EXOTIC VERSUS NATIVE PLANT SPECIES ROLE IN URBAN BIOMASS CARBON SEQUESTRATION

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Abstract : The exotic plant species occurs virtually in all urban ecosystems. The exotic plant species were planted in urban areas with the aim of rapid greening that has resulted in rapid alteration of land use. The Pimpri-Chinchwad Municipal Corporation (Pune, India) area is no exception to this. During the field surveys 8,586 individual trees (67 species) of exotics were documented in sampled area (181 km^2). Total numbers of native trees were 2,757 in sampled area. After comparing between exotic and native species among four zones (residential, industrial, roadside and garden); the contribution of exotic species in carbon sequestration was more (1957.67 t) than the native ones (445.52 t). The overall biomass carbon was higher in exotic species (81%) than native ones (19%). The amount of carbon accumulated in individual trees showed higher variation among exotic and native species. Small tree size and low wood density results in less amount of carbon storage. These exotic species counted were high in number but most of these trees were of younger age (31 years old plantation started from 1983-2014). The gardens were developed on the barren land as well as old forest land (PCMC ESR, 2013-14) where the major vegetation was native trees. The biomass of individual exotic trees was not so high but altogether their carbon accumulation was higher (81%) than native species (19%). Homogenous plantations (*Leucaena leucocephala*) were preferred by respective authorities in all zones. The carbon sequestration potential (488.89 t/year) of such woody exotic species has added the advantage in this regard.

***IndexTerms* - Exotic species, native species, wood density, biomass carbon sequestration.**

I. INTRODUCTION:

Exotic species establish themselves in new geographical area and exponentially increase their population, thus out-competing the native species and usually bring change in ecosystem functions. According to Pokharkar et.al. (2009) and Punalekar et.al (2010) there is gradual change in species composition in urban area. Importance of forested areas in carbon sequestration is already accepted, and well documented, however very few attempts (Choudhari et.al, 2014; Hamed et.al, 2011; Shinde and Mahajan, 2015) have been made to address the carbon sequestration potential of exotic trees in urban expanse. The urban planners and landscape designers have always preferred the exotic species while planning for plantation programs. Despite the vital role played by urban trees in city environments, these are also contributing in climate change mitigation. Cities are net producers of carbon dioxide and have lower amounts of stored carbon. Exotic species are used to reduce deforestation and land degradation, as they are more productive. The most important beneficial approach was to increase biomass production.

During the initial plantation programs (1983) Pimpri-Chinchwad Municipal Corporation (PCMC) has given more attention on exotic species. This could be because of its fast growth rate and adaptability, in addition to the biomass production. However, in the later stages of plantation programs, the PCMC has also maintained the native flora very well and aware of the importance of native species. Eventually, it was equally important to establish the role of exotics in carbon accumulation. Therefore, the focus of this study was to assess the carbon sequestration potential of exotic species in PCMC area.

II. MATERIALS AND METHODS:

2.1 Study Area:

The city of Pimpri-Chinchwad is situated towards northeast of Pune and 160 km from Mumbai, the capital of state of Maharashtra. It is predominantly an industrial area, which has developed during the last four decades. Pimpri-Chinchwad is a major industrial hub and hosts one of the biggest industrial zones in Asia. The city is home to the Indian operations of major automobile companies like Tata Motors (formerly Telco), Premier limited, Bajaj Auto, Force Motors (formerly Bajaj Tempo), BEL Optronic Devices Ltd, Kinetic Engineering, and Daimler-Chrysler.

The establishment of the Maharashtra Industrial Development Corporation (MIDC) in 1961-62 considerably facilitated industrial development in the area (CMP-PCMC, 2008). The PCMC area is bounded by 73^0 40' E to 73^0 55' E longitudes and 18^0 30' N to 18^0 45' N latitudes (Fig. 1). The total geographic area is about 181 km^2. The topography is almost flat with an altitude ranging from 530 m to 566 m above MSL. The area is situated on the eastern fringe of Western Ghats. The temperature during winter ranges from 12 ^{0}C to 30 ^{0}C and during summer it ranges from 23^0C to 40^0C. Pimpri and Chinchwad are well connected to Pune, Mumbai and Nasik cities. The climate is generally moist dry.

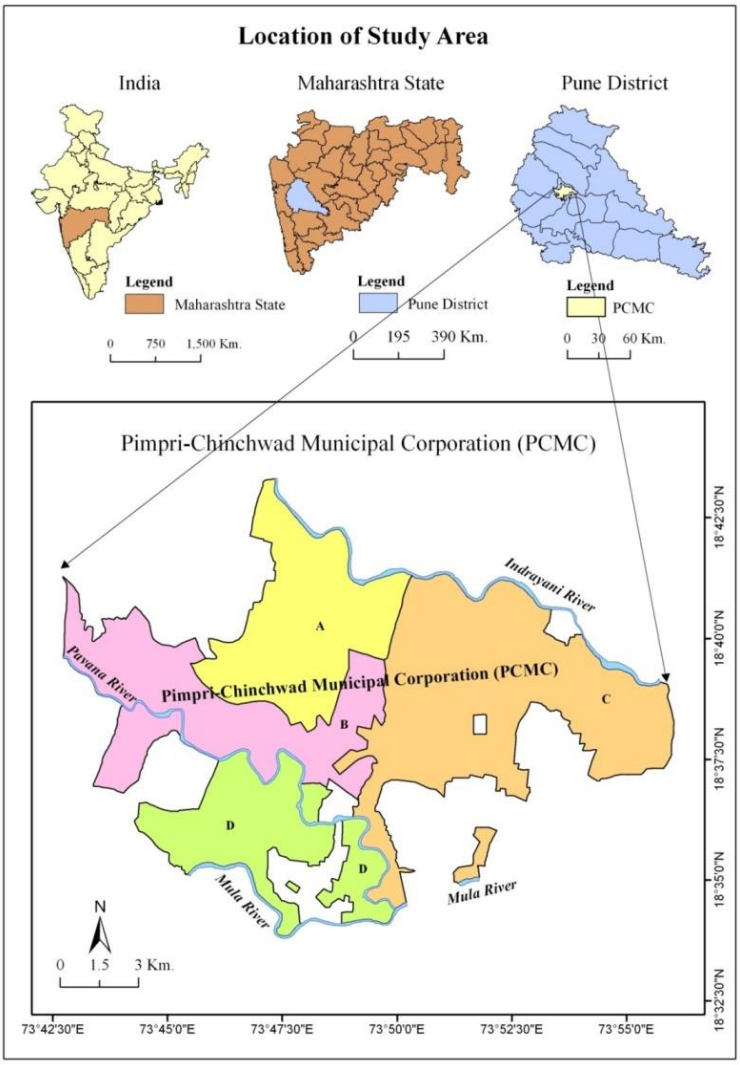

Fig. 1: The study area: Pimpri-Chinchwad, Pune.

The city is also home to India's premier antibiotics research institute - Hindustan Antibiotics Limited. In addition to this, several heavy industries such as Forbes-Marshall, Thyssen Krupp, Alfa Laval and Sandvik Asia have their manufacturing units in the city. Recently the New Software Park 'Rajiv Gandhi Info-tech Park' has been established with number of Software and Information Technology companies like Infosys, Wipro and TCS has started their operation bringing the city in the world's map. This has resulted into rapid growth of the city.

2.2 Sampling Strategy:

While designing the sampling strategy, the study area was primarily divided in to four zones based on the land use pattern and vegetation density. The four zones include roadside, garden, residential, and industrial zone (Table 1). The simple random sampling method was adopted (Ravindranath and Premnath, 1997). The area sampling method (*i.e*. quadrat) has been used. The size of quadrat was 25m x 25m for all zones except roadsides, where a 30m x 5m belt was used. The fig. 2 illustrates the sampling locations in the study area.

The quadrat method was utilized to quantitatively determine the distribution and abundance of perennial vegetation. Quadrat methods are useful for determining the distribution of native and exotic plants in an urban ecosystem. The total area was systematically surveyed for perennial plant species having girth of more than 10 cm at Breast Height (GBH). Total 228 quadrats were laid and data was collected from the respective quadrats. The total numbers of quadrats taken at each zone were added up. The data collected from each quadrat was analyzed quantitatively using standard formulae.

2.3 Sampling Design and Physical Measurement:

Carbon inventory methods suggested by Ravindranath and Ostwald (2008) were used for measuring the above and belowground biomass and estimation of carbon pool. All the terrestrial carbon pools were measured step by step. Random sampling was used to collect different variables since it was the most versatile, and scientific method for estimating above ground biomass. To apply simple random sampling technique, study area was alienated into large equal sized grids. In this method, the sample plots were laid out randomly to avoid the bias in locating the plots. Random sampling ensures that each point or grid in inventory area has an equal chance of being included in sample. Randomization made it possible to obtain unbiased estimates of variability as well as the mean per unit area.

Table 1: The sampling zones with total area sampled.

Zones	Total area (ha)	Total sampled area (m^2)
Roadside	2748.12	28125
Garden	176.51	44375
Residential	211.26	78125
Industrial	937.06	53750
Total	**4072.95**	**145000**

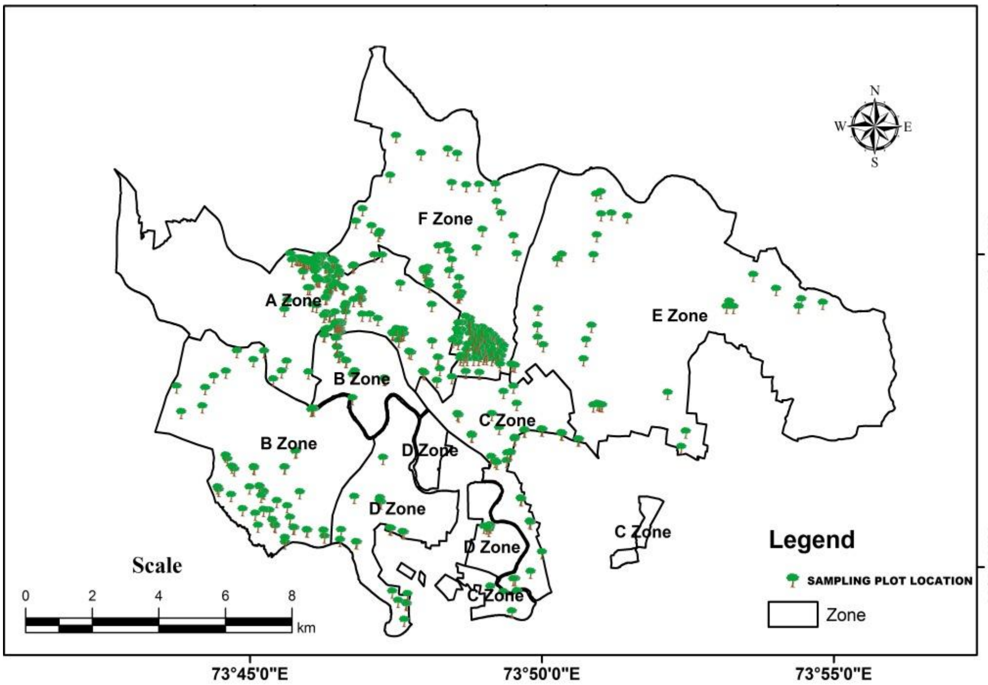

Fig. 2: Sampling plot locations in PCMC urban area.

2.4 Calculation of Above Ground Biomass (AGB):

Based on field survey and data collection such as height and DBH, calculation of biomass and eventually volume of sequestration were done. These values were used to estimate the volume of the trees, which eventually converted into weight using wood density. Sequestration was accepted as half of the core biomass of the plant. Method used involves the following steps:

Step 1: The height and DBH of all the trees in the sample plots were measured.
Step 2: All the recorded data including height and DBH were tabulated.
Step 3: Volume of each tree in the sample plot was calculated using the following formulae.

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

Where**:** V = volume of the tree in cubic centimeters or cubic meters
r = radius of the tree at 130 cm above the ground = DBH/2
H = height of the tree in centimeters or meters.

Step 4: Wood density values were obtained for each of the tree species from http://www.worldagroforestrycentre.org/sea/Products/AFDbases/WD/, or in case density was not available, 0.6 was accepted as wood density (Ravindranath & Ostwald, 2008).
Step 5: Dry weight of any tree was calculated from multiplying the volume of the tree with the respective wood density and convert the weight from grams to kilograms or tonnes.

(Weight of tree (g) = volume of the tree (cm^3) × wood density (g/cm^3))

Step 6: The weight of all trees of each species were summed in the selected sample plots (kilograms or tonnes for each species).
Step 7: In the next step the results were extrapolated from the weight of each species from the total sample area (sum of all the plots) to per hectare value (tonnes of biomass per hectare for each species).
Step 8: In the final step the biomass of each species was summed to obtain the total biomass of all the trees in tonnes per hectare (dry matter).

2.5 Below-Ground Biomass (BGB):

The below ground biomass was calculated based on the relationship between shoot and roots for a tree of a given species. The below ground biomass was obtained from multiplying above ground biomass in 0.26 as an indirect method to obtain the value of below-ground biomass (Cairns *et.al*, 1997).

III. RESULTS AND DISCUSSION:

Assessment of biomass provides information on the structure and functional aspect of trees. Biomass is an important indicator in carbon sequestration therefore estimating the biomass in trees is the first step in carbon accounting. The plant species were separated as native and exotic in each zone. The study revealed the documentation of 8,586 individual trees of exotics in sampled area that belong to 67 exotic species.

3.1 Residential zone:

The contribution of exotic species was estimated. It was 14.33 t (above-ground biomass), 3.73 t (below-ground biomass), 18.05 t (total biomass), and 8.67 t (carbon stock); whereas, the native species represents 9.33 t, 2.43 t, 11.76 t and 5.64 t respectively (Fig.3). The overall biomass carbon was higher in exotic species (65%) than native ones (35%). It was observed that the residents always preferred ornamental and horticultural trees of their choice. Most of these trees were exotic (*Samanea saman*, *Cocus nucifera*, *Peltophorum pterocarpum*, *Eucalyptus globulus* and *Polyalthia longifolia*) and contributed higher amount of carbon stock as compared to native tree species. Out of these exotic species the maximum amount of carbon stock was reported in *Samanea saman* (33.15 t), *Cocus nucifera* (26.37 t) and *Peltophorum pterocarpum* (23.42 t). Among native species, higher carbon stock was logged in *Azadirachta indica* (19.24 t) and *Mangifera indica* (19.16 t). The total biomass carbon accumulated in exotic species was 197.41 t; whereas in native species it was 105.59 t in sampled area (Fig. 3), indicating the dominance of exotics in number as well as biomass. The total biomass carbon after extrapolation in residential zone contributed by exotic species was 432.6 t.

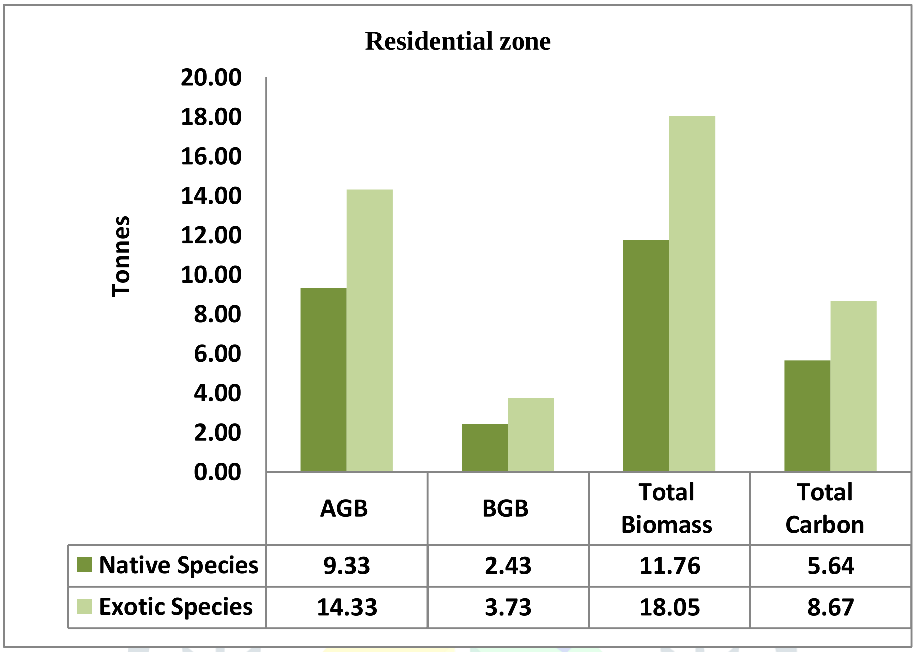

Fig. 3: Total of AGB, BGB, and carbon stock in exotic and native trees (t) in sampled residential zone.

3.2 Industrial zone:

This zone has represented the contrasting results as compared to the residential zone. The native species showed higher values towards AGB (10.43 t), BGB (2.71 t), total biomass (13.14 t) and carbon stock (6.31 t), than that of exotic species which showed the values *viz.* 4.54 t, 1.18 t, 5.72 t and 2.74 t, respectively (Fig. 4). In industrial zone dense vegetation of exotic species were observed. The populations of exotic species were abundant; however, their biomass was much less than that of native species. This was because of the recent plantations, and very high competition among the populations of same species. We have observed the thickets of *Leucaena leucocephala* in the plantations. The number of individuals of exotic species i.e. *Leucaena leucocephala* (1,821), *Gliricidia sepium* (596) and *Peltophorum pterocarpum* (536) were higher and the amount of stored carbon was 323.632 t, 135.203 t and 77.908 t, respectively. Overall, the native and exotic tree individuals were 459 and 3,183 respectively. Among the native species, highest amount of biomass carbon was recorded in *Albizia lebbeck* (12.59 t) and least in *Sesbania grandiflora* (0.004 t). Total amount of biomass carbon was 78.61 t and 589.386 t respectively, in native and exotic species. Overall, there was big difference in biomass carbon between native species (12%) and exotic ones (88%). The above results indicating the exotic species dominated in number as well as biomass. The total biomass carbon after extrapolation in industrial zone contributed by exotic species was 16,121.22 t.

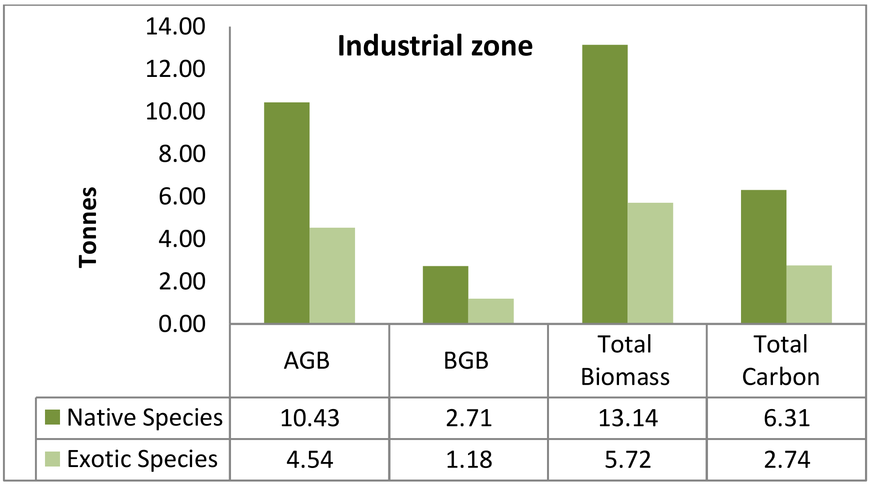

Fig. 4: Total of AGB, BGB, and carbon stock in exotic and native trees (t) in sampled industrial zone.

3.3 Roadside zone:

The roadside trees are vital in reducing pollution. They are at the proximity of vehicle emissions. Beckett *et.al*, (2000) found that roadside trees capture more large-size particulate matter than trees not near the road. We have selected this belt of vegetation for estimation of biomass carbon with special reference to exotic species. The biomass carbon along roadside native and exotic trees was estimated. The native species illustrated 20.14 t of AGB, 5.24 t BGB, 25.38 t total biomass and 12.18 t of carbon stock, whereas the exotic species demonstrated 22.30 t AGB, 5.80 t BGB, 28.09 t total biomass, and 13.49 t of carbon stock in sampled plots (Fig. 5).

It was also noticed that most of the exotic species along roadside were planted as ornamentals and landscaping purpose; and includes the bushy and scandent habit forms such as *Caesalpinia pulcherrima*, *Tecoma stans*, *Bougainvillea spectabilis* and *Lantana camara.* Among the exotic species higher amount of carbon stock was reported in *Samanea saman* (295.406 t) and lowest in *Thuja aphyla* (0.002 t). Among the native species, highest amount of carbon was recorded in *Ficus religiosa* (8.150 t) and lowest in *Lawsonia inermis* (0.002 t). Overall, the exotic species exhibited 419.919 t and native one showed 42.191 t total carbon stock in sampled area. The percentage of biomass carbon was highest in exotic species (91%) than native ones (9%) due to number of tree individual and total accumulated biomass. The total biomass carbon after extrapolation in roadside zone contributed by exotic species was 8,779.158 t.

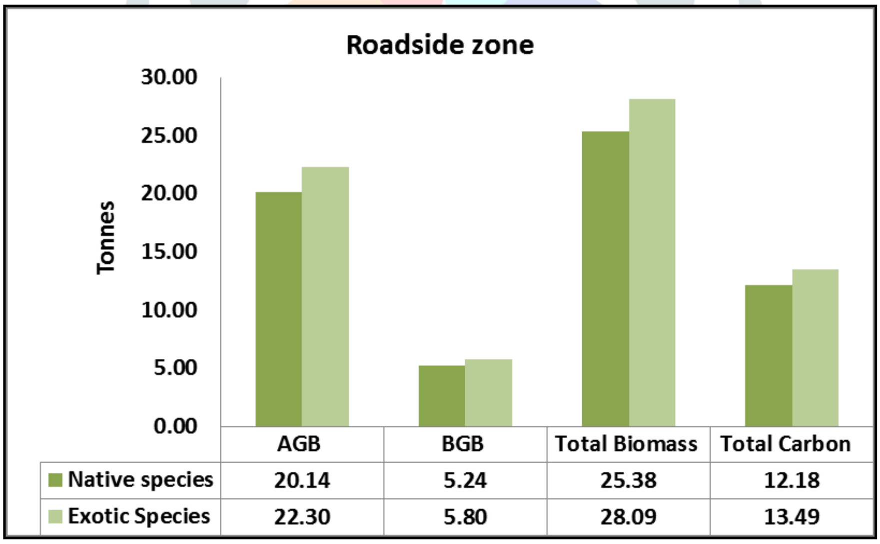

Fig. 5: Total of AGB, BGB, biomass and carbon stock in exotic and native trees (t) in sampled roadside zone

3.4 Garden zone:

Urban parks and gardens are considered as lungs of the cities and have the ability to eliminate significant amounts of air pollutants, thereby improving environmental quality (Nowak *et.al*, 2006); and provides a wide variety of ecological services. Development of sustainable green cities in the near future is the prior and important need of today's fast urbanizing world. The gardens were analyzed for biomass estimation. The native species illustrated 15.44 t AGB, 4.01 t BGB, 19.46 t total biomass and 9.34 t of total carbon stock; whereas, exotic species showed 14.07 t AGB, 3.66 t BGB, 17.73 t total biomass, and 8.51 t carbon stock (Fig. 6). In garden zone, the exotic and native tree species showed very less difference in total carbon stock value, indicated the young plantation of exotics (4,163 in number of trees) with mature plantation of native trees (1,407 in number of trees). In exotic species higher amount of carbon stock was estimated in *Samania saman* (33.88 t) and lower in *Tecoma gaudichaudi* (0.001 t). Among native species *Syzygium cumini* displayed higher amount (30.51 t) of carbon stock and *Aegle marmelos* exhibited lowest (0.0004 t). From garden zone, total carbon stock recorded in exotic species was 750.95 t and that of native species was 229.96 t. This result illustrates that the exotic species contribution in carbon accumulation was higher than the native species. The newly planted exotic species from garden zone were more in number. These were ornamentals (*Tabebuia sp*, *Delonix regia*), timber (*Acacia auriculiformis*, *Leucaena leucocephala*, *Kigelia pinnata*), and palms (*Roystonea regia*). The total biomass carbon after extrapolation in garden zone contributed by exotic species was 23598.35 t.

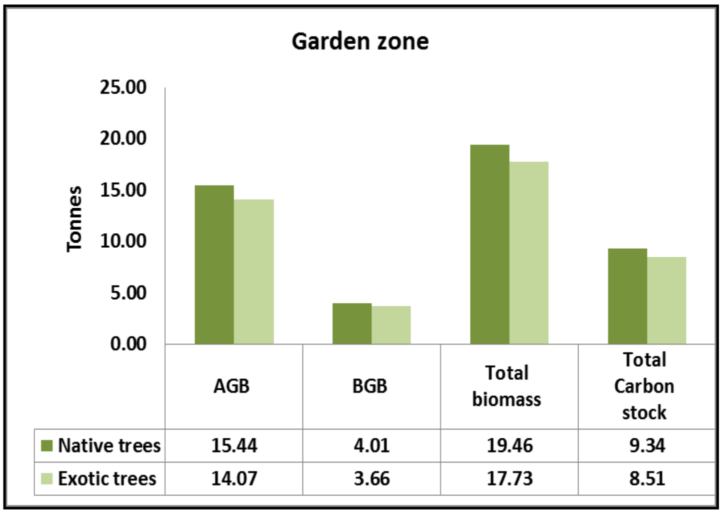

Fig. 6: Total of AGB, BGB, biomass and carbon stock in exotic and native trees (t) in sampled garden zone

After comparing between exotic and native species among four zones (residential, industrial, roadside and garden), it can be said that the exotic species has contributed more (1957.67 t) than the native ones (445.52 t). Total numbers of exotic trees were 8,586 and that of native were 2,757 in sampled area.

The overall biomass carbon was higher in exotic species (81%) than native ones (19%) (Fig. 7). Based on above results the sequence among the zones from highest to lowest (Fig. 8) amount of carbon was:

Total number of trees: Garden > Industrial > Residential > Roadside

Total carbon stock: Garden > Industrial > Roadside > Residential

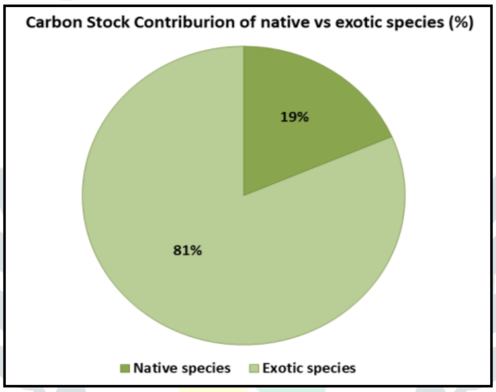

Fig. 7: Total carbon stock contribution (%) of native and exotic trees in sampled area.

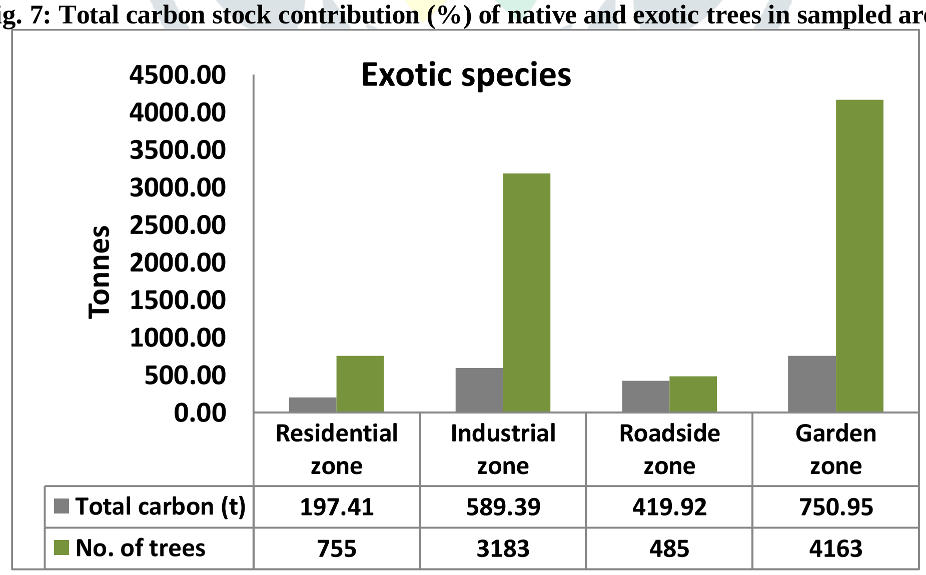

Fig. 8: Exotic trees- zone wise number of trees and carbon in total trees

The amount of biomass carbon stock at higher taxonomic level was also calculated. The taxonomic rank selected was 'family'. The amount of biomass carbon accumulated at family level among exotic species in decreasing order was Mimosaceae, followed by Caesalpiniaceae, Bignoniaceae, Annonaceae, Arecaceae and Myrtaceae; whereas among native species the order in decreasing manner was Moraceae, followed by Mimosaceae, Meliaceae, Poaceae, Caesalpinaceae and Anacardiaceae (Table 2). Among these families, carbon stock of exotic trees (1084.88 t) was highest in Mimosaceae while in native trees; carbon stock (114.85 t) was highest in Moraceae.

Table 2: Native and Exotic species contribution at higher taxonomic (family) level.

Zones	Native		Exotic	
	Family	Total carbon (t)	Family	Total carbon (t)
Residential	Moraceae	34.04	Mimosaceae	44.07
	Meliaceae	19.64	Caesalpiniaceae	41.23
	Anacardiaceae	19.20	Arecaceae	37.14
	Caesalpiniaceae	7.14	Bignoniaceae	21.31
	Myrtaceae	6.96	Myrtaceae	18.71
Industrial	Mimosaceae	23.80	Mimosaceae	328.29
	Meliaceae	17.43	Fabaceae	135.39
	Fabaceae	13.16	Caesalpiniaceae	105.30
	Moraceae	12.38	Myrtaceae	16.33
	Caesalpiniaceae	6.45	Bignoniaceae	2.30
Roadside	Moraceae	14.67	Mimosaceae	301.80
	Mimosaceae	6.24	Caesalpiniaceae	74.01
	Poaceae	6.08	Myrtaceae	8.89
	Anacardiaceae	4.88	Bignoniaceae	6.53
	Fabaceae	4.04	Fabaceae	6.24
Garden	Moraceae	53.77	Mimosaceae	410.72
	Poaceae	40.64	Caesalpiniaceae	166.57
	Myrtaceae	30.57	Arecaceae	88.07
	Meliaceae	25.14	Bignoniacea	23.13
	Caesalpiniaceae	15.46	Myrtaceae	18.73

The amount of carbon accumulated in individual trees showed higher variation among exotic and native species. Small tree size and low wood density results in less amount of carbon storage. Total tree carbon accumulation potential is also biased due to number of tree individuals and their fast growth rate (Campioli *et.al*, 2010). These exotic species counted were high in number but most of these trees were of younger age (31 years old plantation started from 1983-2014; The gardens were developed on the barren land as well as old forest land (PCMC ESR, 2013-14) where the major vegetation was native trees. While developing the gardens on such locations, the PCMC authorities have maintained these old trees as it is, and added new plantations. Most of these selected species were of exotic in nature that primarily includes *Luecaena leucophloea*, *Peltophorum*, *Gliricidia sepium*, *Samania saman*, *Tabebuia* sp. and palms. The biomass of individual exotic trees was not so high but all together their carbon accumulation was higher (81%) than native species (19%). Homogenous plantations (*Leucaena leucocephala*) were preferred by respective authorities in all zones. This was because of certain advantages of homogenous plantations over mixed species plantations (Piotto, 2008). Monoculture plantations are highly productive, relatively simple to manage and usually produce uniform harvest products (Kelty, 2006; Evans, 1992). On the other hand, native species have been identified to have the potential to perform as well as or even better than most commonly used exotic species (Wagner *et.al*, 2008; Lamb, 1998). According to Patwardhan and Warran (www.ranwa.org) from Pune University campus (166 ha) the exotic species like *Dalbergia melanoxylon* and *Gliricidia sepium* showed monoculture type of vegetation and covered 32% of area. *Dalbergia melanoxylon* – an exotic species, alone have sequestered 49% of total amount of carbon in Pune University Campus (Hamed, 2011); and was followed by *Gliricidia sepium* amounting 31% of carbon sequestration. During the present study, a massive plantation of *Luecaena leucocephala* and *Gliricidia sepium* was observed and quantified; in sampled area total numbers of trees were 2962 and 1521, respectively. The carbon sequestration potential (488.89 t and 148.70 t respectively) of such woody exotic species has added the advantage in this regard. Above results shows that the carbon pool of these fast growing *Luecaena leucocephala* was 17% and *Gliricidia sepium* accounted 6% among total carbon stock estimated in sampled area.

IV. CONCLUSION

There is a need to focus on the selection of trees in cities, not just with a view to easy maintenance as is currently the case, but to select an appropriate mixture of trees. If we observe the current trend across the cities for tree diversity, the exotics dominate the native species and the value of native species as a sustainable advantage is often ignored. Therefore, challenges towards building native biodiversity are needed as it may bring about ecological integrity and ability to sequester carbon in coherent landscapes. Native trees like *Azadirachta indica*, *Tamarindus indica*, *Ficus religiosa* and *Madhuca latifolia* are considered ecologically beneficial as they have relatively high efficiency of carbon fixation; these species may be suitable for checking urban pollution and may provide a good option for maximum carbon fixation apart from innumerable ecological services. Mixed planted forest of exotic and native species could be more efficient in sequestering carbon in an urban area than the monoculture plantation. The old and native trees are being cut or removed due to high pressure of urbanization process that includes road widening, construction of new buildings, etc. Pimpri-Chinchwad is one of the fast growing cities in India. For mitigating the various environmental issues like global warming and climate change, the sustainable development of urban vegetation will be helpful with purposes of carbon sequestration.

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