent is constituted by ten out of 43 species found in parks while in Lake Ecosystem 93 per cent of trees were from ten out of 15 species found in this landscape (Table 2). This was further reiterated from the Shanon weiner's index which indicate the species richness and Jacquard β-diversity index (Table 5 & 6) that indicates the uniqueness of species in a given landscape (Maza *et al.* 2002). Similar type of results were reported by a study conducted in other part of Bangalore (Cornelis and Hermy, 2004; Sudha and Ravindranath, 2000). This further reiterates the fact that, although these species in general had higher stress tolerance the conditions prevailing in these three landscapes is not uniform and hence more suitable for certain species. It is important to understand these finer details of conditions prevalent in these landscapes which can help in addressing the urban pollution related issues more efficiently.

Further, the purpose of planting trees in these landscapes is different. For instance, trees planted on road side are planted with the intention of providing shade and therefore should have large canopy and also help in retaining more dust and suspended particles so that the air may remain clean, on the other hand in parks trees selected would be more of aesthetic value as people visit parks for relaxation. However, it is important to note that 46 tree species seen in these urban landscape contribute in conserving the tree diversity to a considerable extent. Ward 4 is one of 198 wards over 741 km^2 across Bangalore and urban tree planting is a common developmental program of Bangalore City Municipal Corporation. When loss of biodiversity is of critical concern, an increasing amount of research indicates that diversity plays an important role in long-term ecosystem functioning, trees planted in urban areas can make significant contribution in biodiversity conservation (Cornelis and Hermy, 2004). Many factors are contributing to biodiversity loss including habitat modification, competition from introduced species, human demand for certain species and products, and rapid environmental changes such as climactic fluctuations (Groombridge and Jenkins, 2002). Presence of 46 tree species in three landscapes is an indication of conservation of good number of tree species from urban tree planting.

Presence of species such as *Michelia champaca, Santalum album* which are considered to be vulnerable and *Saraca asoca* which is listed as endangered in Karnataka region according to IUCN red list of tree species (Anon. 2015) reiterate the importance of urban tree planting in biodiversity conservation. Thus a comprehensive study across the city can help in quantifying the biological diversity in the urban areas and also help in utilizing the urban landscapes more efficiently for conserving the biological diversity.

Apart from conserving tree diversity, another important ecosystem service provided by the standing trees is clean air for breathing and regulating atmospheric temperature. It is a fundamental biological process where in trees absorb carbon dioxide from the air and assimilate through the process of photosynthesis and also simultaneously release oxygen into the atmosphere. A rough estimation (Canada's national environmental agency) suggests that, on an average about 2.51 tons of oxygen is released from the standing trees per day. The carbon withheld or carbon sequestered in the trees from the above process is stocked in the tree biomass. Among the three ecosystems, avenue trees contributed maximum biomass (Table 3) followed by trees in the Parks and least was seen in Lake ecosystem. Among the tree species *Ficus benghalensis* in all the three landscapes recorded the highest biomass. Amount of biomass contributed from different tree species in three landscapes varied considerably. The biomass produced by the tree species depends on tree size which was quite evident from the similarity in the list and order of tree species seen among the top ten species across the three landscapes (Table 3 & 4). Basal area of trees is also an indication of the ratio of area occupied by the trees to the total land area of the region. Higher the area occupied by the tree, better will be the environmental protection (Sudha and Ravindranath, 2000). Among the three landscapes avenue trees had higher basal area (Table 3) as well as higher number of individuals (Table 1) resulting in higher area covered by the trees. Trees along the road side therefore contribute more towards absorbing the carbon dioxide released by the vehicles and also provide larger surface area in their foliage to accumulate dust and soot particles thereby help in providing clean air. A strong relationship is seen between the basal area and biomass as well as height of the tree among all the three landscapes (Table 12, 13 & 14) indicate that larger trees are better in both absorbing more carbon dioxide released by vehicular pollution and will also have larger canopy that absorb more particulate matter and also provide higher shade to the roads and provide comfort to commuters and also contribute in reducing fossil fuel consumption.

The amount of carbon sequestered by trees and thereby the amount of CO_2 removed from the atmosphere is derived from the biomass accumulated by the trees as explained in the methodology. A total of 3,144 tons of carbon which is equivalent to 11,538 tons of CO_2 is absorbed because of the tree cover in this region. Out of the total carbon sequestered, maximum contribution has come from avenue trees followed by trees in the park and least was seen in Lake Ecosystem (Table 7). This is mainly because of the more number of individuals in the avenue trees, as larger area is available along the road side compared to parks and lake. In order to understand how diverse tree species and their size contribute for assimilating atmospheric carbon, correlations were worked out. From this a close relationship between the biomass and basal area, biomass and tree density and basal area and density is noticed in all the three landscapes studied (Figure 1, 2 & 3). This suggests that both less density of larger trees or more density of smaller trees can contribute for removing carbon from the atmosphere. Further, the process of carbon assimilation (photosynthesis) that invariably occurs in leaves, the size of the canopy and leaflet size and other morphological features also play important role in photosynthesis process. Therefore both tree sizes as well as number of individuals are equally useful in abating carbon from the atmosphere. Thus from such analysis it is possible to identify suitable tree species to different landscapes based on the space available for tree planting. Tree cover data can also be useful in air pollution abatement was evident from a study where estimated average hourly improvement (in-leaf season) in air quality owing to trees ranged from 0.002 per cent for carbon monoxide to 0.4 per cent for particulate matter. Maximum hourly improvement for the area was estimated at 1.3 per cent for sulfur dioxide, though localized improvements in air quality can reach 5-10 per cent in areas with relatively high tree cover (Nowak, 1994). Thus from such studies it is possible to understand variations in tree cover so as to take appropriate measures to increase tree cover in heavily polluted areas that will improve the urban environment.

Some important physiological features which enhance carbon dioxide uptake, photosynthetic efficiency and thus carbon sequestration include: Tree crown architecture, phyllotaxy, number and orientation of stomata on leaf surface, availability of CO_2 around stomata, stomatal aperture and conductance etc. (Tripathi, 2016). A detailed study of all these aspects will provide clear insight in understanding whole process of plant response to environment. However in order to understand the physical aspects of pollution individual leaf size was analyzed plays an important role in regulating some of the environmental characters such as abating the dust, particulate matter and other obnoxious gases that has direct impact on health. Trees with larger leaves and larger canopies help in retaining more such matter on their surface area (Smith, 1984; Fowler, 1985). Adsorption of these particles also depends on some of the morphological characters of leaf such as presence of epicuticular wax on the leaf surface, presence of hairy structures on the leaf, etc. (Das and Pattanayak, 1977). From the current study for instance; it is found that *Pongamia pinnata* which constituted 16 per cent of the total population (Table 2) had relatively higher wax content (Table 11) and also reasonably larger canopy spread (Table 9) and therefore help in retaining higher amounts of pollutants on their leaves (Rowntree and Nowak, 1991; Nowak, 1994). Total areal space occupied by the tree canopy of all the trees in the entire study area was found to be 0.82 km^2 which accounts for 16.7 Per cent of the total study area. This is to further advert the importance of role of tree foliage in pollution abatement. Trees with varying leaf area and canopy size can be utilized depending upon the space available as well as the purpose. Trees with more number of such morphological features in combination with the tree size and density will have better ability to remove more pollutants from the air (Das and Pattanayak, 1977). The particles retained on the leaf would be discharged when it is washed away in rain water or when these leaves are shed from the tree, by which the pollutants are disposed in a less harmful way. Hence choice of *Pongamia pinnata* is a good choice. Hence planting tree species with such specific characters in the area of higher pollution zones can help in reducing particulate matter to considerable extent.

From the above results it is clear that it is essential to make provisions to grow trees on the road side as avenue trees. It is also essential to dedicate land for parks which will act as lung space especially for elderly people. Utilizing available water bodies as well as any possible land to grow trees can help not only in conserving biodiversity but also provide that contribute in provide many environmental benefits.

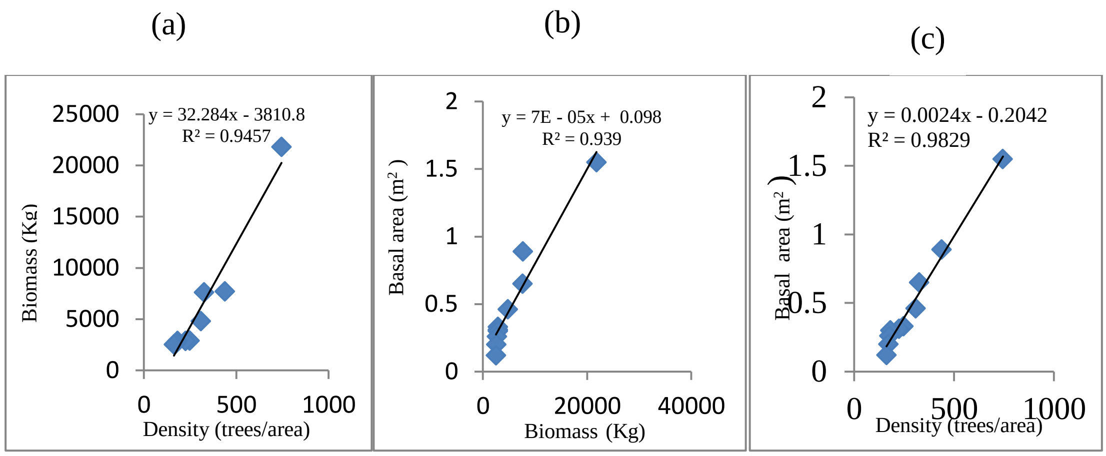

Fig. 1: Relationship between the Biomass & density (a), basal area & biomass (b) and basal area & density (c) of avenue trees

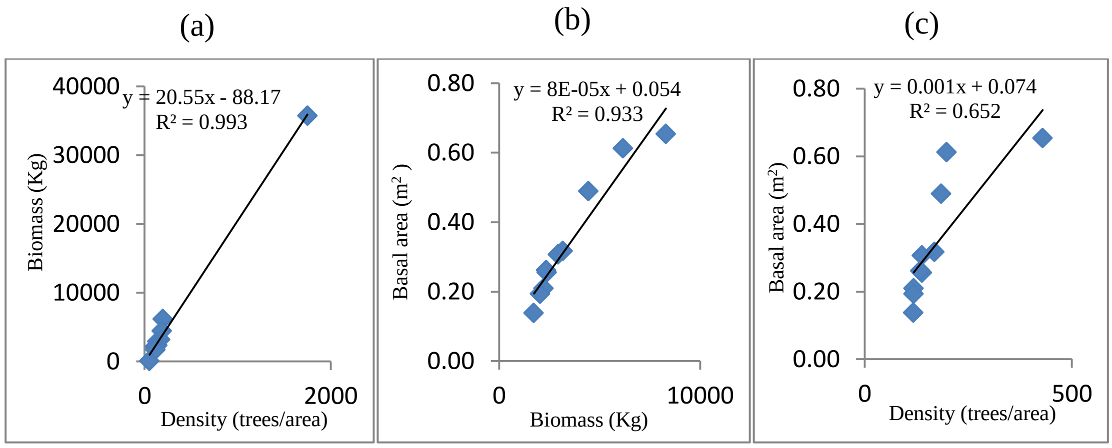

Fig. 2: Relationship between the Biomass and density (a), biomass and basal area (b) and basal area and Density (c) of trees in Parks

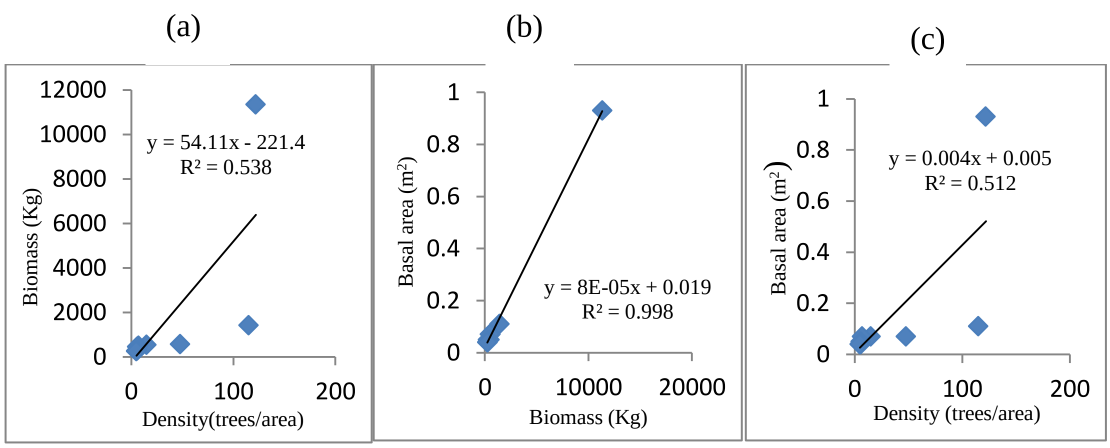

Fig. 3: Relationship between the Biomass and density (a), biomass and basal area (b) and basal area and Density (c) of trees in Lake

VI. SUMMARY

India is considered to be one of the fast growing economies in the world. Economic progress of the country has seen a wide range of developmental activities especially centered around major cities in India. This has led to large scale urbanization resulting in considerable reduction of green cover due to reduction in forests and agricultural land adjoining the cities. Such land use changes can have serious implication on the local environment and human health and cascading changes are clearly shown to create imbalances in the natural ecosystem and contribute towards global climate change.

Bangalore is popularly known as garden city of India and is one of the rapidly growing cities of India. In the past few decades city has significantly grown. It is important to take measures to maintain a healthy and clean environment along with the developmental changes. Present study is an effort to assess the benefits derived from the trees planted in major landscapes in one of the new extensions of Bengaluru city with a total area of 4.9 km^2. The tree diversity and carbon stocks in avenue trees, parks and lake landscapes was assessed to understand the tree diversity existing, carbon dioxide removed from the atmosphere and oxygen released from these standing trees which helps in climate amelioration.

From the study it is found that a total of 7854 trees present in three landscapes belonging to 46 different tree species from 25 different families, with an average tree density of one tree per every 1.6 m^2. Out of 46 species, highest population is contributed from *Pongamia pinnata* followed by *Bauhinia purpurea, Dolichandrone platycalyx, Azadirachta indica, Lagerstroemia flosreginae, Michelia champaca, Peltophorum pterocarpum, Spathodea companulata, Swietenia mahogany, Tabebuia avellanedae* species. Out of these 46 species *Michelia champaca, Santalum album* is found to be vulnerable and *Saraca asoca* was found to be endangered in Karnataka region according to IUCN red list of tree species. Thus, urban tree planting is of considerable use in conserving the dwindling biodiversity, which is one of the major ill effects of climate change.

Another important environmental benefit derived from the urban trees is removing atmospheric carbon dioxide and enriching air with life saving oxygen, both of which will enhance the air quality. About 11,538 tons of CO_2 is removed from the atmosphere and 2.51 tons of oxygen is added to the air because of the presence of trees in study area.

Study also indicates that, a total area of 0.82 Km^2 area is covered by the tree leaf canopy. Such a large areal space occupied by leaf canopy help in retaining dust and particulate matter released due to increasing vehicular movement. Various leaf morphological and biochemical characters of forty six different tree species make significant contribution in improving the air quality within the city and contribute towards reducing air pollution.

With these environment and social benefits realized from urban tree planting in a cost effective manner, it is imperative to rationalize tree planting in cities religiously with the city expansion so as to achieve the sustainable healthy and aesthetic environment.

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VII. APPENDIX

Sl. No	Binomial name	Family	Common Name
1	*Albizia lebbeck* (L.)Benth.	Fabaceae	Baage
2	*Alstonia scholaris* (L.) R.Br.	Apocynaceae	Devil tree
3	*Anthocephalus cadamba* (Roxb.)Miq	Rubiaceae	Kadamba
4	*Araucaria columnaris* J.R.Forst.Hook.	Araucariaceae	X-mass tree
5	*Artocarpus heterophyllus* Lam.	Moraceae	Jack Fruit
6	*Azadirachta indica* A.Juss.	Meliaceae	Neem
7	*Bauhinia purpurea* L.	Fabaceae	Basavanapaada
8	*Bixa orellana* L.	Bixaceae	Achiote
9	*Callistemon lanceolatus R.Br.*	Myrtaceae	Bottle Brush
10	*Cassia spectabilis* DC.	Fabaceae	Golden Cassia
11	*Cocos nucifera* L.	Aracaceae	Coconut
12	*Couroupita guianensis* Aubl.	Lecythidaceae	Nagalinga
13	*Dalbergia sissoo* Roxb.	Fabaceae	Indian Rosewood
14	*Delonix regia* (Bojer ex Hook.) Raf.	Fabaceae	Gulmohur
15	*Dolichandrone platycalyx* (Baker)	Begnoniaceae	Nile Tulip Tree
16	*Eucalyptus globulus* Labill.	Myrtaceae	Eucalyptus
17	*Ficus benghalensis* L.	Moraceae	Banyan tree
18	*Ficus racemosa* L.	Moraceae	Indian Fig
19	*Ficus religiosa* L.	Moraceae	Pipal tree
20	*Grevillea robusta* A.Cunn. ex R.Br.	Proteaceae	Silver Oak
21	*Hyophorbe lagenicaulis* H.E.Moore	Aracaceae	Bottle Palm
22	*Jacaranda mimosifolia* D.Don	Bignoniaceae	Jacaranda
23	*Kigelia pinnata* (Lam.) Benth.	Bignoniaceae	Sausage Tree
24	*Lagerstroemia flosreginae* Retz.	Lithraceae	Queen’s Flower
25	*Mangifera indica* L.	Anacardiaceae	Mango
26	*Michelia champaca* L.	Magniliaceae	Sampige
27	*Millingtonia hortensis* L.f.	Bignoniaceae	Akasha Mallige
28	*Muntingia calabura* L.	Muntingiaceae	Singapore cherry
29	*Peltophorum pterocarpum* (DC.)	Caesalpiniaceae	Copper Pod
30	*Phyllanthus emblica* L.	Phyllanthaceae	Amla
31	*Plumeria alba* L.	Apocynaceae	Kaadusampige
32	*Polyalthia longifolia* (Sonn.)Thwaites	Annonaceae	Mast Tree
33	*Pongamia pinnata* (L.) Taub.	Fabaceae	Honge
34	*Enterolobium saman* (Jacq.) Prain	Fabaceae	Rain tree
35	*Santalum album* L.	Santalaceae	Sandalwood
36	*Saraca asoca* (Roxb.) Willd.	Fabaceae	Ashoka tree
37	*Schefflera actinophylla* (Endl.) Harms	Araliaceae	Umbrella Tree
38	*Spathodea companulata* P.Beauv.	Bignoniaceae	African Tulip Tree

39	*Swietenia mahagoni* (L.) Jacq.	Meliaceae	Mahogany
40	*Syzygium cumini* L.	Myrtaceae	Jamun
41	*Tabebuia argentea* Bureau	Bignoniaceae	The Tree of Gold
42	*Tabebuia avellanedae* Kuntze	Bignoniaceae	Pink Tabebuia
43	*Tabebuia rosea* DC.	Bignoniaeae	Pink Poui
44	*Tamarindus indica* L.	Fabaceae	Hunase
45	*Terminalia catappa* L.	Combretaceae	Kaadubadami
46	*Thespesia populnea* (L.) Sol.	Malvaceae	Bhendi tree