International Journal of Advanced Research in Biological Sciences
ISSN: 2348-8069
www.ijarbs.com
DOI: 10.22192/ijarbs Coden: IJARQG (USA) Volume 7, Issue 10 -2020

Research Article

DOI: http://dx.doi.org/10.22192/ijarbs.2020.07.10.016

Standing carbon stock assessment of woody perennials grown in AFRI, campus, at Jodhpur, Rajasthan

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Abstract

This study aims to determine the stand density, basal area and above-ground biomass (AGB) of mixed species plantation in the AFRI, campus, Jodhpur. Plants were identified and measured for height and diameter at breast height. Standing above-ground biomass and carbon stock were assessed using the allometry equations. The results revealed that the dominant species having a high carbon concentration included *Azadirachta indica* A. Juss (86.26 ton/ha), *Prosopis cineraria* (L.) Druce (23.95 ton/ha), *Acacia tortilis* (Forssk.) Hayne (14.59 ton/ha) and *Eucalyptus camaldulensis* Dehnh. (7.34 ton/ha). Shrubs like *Bougainvillea glabra. Choisy* (7.75 ton/ha), *Clerodendrum inerme* (L.) Gaertn (3.22 ton/ha), *Ziziphus nummularia (*Burm. f.) Wight et Arn. (2.20 ton/ha) and *Duranta repens* L. (2.11 ha/ton) showed maximum carbon concentration in them. This study highlights the role of urban tree cover in carbon sequestration and emphasizes the need for greater attention to be paid for the selection of trees as well as shrubs in cities as a urban forestry species. The urban green spaces with such rich plant diversity need to be conserved, especially with the help of the local population, in order to maintain biodiversity, a good environment and its services by improving the overall quality of life.

Keywords: AFRI, Allometric, carbon sequestration, Climate change, standing carbon.

Introduction

Plants are capital assets in urban areas by providing myriad of benefits to the urban dwellers. They provide shade, filter air pollutants, absorb greenhouse gases, improve property value and contribute to the aesthetic beauty (Prachi *et al.*, 2010). Landscaping by planting trees, shrubs and grass not only creates naturalistic and picturesque effects but also improves environmental quality and public health (Beard *et al.*, 1994). Tree in urban area offer the benefits of carbon storage and maintenance of climate condition by its geochemical processes (Chavan and Rasal, 2010). Increased urbanization and corresponding area under urban parks and green spaces also leads to enhance biological diversity, sequestering atmospheric carbon-di-oxide and serve as long term carbon sink (Munishi et al., 2008; De la Sota et al., 2019). However, extent of carbon sequestration depends on climatic conditions and types of species in the urban environment, which require assessment and quantification. Despite extensive evidences supporting the role played by urban green spaces in urban environments, urban planners and architects have often undervalued the role played by such trees. Estimation of carbon stocks in tree biomass (i.e., above and belowground) are necessary for reporting to the United Nations Framework Convention on Climate Change

(UNFCCC) also (Green *et al.*, 2007). In light of environmental management, biomass assessment is an important indicator in carbon sequestration and storage. Estimating above ground biomass (AGB) is therefore a useful measure for comparing structural and functional attributes of green patches. The calculation of biomass equations for the efforts to improve carbon budget estimates is based on the link between individual-tree and whole-stand biomass estimates, coupled with the assumption that wood mass is about 50% carbon (Ravindranath *et al.,* 1997). Photosynthetic process in plants fix carbon dioxide from the atmosphere and the carbon is stored in wood and other plant tissues (Dilling *et al.*, 2006). As more photosynthesis occurs, more CO_2 is converted into biomass, reducing CO_2 in the atmosphere and sequestering it in the plant tissues, i.e. above and below ground biomasses as a result of growth of different parts (IPCC, 2003; Gorte, 2009). Raising trees in different forms including urban aforestation plays important role in carbon sequestration and improving environmental quality (Chavan and Rasal, 2012). Despite extensive evidence of the critical role played by urban trees in city environments, urban planners and architects have often undervalued the role played by these trees as cities are net producers of carbon dioxide and have lower amounts of stored carbon and regarded widely as having lower biodiversity. If we are to make the cities of the future more sustainable we must learn to minimize and manage these ecological effects (Prachi *et al.,* 2010). The educational institutes also contribute significantly to the green cover of urban areas. Few studies also focus on the floral diversity of educational institutes (Patel *et al.,* 2010; Mulia *et al.,* 2010).

Jodhpur is second largest city and occupies an important position in the overall development of the state. The green spaces in the city area are unevenly distributed and not based primarily for the ecological aspects. The green space in the city is mostly restricted to colleges, University campuses, Institute campuses, parks and gardens. This study focuses on the floristic diversity and carbon stock of the green space developed at Arid Forest Research Institute, Jodhpur which harbors a rich floral diversity. The campus have been maintained for its greenery since 1995 and visited regularly visited by several students, researchers and the people involved in forestry activities. Floristic studies from virtual component of natural system may help suitable in develop greenery in an urban area to improve environment quality and related aesthetics benefits. In view of this assessment of sequestered standing carbon stock in tree species grown in campuses of universities, parks, and institutes is essential. Therefore by highlighting the diversity and role of tree cover in Carbon storage may be beneficial in selecting trees for maximizing ecological services and improving environmental quality of the urban areas.

Materials and Methods

Study area

Jodhpur is among the largest districts in the Rajasthan, covering a total geographical area of about 22850 km^2. Jodhpur occupied 11.6 percent of the total area of the arid zone of Rajasthan. The city is known as “sun city” because of the bright and sunny weather. Total population of Jodhpur is 3,687,165 individuals in 2011 (GoI, 2011). The climate of Jodhpur is generally hot.

The study was conducted at the Arid Forest Research Institute, Jodhpur, which is a premier research institute in the field of forestry situated in arid hot region of India. This region forms the part of Indian Thar Desert. Soils had low organic matter content (0.27%) and available P (10.2 mg kg^{-1} soil) and pH of 7.8 (Singh *et al.,* 2007). Microclimates over the study area (20.82 ha) is assumed as uniform considering the small size of the area. The average rainfall is around 380 millimeters, it varies widely. Temperatures are extreme throughout the period from March to October, except when monsoonal rain produces clouds to lower it slightly. In the months of April, May and June, high temperatures routinely exceed 40^oC.

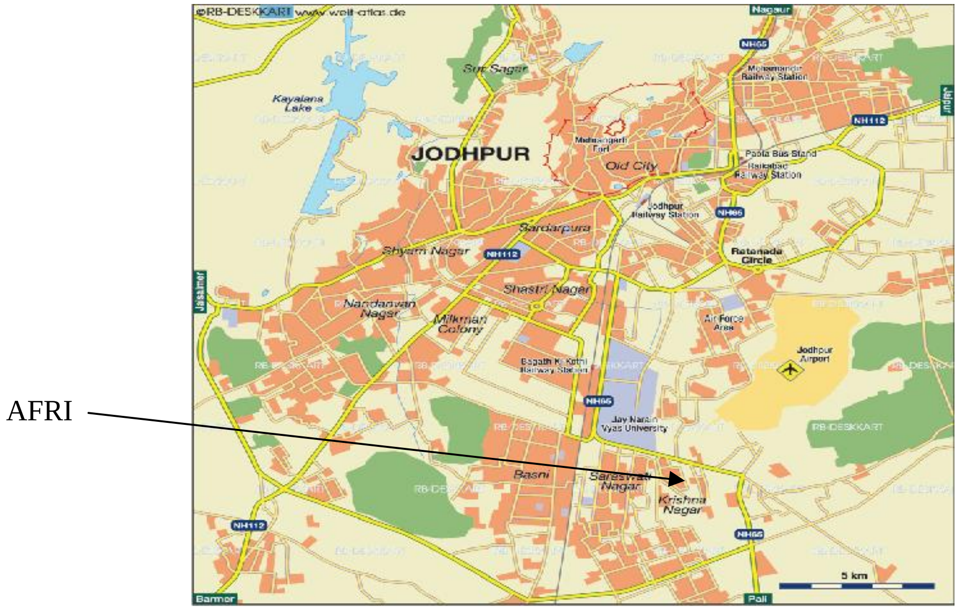

Figure: 1. Location of study area, Arid Forest Research Institute, Jodhpur

Data recording

Study was conducted in the month of April 2014 in AFRI, campus Jodhpur. Populations of trees and shrubs were recorded. Fifteen plots of 0.1 ha (31.6 m x 31.6 m) were laid randomly in the campus. Each species in the plot was counted and measured for diameter at breast height, ideal height and crown spread. Species richness, species diversity, species dominance, species evenness and importance value index (IVI) were calculated following standard procedures (Shannon and Weiner, 1963; Simpson, 1949; Mishra, 1968; Bhandari, 1990).

x (IVI) = Relative frequency + Relative Density + Relative Basal Area.

Data analysis

Data were analyzed using MS excel and SPSS statistical package. Both above ground and below ground dry biomass were calculated using regression equation developed by Singh (2014) for Rajasthan for both trees and shrubs. An amount of carbon stored in biomass was calculated by multiplying the estimated dry biomass by a factor of 0.4477 (Singh, 2014). Pearson correlation was also performed to observe the relationship between growth and diversity variables and above ground biomass as well as below ground biomass. Above-ground and below-ground biomass of trees was calculated using dbh of the trees and shrub using common regression equations developed at AFRI (Singh, 2014) and useful for Rajasthan. These equations are as below:

For trees

AGB (kg) = 0.181494261*D2.058650773 (1)
BGB (kg) = 0.084773863*D2.028825779 (2)

For shrub

AGB (kg)=1.422873-0.909824*D+ 0.199237(1)
RB (kg)=1.2214400.76480*D+0.138231*D2(2)

Whereas AGB is above ground dry biomass, BGB is below ground dry biomass and D is diameter at below height increase of trees.

Carbon stock refers to the amount of carbon stored in the forest ecosystem, mainly in living biomass. The total AGB and BGB obtained through above regression equation were converted to carbon stock using carbon conversion factor of 0.447 (Singh, 2014) like:

Carbon Stock (kg)=AGB/BGB (kg)x 0.4477

Results

Plant growth

Tree species showed a wide variation in their growth variability like dbh and crown spread. *Eucalyptus camaldulensis* attained the maximum average height (2066.7 cm) as well as DBH (39.28 cm) among the tree species (Table 1). It was followed by *Albizia lebbeck* (1360 cm), *Ceiba pentandra* (1350 cm) and *Leucaena leucocephala* (1300 cm) respectively. Palmgrows slowly showing less height (146.4 cm), where as *Holoptelea integrifolia* (6.81 cm) was lowest in dbh diameter. The lowest crown diameter was *Pongamia pinnata* (225 cm). *Ziziphus numularia* attained maximum height (480 cm) as well as collor diameter (55 cm) among the shrub species. It was followed by *Jatropha curcus* and Bougainvillea. *Clerodendrum inermae* were smallest in height (62.9 cm), where as *Aspergus recemosus* was lowest in collar diameter (3.25cm) (Table-2).

Table 1. Average growth data of tree species of AFRI Campus, Jodhpur (in 15 plots)

S. No.	Trees species	Height (cm)	DBH (cm)
1.	*Acacia nilotica* (L.) Del.	772.0	26.27
2.	*Acacia senegal* (L.) Willd.	640.0	11.15
3.	*Acacia tortilis* (Forssk.) Hayne	737.8	15.90
4.	*Ailanthus excelsa* Roxb.	548.3	20.54
5.	*Albizia procera* (Roxb.)Benth	1360.0	19.45
6.	*Alstonia scholaris* (L.) R. Br	672.2	17.20
7.	*Polyalthia longifolia* (Sonn.) Benth. & Hook. f	600.1	12.90
8.	*Azadirachta indica* A. Juss.	650.0	12.20
9.	*Balanites aegyptiaca* (L.) Del	628.5	11.15
10.	*Cassia fistula* L	1350.0	50.95
11.	*Ceiba pentandra* (L.) Gaertn	610.0	12.34
12.	*Colophospermum;* Kirk ex J.Léonard	1065.0	32.64
13.	*Dalbergia sissoo* Roxb. ex DC.	800.0	20.70
14.	*Delonix regia* (Boj. ex Hook.) Raf.	2066.7	39.28
15.	*Eucalyptus camaldulensis* Dehnh.	1250.0	36.62
16.	*Ficus religiosa* L.	267.7	6.81
17.	*Holoptelea integrifolia* (Roxb).Planch	1300.0	25.50
18.	*Leucaena glauca* (L.) Benth	146.4	16.65
19.	Palm species	225.0	3.10
20.	*Pongamia pinnata* (L.) Pierre	585.5	16.80
21.	*Prosopis cineraria* (L.) Druce	320.0	14.64
22.	*Roystonea regia* (Kunth) O.F. Cook, nom. cons	392.5	8.66
23.	*Tecomella undulata* D. Don	480.0	13.37
24.	*Terminalia catappa* L	593.3	9.95
25.	*Ziziphus mauritiana* Lam.	390.0	13.66

Table 2. Average growth variables of shrub species of AFRI, campus, Jodhpur (in 15 plots).

S. No.	Shrub species	Height (cm)	Collar diameter (cm)
1	*Bougainvillea glabra* Choisy	140.0	3.25
2	*Capparis decidua* (Forssk.) Edgew.	187.6	39.70
3	*Clerodendrum inerme* (L.) Gaertn.– embrert	150.0	10.74
4	*Commiphora wightii* (Arn.) Bhandari	62.9	13.31
5	*Duranta repens* L.	160.0	8.80
6	*Jatropha curcas* L.	163.3	23.45
7	*ecoma stans* (L.) Juss. ex Kunth	176.0	46.30
8	*Calliandra calothyrsus* Meisn	149.6	9.11
9	*Cryptostegia grandiflora* R.Br.	74.2	9.85
10	*Ficus* virgata Reinw. ex Blume. Blume, C.L. von	190.0	14.50
11	*Hamelia erecta Jacq.*	180.0	9.26
12	*Thuja occidentalis* L. eastern	232.9	16.00
13	*Ziziphus nummularia (*Burm. f.) Wight et Arn.	170.0	23.38
14	*Asparagus racemosus* Willd	164.0	27.60
15	*Calotropis procera* (L.) Dryand	64.6	5.71
16	*Withania somnifera* (L.) Dunal	480.0	55.00

Biomass

Calculation of carbon stock for under investigated area is 25 tree species and 15 shrub species present in 15 plots. The total above ground and below ground biomass and total carbon stock (kg/tree) in the trees studied is summarized in (Table 3). Total highest biomass (above ground, below ground) and Total carbon stock was observed for *A. indica* (19297.35, 8625.92 kg). It was followed by *P. cineraria* (5356.87, 2394.52 kg) and *A. tortilis* (3263.24, 1458.67 kg). Total average lowest Biomass (AB+BG), and Total Carbon Stock (AG+BG) was observed for *P. pinnata* (11.0042, 4.91 kg/tree) (Table 3; Fig.2) Highest average biomass per tree was recorded for *C. pentandra* (839.95 kg/tree) (Table.3)

Table 3. Average and total Biomass and Average and total carbon stock in tree species of AFRI, campus.

SNo.	Trees species Name	Pop/1.5 ha	Dia (cm)	Dry biomass		Carbon Stock	
				(kg/tree	kg/ha	kg/tree	kg/ha
1.	*A. nilotica*	5	34.71	441.18	2205.89	197.20	986.01
2.	*A. senegal*	1	11.14	37.26	37.26	16.65	16.65
3.	*A. tortilis*	27	16.19	120.86	3263.24	54.02	1458.67
4.	*Ailanthus excelsa*	6	20.54	258.86	1553.15	115.71	694.26
5.	*Albizia procera*	5	19.42	139.30	696.58	62.27	311.37
6.	*Alstonia scholaris*	9	17.19	94.82	853.39	42.38	381.46
7.	*P. longifolia*	4	7.96	19.50	78.01	8.72	34.87
8.	*Azadirachta indica*	306	12.89	63.06	19297.35	28.19	8625.92
9.	*B. aegyptiaca*	3	12.20	80.94	242.82	36.18	108.54
10.	*Cassia fistula*	26	11.14	42.82	1113.21	19.14	497.60
11.	*Ceiba pentandra*	1	50.95	839.95	839.95	375.45	375.45
12.	*Colophospermum*	8	16.63	48.74	389.97	21.84	174.31
13.	*Dalbergia sissoo*	2	32.64	385.68	771.36	172.39	344.79
14.	*Delonix regia*	1	20.70	132.54	132.54	59.24	59.24
15.	*E. camaldulensis*	4	34.63	410.17	1640.66	183.34	733.37
16.	*Ficus religiosa*	2	36.61	448.55	897.10	200.50	400.99
17.	*H. integrifolia*	28	6.82	14.34	401.55	6.41	179.49
18.	*Leucaena glauca*	1	25.47	202.86	202.86	90.67	90.67
19.	*Palm species*	7	16.65	87.07	606.90	38.75	271.28
20.	*Pongamia pinnata*	4	3.12	2.75	11.00	1.22	4.91
21.	*Prosopis cineraria*	38	19.10	140.97	5356.87	63.01	2394.52
22.	*Roystonea regia*	1	14.65	65.25	65.25	29.16	29.16
23.	*T. undulata*	1	13.376	54.15	54.15	24.20	24.20
24.	*T. catappa*	4	9.95	44.85	179.42	13.99	55.99
25.	*Z. mauritiana*	15	13.67	57.36	860.52	41.14	617.15

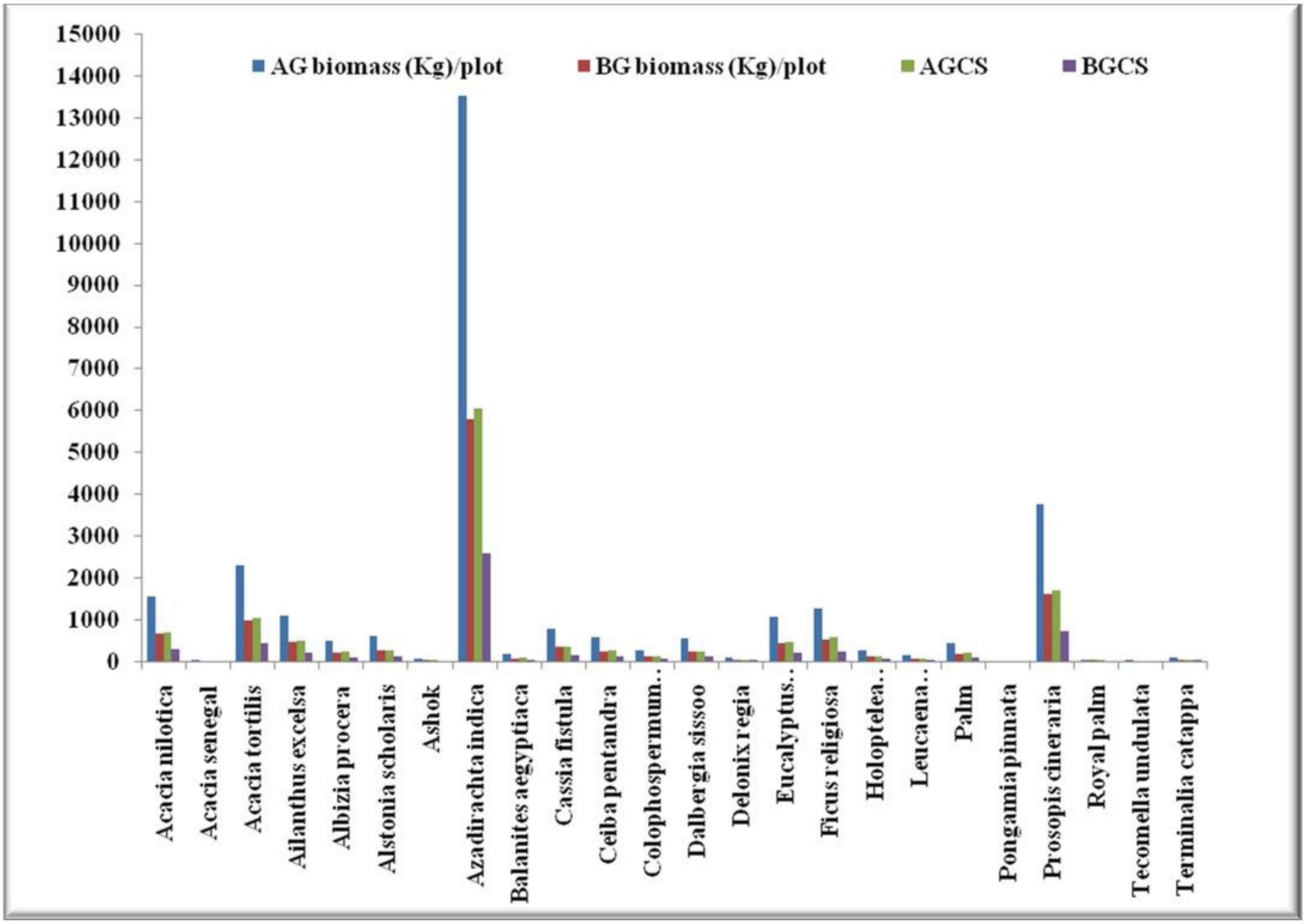

Fig. 2 Above ground and below ground biomass and carbon stock show in tree species

Maximum total above ground and below ground biomass and total carbon stock in the shrub species was recorded for *Bougainvillea* (1689.09, 755.02 kg). It was followed by *C. inerme* (1015.44, 322.13kg), D. *repens* (711.09, 211.97 kg), while lowest total above and below ground biomass and carbon stock was observed for *A. racemosus* (1.90 kg /shrub) (Table- 4).

Table -4. Average and total biomass and average and total carbon stock in shrub species.

S. No.	Shrub species Name	Population/1.5ha	Dia (cm)	Dr biomass		Carbon stock	
				kg/shrub	kg/plot	kg/shrub	kg/plot
1	*Bougainvillea glabra*	38	14.06	44.44	1689.1	19.87	755.02
2	*Capparis decidua*	1	14.74	46.59	344.81	20.83	154.13
3	*Clerodendrum inerme*	125	4.24	5.76	720.65	2.58	322.13
4	*Commiphora wightii*	26	7.02	5.32	37.25	2.38	16.65
5	*Duranta repens*	140	3.13	1.90	266.90	1.51	211.97
6	*Jatropha curcas*	29	5.44	3.13	90.91	4.11	119.30
7	*Tecoma stans*	14	10.73	33.91	1.31	15.16	40.64
8	*Calliandra calothyrsus*	1	3.42	0.60	0.60	0.58	0.58
9	*Cryptostegia grandiflora*	1	2.80	2.10	2.10	0.26	0.26
10	*Ficus virgata*	1	4.61	0.64	0.64	0.94	0.94
11	*Hamelia erecta*	1	2.94	0.58	2.25	0.28	0.28
12	*Thuja occidentalis*	9	7.44	6.05	4.91	7.88	70.89
13	*Ziziphus nummularia*	5	17.51	42	2.10	24.38	219.47
14	*Asparagus racemosus*	1	1.03	1.90	1.90	0.01	0.01
15	*Calotropis procera*	2	7.46	9.83	19.66	4.39	8.79
16	*Withania somnifera*	7	1.81	0.84	5.88	0.04	0.30

The highest mean biomass and carbon stock was observed in shrub species *C. deciduas* (46.59, 20.83kg/shrub). It was followed by *Bougainvillea* (44.44, 19.87 kg/shrub), *Z. numularia* (42, 24.38kg/shrub) *T. stans* (33.91, 15.16 kg/shrub) shown (Table- 4; Fig 3).

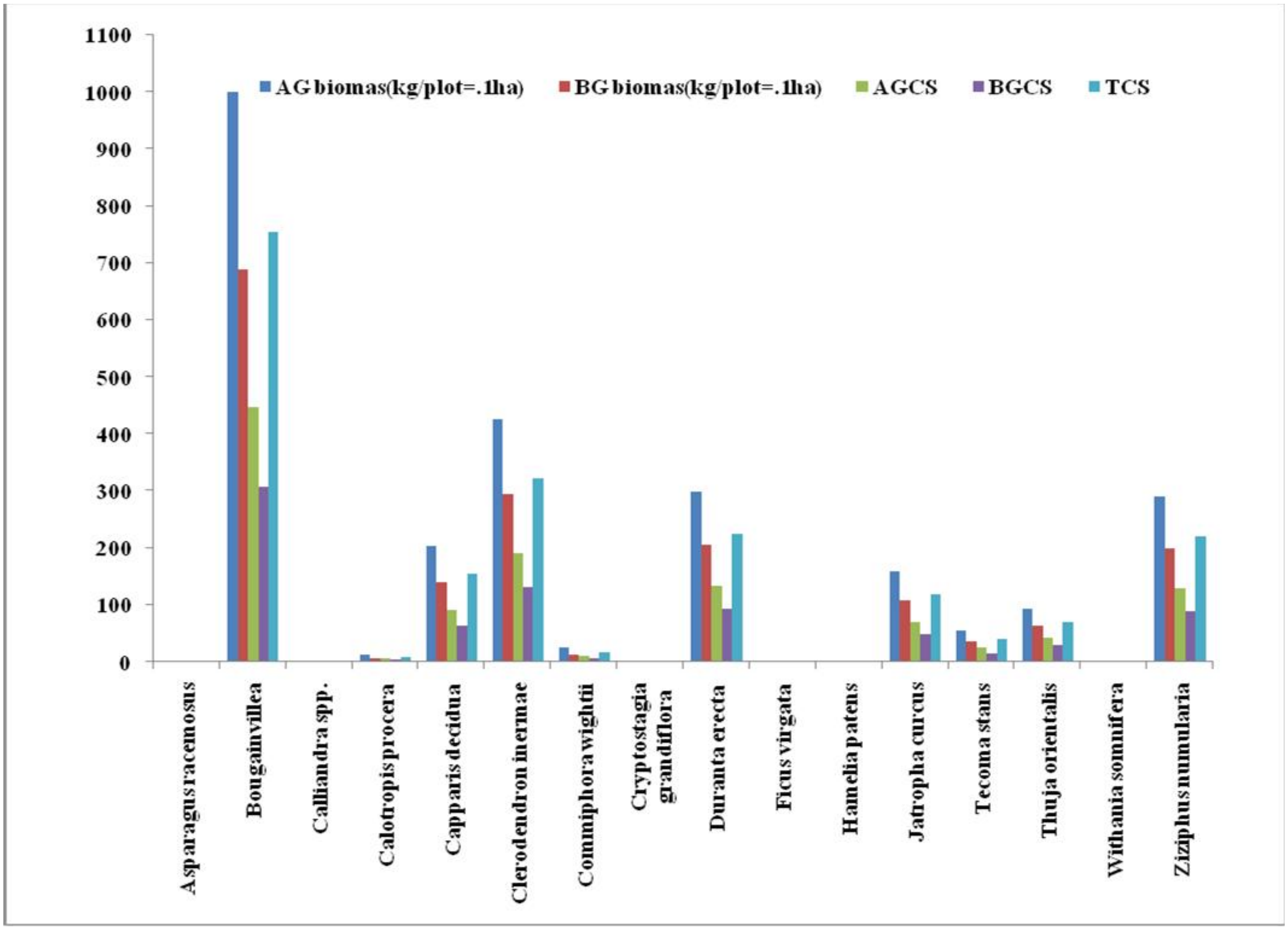

Fig. 3 Above ground and below ground biomass and carbon stock show in shrub species.

Discussion

Absorption of carbon dioxide (CO_2) from the atmosphere in photosynthetic process and its subsequent storage in the biomass of growing trees or plants is the carbon sequestration (Baes *et al.,* 1977). Thus tress contributes to capturing carbon and reducing atmospheric CO_2 and helps mitigate climate change. Growing trees in urban areas can be a potential contributor in reducing the concentration of CO_2 (atmospheric) (Mathews *et al.,* 2000). Gupta *et al*. (2012) assessed the performance of few ornamental plant species like *Alstonia scholaris*, *Bougainvillea glabra*, *Ervatamia divaricata* and *Hibiscus rosa-chinensis* in different combination with turfgrass and soil tilling intervals and the result some results of these species in form of height/crown diameter with turfgrass and without turfgrass are reported. This revealed positive associations among the plant communities in maintaining species diversity. 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 micro-climate. For examples urban areas in the United States have doubled during 1969 to 1994, and currently occupy 3.5% of the land base with an average tree cover of 27.1% (Dwyer *et al.,* 2000; Nowak *et al.,* 2001). Urban areas continue to expand and play a significant role in environmental quality and human health. Urban forests sequester atmospheric CO_2 and affect the emission of CO_2 from the urban areas, thus play a critical role in helping combat increasing levels of atmospheric carbon dioxide. The first estimate of national carbon storage by urban trees was reported to 350 and 750 million tons for Oakland, CA city for USA (Nowak, 1993). A study of 439 cities in China in 1991 indicates that the overall green space was 380,000 ha or 20.1% of the urban area. Some 40% of the cities China had more than 30% green cover in 1991 (Ming and Profous, 1993). The green space coverage and public green area per capita were 16.9% and 3.5 m², respectively, in 1986 and increased to 23.0% and 6.52 m² by 2000 (Wang, 2009). Further, by the end of 2006, greening coverage in China's cities has increased to 32.54%.

Since 1994 about 34 million trees were planted in and around Nanjing city, China Beijing municipality, i.e. 23 trees per city dweller. This has also enriched in vascular plant diversity (2,276 species) including 207 species of conservation concern such as endemic, threatened and protected species during past two decades (Wang *et al.,* 2007). In India, except for a few cities, urban forests are not well-studied. There are, however, some studies on Bangalore (Sudha and Ravindranath, 2000; Nagendra and Gopal, 2010), Vishakapatnam (Mitra, 1993; Madan, 1993, Ahmedin, *et.al.*, 2013), and urban forest of Chandigadh (Chaudhary, P., 2006; Chaudhary and Tewari, 2010a, b) cities. Some studies on biodiversity and carbon storage are also available for Bhopal (Dwivedi *et al.;* 2009), Delhi (Khera, 2009), Jaipur (Verma, 1985), Mumbai, (Zérah, 2007), Ahmedabad, (Nainesh *et al.;* 2013), Pune (Patwardhan *et al*., 2001) and Delhi (FSI, 2009). About 600 trees in one acre area in the tropics sequester up to 15 tons of CO_2 annually (Nowak, 1994). Brack (2002) reported the effect of 4, 00,000 trees planted in Canberra in recruiting combined energy and reducing pollution together with mitigation and carbon sequestration value of US$20–67 million during 2008–2012. Yang *et al*. (2005) estimated the storage of carbon dioxide (CO_2) in biomass of urban forest amounted to about 0.2 million tons in Beijing. Chauhan and Rasal (2009, 2011a) estimated standing carbon stock in selective tree species of University campus at Aurangabad, Maharashtra, where above ground biomass of *Ficus religiosa* was 4.27 tons per tree, *Ficus Benghalensis* was 3.89 tons per tree, *Mangifera indica* 3.13 tons per tree, *Delonix regia* 2.12 tons per tree, *Butea monosperma* 2.10 tons per tree, *Peltophorum pterocarpum* 2.01 tons per tree, *Azadirachta indicaAzadirachta indica* 1.91 tons per tree, *Pongamia pinnata* 1.57 tons per tree. The study emphasize that when the urban trees are young the standing carbon stock is not substantial, however, the growth of the trees represents a potential increase in biomass and hence carbon sequestration is dependent on the growth rate

All these studies highlighted the importance of trees outside forest particularly the urban trees focusing on non-forested but tree dominated areas including avenues plantation in public gardens, forests, cities open areas etc. A large quantity of carbon is sequestered and the quality of air can be improved around habitation and the city areas by effective planning and plantation.

Conclusion

Urban dwellers need to recognize and articulate the importance of urban trees as a vital component of the urban landscape. There is a need for greater attention to be paid to the selection of trees in cities, not just with a view to easy maintenance as is currently the case, but to select an appropriate mix of trees because if we view the current trend across the cities for tree diversity, the exotics dominate the native species and the value of native species as an sustainable asset is often ignored therefore challenge towards building native biodiversity is needed as it may bring about ecological integrity and ability to sequester carbon in legible landscapes. Native trees like *P. cineraria*, *A. nilotica*, *T. undulata* and *A. indica* 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.

Acknowledgments

We acknowledge the support extended by Director, AFRI and Sh. N. Bala Scientist-G, FRI, Dehradun for providing valuable inputs and suggestions.

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DOI:10.22192/ijarbs.2020.07.10.016	

How to cite this article:
S.R. Baloch, G. Singh. (2020). Standing carbon stock assessment of woody perennials grown in AFRI, campus, at Jodhpur, Rajasthan. Int. J. Adv. Res. Biol. Sci. 7(10): 156-167.
DOI: http://dx.doi.org/10.22192/ijarbs.2020.07.10.016