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Assessment of biomass and carbon stock of trees within the campus of IGNOU, New Delhi (India)

Evaluación de biomasa y stock de carbono de árboles dentro del campus de IGNOU, Nueva Delhi (India)

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ABSTRACT

This study aims to assess the biomass and carbon stock of the trees within IGNOU campus situated at the Indian national capital, New Delhi for an enhanced understanding about the carbon sequestration potential of the university campuses in urban setting. The aim of the paper is centered on the need to assess terrestrial carbon pools within a campus situated in the semi-arid forests of India which is significant for building suitable action plans for the purpose of managing ecosystems amidst the threat of anthropogenic climate change occurring due to rapid urbanization. The assessment of the biomass and carbon stock of the trees of the selected species within the campus was done by non-destructive method using allometric equations used prominently in previous studies identifying a total of 20 species of the trees comprising 1260 individual trees belonging to 14 different families of the trees. Findings of this study on identified campus trees, which comprised 1,260 individual trees, demonstrated to have moderate maturity in terms of storing carbon in the form of their biomass with the average DBH 25.34 cm. The values of their estimated total biomass and carbon stock were 75.26446 t/tree and 37.63223 tC/tree respectively. The maximum value of the total biomass 13.01 t/tree was of *Ficus recemosa*, and of the carbon stock 6.50tC/tree was of *Ficus recemosa*. *Azadirachta indica* species were found to be the most dominant species and their sampled trees were found to be able to sequester 537.526 tons of carbon in their standing biomass. The *Phyllanthus emblica* had the lowest carbon sequestration potential with 10.9 tons. This paper offers valuable insight with respect to the carbon sequestration potential of university campus situated in urban settings of a semi-arid forest ecosystem of Delhi by assessing the above- and below- ground carbon storage potential of the trees. The findings are of significance for different stakeholders including primarily future researchers, planners and decision-makers engaged in the process of urbanization.

Keywords: Biomass, Campus, Carbon Pool, Carbon Stock, Semi-arid forest, Sequestration.

RESUMEN

Este estudio tiene como objetivo evaluar la biomasa y las reservas de carbono de los árboles dentro del campus de IGNOU ubicado en la capital nacional de la India, Nueva Delhi, para comprender mejor el potencial de secuestro de carbono de los campus universitarios en entornos urbanos. El objetivo del artículo se centra en la necesidad de evaluar los reservorios de carbono terrestre dentro de un campus ubicado en los bosques semiáridos de la India, lo cual es importante para construir planes de acción adecuados con el fin de gestionar los ecosistemas en medio de la amenaza del cambio climático antropogénico que se produce debido a a la rápida urbanización. La evaluación de la biomasa y las existencias de carbono de los árboles de las especies seleccionadas dentro del campus se realizó mediante un método no destructivo utilizando ecuaciones alométricas utilizadas de manera destacada en estudios previos identificando un total de 20 especies de árboles que comprenden 1260 árboles individuales pertenecientes a 14 diferentes familias de los árboles. Los hallazgos de este estudio en árboles del campus identificados, que comprendían 1260 árboles individuales, demostraron tener una madurez moderada en términos de almacenamiento de carbono en forma de biomasa con un DAP promedio de 25,34 cm. Los valores de su biomasa total estimada y stock de carbono fueron 75.26446 t/árbol y 37.63223 tC/árbol respectivamente. El valor máximo de la biomasa total 13,01 t/árbol fue de Ficus recemos, y del stock de carbono 6,50 tC/árbol fue de *Ficus recemosa*. Se encontró que la especie *Azadirachta indica* era la especie más dominante y se encontró que sus árboles muestreados podían secuestrar 537.526 toneladas de carbono en su biomasa en pie. *Phyllanthus emblica* tenía el potencial de secuestro de carbono más bajo con 10,9 toneladas. Este documento ofrece información valiosa con respecto al potencial de secuestro de carbono del campus universitario situado en entornos urbanos de un ecosistema de bosque semiárido de Delhi mediante la evaluación del potencial de almacenamiento de carbono de los árboles por encima y por debajo del suelo. Los hallazgos son importantes para diferentes partes interesadas, incluidos principalmente futuros investigadores, planificadores y tomadores de decisiones involucrados en el proceso de urbanización.

Palabras clave: Biomasa, Campus, Reservorio de Carbono, Stock de Carbono, Bosque semiárido, Secuestro.

INTRODUCTION

Climate change and resultant global warming have been affecting humans negatively by having irreversible impact on the entire ecosystems of our planet (Kant & Anjali, 2020a). Rapid increase in greenhouse gases (GHGs) is known to be the primary cause of this change (Gupta & Bhatt, 2019). Carbon dioxide (CO2) constitutes an important components of all the GHGs, and is also the most important gas which is responsible for the global warming (IPCC, 2014). Its atmospheric level, which has continuously increased from its pre-industrial period level of 279 ppm through 393.84 ppm in 2012 to 395.15 ppm in 2013 is expected to show the concentration of main GHGs in 2100 in the range of 540 to 970 ppm resulting into the increase in the temperature by 1.8°C to 4.0°C (Narayana, Shashidhar, Nanda, & Savinaya, 2020; WMO, 2017). The anthropogenic activities in the urban areas are found to be the top contributor of the atmospheric level of CO2 (Avni & Chaudhry, 2016; Lahoti, Lahoti, Joshi, & Saito, 2020), and thus are responsible for the global anthropogenic climate change (Abdollahi, Ning, & Appeaning, 2000; IPCC, 2007) and global warming which are considered to be the major environmental issues of this century (Kant, 2020; Kant & Agrawal, 2020).

Urban forests play crucial role with the support of the carbon cycle in sequestering atmospheric CO2 and thereby mitigating global warming as well as climate change (Anjali, Khuman, & Sokhi, 2020; Livesley, McPherson, & Calfapietra, 2016; Nowak &

Crane, 2002). Tree cover in the urban settings across the globe is on decline giving rise to the increase in the impenetrable cover as a result of the increase in the demand of the area for development (Arya et al., 2017). Nonetheless, carbon sequestration offers itself as a natural atmospheric carbon removal mechanism by plants and soil which deposit it in the reservoir and thus can address these problems. It is defined as any of the few processes which remove excess atmospheric CO2 for moderating global warming (Subramaniyan, Jothi, Shoba, & Murugesan, 2017). Trees are the natural CO2 sink which fix carbon during the process of the photosynthesis and store carbon as their biomass (Lal, 2008). Trees in urban areas which are commonly known as urban forests are responsible for sequestering and storing carbon as they grow, affecting thereby local climate, carbon cycles, air temperature, climate change, energy use, and altering emissions, in the end, from different urban sources (Ragula & Chandra, 2020).

Carbon sequestration in the atmosphere is significant not only for environmental but also for socio-economic perspectives (Tripathi, 2016), and therefore mapping of carbon stock at various geographic levels is required for the establishment of the policies and the development of the strategies related to carbon sequestration in order to ensure mitigation of climate change (Anjali et al., 2020; Kant & Anjali, 2020b; Salunkhe, Khare, Kumari, & Khan, 2018). In addition to removal of atmospheric CO2, trees are ecologically important because of its functions for maintaining carbon cycle and decreasing pollution (Sahu & Sahu, 2015; Velasco, Roth, Norford, & Molina, 2016). The canopies of the trees are also responsible for the cooling of microclimate directly through shading the ground surface and indirectly through the process of transpiration (Subedi et al., 2010). Trees are also responsible for absorbing major pollutants including CO2 which are emitted by industries and automobiles restricting them from escaping to the upper atmosphere resulting into trapping of the heat and global warming. Tree plantation is therefore an important step for the mitigation of climate change (Nowak, 2010) which facilitates greater carbon sequestration in growing forests as an affordable alternative of climate change mitigation, contributing to the reduction in the global atmospheric carbon (Anjali et al., 2020; Arya et al., 2017; Marak & Khare, 2017). Naturally, forest ecosystems are known as a carbon reservoir which store huge amount of carbon and regulate its cycle exchanging CO2 from the atmosphere, acting as an important sink of carbon in the terrestrial ecosystem (IPCC, 2000).

The role of trees in the urban areas in decreasing GHGs including CO2 levels in the atmosphere has been recognized as a significant benefit which they do through carbon sequestration resulting into reduction of emissions and also conservation of energy while using it for the purpose of heating and cooling (Devi, 2017). Urban ecosystems play a dynamically significant role as regards reduction of air pollution and atmospheric carbon sequestration. Absorption of CO2 removing it from the atmosphere during and through the photosynthesis process and storing carbon as biomass by plants in the urban forests, road plantations, and many other areas help them serve as CO2 sinks (Kiran & Kinnary, 2011).However, only a limited number of successful studies in India have focused exclusively on estimation and sequestration of carbon and the potential of urban forests (Bhalla & Bhattacharya, 2017).

Tree dominated areas in urban settings are known as 'green pockets' which primarily include university campuses, streets, avenues and parks. They have received less attention from the urban planners and architects who have undervalued the role played by these trees ignoring the evidences supporting trees as important players in urban areas (Anjali et al., 2020). It s notable that tree covers in university campuses are significant contributors in carbon sequestration (Gavali & Shaikh, 2016). There have been fewer studies conducted with the focus on campuses of educational institutions such as universities (Potadar & Patil, 2017). The few such efforts in the past include studies on the potential of trees in urban areas for carbon sequestration conducted at Pune, India (Waran & Patwardhan, 2001) and at Aurangabad, India (Chavan & Rasal, 2010) which have showcased the context and underscored the need of the non-forested tree dominant areas such as university campuses for carbon sequestration. It is notable that university environment has suffered immensely due to the incessant increase of CO2 emission resulting from the increase in the consumption of energy and fossils fuel for the purpose of powering automobiles and running the facilities for effective learning, teaching, residence and administration within the campuses (Yunusa & Linatoc, 2018).

Variety of species of the trees within the campuses possess huge potential in terms of storage of substantial biomass and contributions to the environmental health (Avni & Chaudhry, 2016; Kongsager, Napier, & Mertz, 2013). Majority of the universities and higher educational institutions have, within their campuses, not only natural forests but also cultivated or managed plantations constituting huge carbon stocks in India and other countries across the globe (Anjali et al., 2020). Their carbon accounting offers huge potentialities in order to reduce carbon emissions not only at the global but also at the regional and national levels. New Delhi, the national capital of India, is considered to be one of the most polluted cities around the world despite having a unique forest ecosystem located on ridge areas which are actually the extensions of Aravalli hills in Delhi. They have a length of 32 km and are known to be serving plethora of ecological, environmental, and social functions (Meena, Bidalia, Hanief, Dinakaran, & Rao, 2019; Mayank Tripathi & Joshi, 2015). This part of the country also boasts to have the green campus of the Indira Gandhi National Open University, popularly known as IGNOU which is a central university under Ministry of Education, Government of India, spanning in around 150 acres at its headquarters at Maidan Garhi situated in the southern part of New Delhi. While this campus has variety of avenue plants representing plethora of species grown in the campus over the years, the multiple natural forest patches are also being maintained in their own natural set-up in the campus (IGNOU, 2020).

Delhi is a metropolitan city which has immensely urbanized over the decades losing its green spaces substantially. The paper attempts to make an assessment of the biomass and carbon stock of the trees within IGNOU campus situated at the Indian national capital, New Delhi. It aims to enhance understanding about the carbon sequestration potential of the campus of a university in urban setting by assessing the terrestrial carbon pools within a campus situated in the semi-arid forests of India which is significant for building suitable action plans for the purpose of managing ecosystems amidst the threat of anthropogenic climate change occurring due to rapid urbanization. The paper also aims to enhance understanding of the current diversity, composition and structure of the different species of the trees within the campus of IGNOU situated in the city considering that urban green spaces are reservoirs of carbon stock and their biomass and carbon stock must be assessed in order to evaluate their carbon sequestration potential. This paper offers huge potentialities by assessing the biomass and carbon stock of trees in IGNOU Campus in order to evaluate the ecological conservation values and carbon sequestration potential of trees in the IGNOU University Campus at New Delhi considering it a suitable case for addressing the challenges related to climate change and global warming.

MATERIALS AND METHODS

Study Area: The Indira Gandhi National Open University, popularly known as IGNOU, is a central university under Ministry of Education, Government of India. IGNOU, with its pan-india presence through its Regional Centres across the country, has its headquarters' campus spanning in around 150 acres at Maidan Garhi situated in the southern part of the Indian national capital i.e. New Delhi. The landscaping as well as the development of greenery including lawns & gardens in this sprawling campus spread over almost 120 acres are maintained by a designated Horticulture Cell (IGNOU, 2020; Nayak, Kant, & Anjali, 2020). Not only the campus but the entire neighboring areas are largely benefitted by the natural availability of the advantages of the green campus. The campus has variety of avenue plants of plethora of species including unusual and rare plant species which have grown in the campus over the years. In addition, multiple natural forest patches are also being maintained in their own natural set-up in the campus providing immense support to the campus in maintaining biodiversity (Anjali et al., 2020).

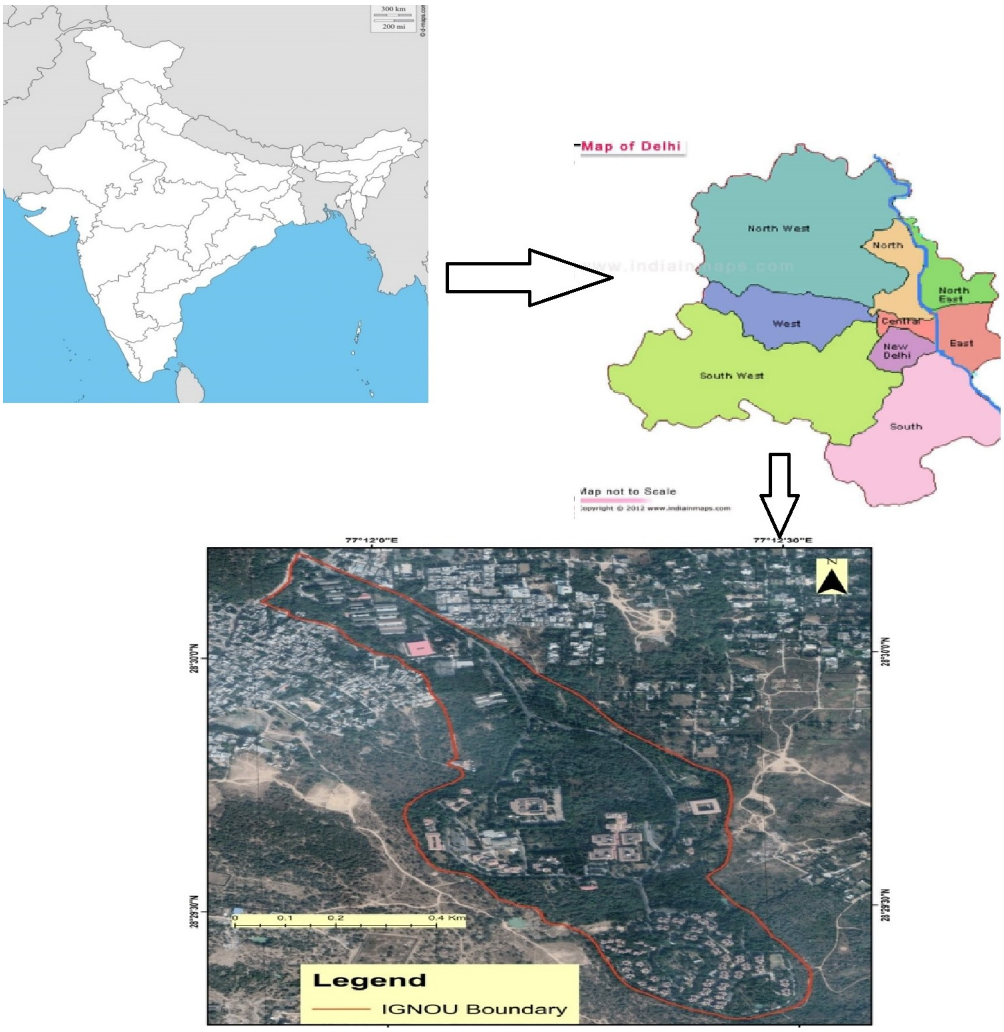

Figure 1. Location map of IGNOU (Retrieved from Google Earth)

This campus of IGNOU, which is a premier Open & Distance Learning (ODL) institution offering quality higher education, is situated in Delhi southern ridge of Aravalli Hills, and comes under sub-urban setting. It has ample vegetation cover which prominently includes gardens, parks, lawns, green roofs, internal planting etc., and covers in excess of 40 per cent of its total area. Approximately 34 per cent is covered with forest landscape. The study area located in the IGNOU campus lies at the Latitude of 28°30'01.06'' N and a Longitude of 77° 12' 03.45'' E with an average elevation of 250 m above mean sea level (Figure 1). This campus has a humid sub tropical climate where the temperature ranges from 5 to 40°C, and annual mean temperature is 25°C. It mainly receives an annual rainfall ranging between 600 to 800 mm. Vegetation of this part of Delhi is thorny scrub and is peculiar to arid and semi-arid region.

Data Collection_ Assessment of Biomass and Carbon stock of trees: In studies conducted for carbon assessment, Biomass is considered to be an important component (Anjali et al., 2020; Das & Mukherjee, 2015; Flora et al., 2018). Estimation of tree biomass can be done with the help of methods such as direct method and indirect method (Anjali et al., 2020; Salazar, Sanchez, Galiendo, & Santa-Regina, 2010), of which destructive sampling which is a direct method is used by harvesting trees for quantifying the biomass (Parresol, 1999; Salazar et al., 2010). Further, allometric equations with measurable parameters are used for quantifying the biomass of a tree in the indirect method which is known as the non-destructive method also (Gupta & Bhatt, 2019; Sundarapandian et al., 2014). Most of the studies in the past have used the diameter at breast height (DBH) for the estimation of the above-ground biomass for its strong correlations with the tree diameter (Anjali et al., 2020; Sandra Brown, 1996; Sandra Brown & Lugo, 1982; Ketterings, Coe, Noordwijk, Ambagau', & Palm, 2001). Additionally, a simple model which needs only the diameter as input has also been accepted as an effective method for the purpose of determining above-ground biomass (Pragasan, 2014). It is notable that not only local but global quantification of carbon sequestration done by trees is significant for tackling the menace of climate change (Stephson et al., 2014).

This study was conducted with the help of a non-destructive method basing it on the tree girth and height followed by DBH (Diameter at breast height). Tree diameter (D) was calculated by using a formula GBH/π where π= 22/7, i.e. GBH x 7/22 which actually is outcome of the division of π (22/7) by the actual marked girth of species (Bohre, Chaubey, & Singhal, 2012). Biomass was estimated for the identified tree species by application of bio-statistics based allometric equations. Height of the trees was found out with the help of pole method using the heights of electric poles within the campus. Allometric equations for biomass, in general, comprise tree Diameter at Breast Height (DBH in cm), total tree Height (H in m), and Wood Density (WD in gm/cm^3) (Tripathi, 2015). However, a standard average value of 0.6 gm/ cm^3 was used whenever wood density of specific plant species was not available (Patwardhan et al., 2003). Above ground Biomass (AGB) was assessed by multiplying the bio-volume with the wood density of tree species (Brown, Gillespie, & Lugo, 1989; Khan, 2013; MacDicken, 1997; Sundarapandian et al., 2014). Tree bio-volume (T_{BV}) value was established by multiplying diameter and height of tree species to a factor 0.4 as has been used in the previous studies (Das & Mukherjee, 2015). Total biomass is calculated by summing up the above and below ground biomass (Pandya, Salvi, Chahar, & Vaghela, 2013; Sheikh & Tiwari, 2013). Above Ground Biomass (AGB), Below Ground Biomass (BGB) and Total Biomass (TB) of the different tree species were calculated using allometric equations from non-destructive method of tree estimation. Carbon estimation is usually done for any species of the plant by considering its half (i.e. 50%) as carbon (Brown et al., 1989). An account of the parameters and formula used in the current study is presented below in Table 1.

Table 1. Parameters and formula used in the current study

Parameters under Study	Formula applied
Bio-volume($T_{BV)}$	(T) = 0.4 x $(Diameter)^2$ x Height
AGB(ton)	Wood Density x $T_{(BV)}$
BGB (ton)	AGB x 0.26
Total Biomass (TB)	Above Ground Biomass + Below Ground Biomass
Carbon Storage	Biomass x 50% (i.e Biomass/2)

RESULTS AND DISCUSSION

In the current study, a total of 20 species of trees at the study sites within the campus of IGNOU, which comprised 1,260 individual trees, were identified. Table 2 presents the descriptions of the identified species including their scientific names, common names, family names, wood density and abundance in terms of individual counting.

Table 2: Description of the Selected Species of the Trees within IGNOU Campus

	Scientific Name	Common Name	Family Name	Number of Trees	Wood Density (g/cm3)
1	*Azadirachta indica*	Neem	Meliaceae	106	0.7
2	*Casurina equistifolia*	Casurina (oak)	Casuarinaceae	61	0.83
3	*Cassia fistula*	Amaltas	Fabaceae	53	0.64
4	*Phyllanthus emblica*	Amla	Euphorbiacea	48	0.88
5	*Acacia nilotica*	Babool	Fabaceae	184	0.9
6	*Zizyphus jujube*	Ber	Rhamnaceae	37	0.33
7	*Ficus recemosa.*	Banayan	Moraceae	15	0.39
8	*Tecoma stans*	Tecoma	Bignoniaceae	110	0.6
9	*Holoptelea integrifolia*	Chillbil	Comberataceae	34	0.64
10	*Cresentia cujete*	Kamandal/Calabash	Lecythidaceae	44	0.6
11	*Callistemon viminalis*	Bottle brush	Myrtaceae	63	0.6
12	*Bauhinia purpurea*	Kachnar	Fabaceae	33	0.67
13	*Butea monosperma*	Dhak	Fabaceae	32	0.48
14	*Albezia lebbek*	Siris	Mimosaceae	209	0.53
15	*Tectona grandis*	Shisham	Lamiaceae	77	0.55
16	*Mimusop elangi*	Maulishri	Sapotaceae	20	0.72
17	*Delonix regia*	Gulmohar	Fabaceae	38	0.6
18	*Grevelia Robusta*	Silver Oak	Proteacea	42	0.6
19	*Dalbergia sissoo*	Shisham	Fabaceae	34	0.64
20	*Syzygium cumini*	Jamun/Java plum	Myrtaceae	20	0.69
	Total Trees			1,260	

Table 3 presents an account of the values of the parameters used in the current study for the assessment of biomass and carbon stock which included Average GBH & DBH (in cm), Average DBH (in m), and Average H (in m). The average DBH of all the tree species were found to be 25.34 cm which indicates that the trees are moderately mature for the purpose of storing substantial amount of carbon in the form of biomass that they have.

Table 3: Values of the Parameters used in the Study for assessment of Biomass and Carbon Stock

	Scientific name	Average GBH (cm)	Average (cm)	DBH Average (m)	Height (m)
1	*Azadirachta indica*	110	35.01	0.3501	18.2
2	*Casurina equistifolia*	65	20.70	0.2070	23.6
3	*Cassia fistula*	55	17.50	0.175	11.4
4	*Phyllanthus emblica*	40	12.73	0.1273	6.4
5	*Acacia nilotica*	78	24.82	0.2482	11.2
6	*Zizyphus jujube*	86	27.37	0.2737	11.9
7	*Ficus recemosa*	190	60.47	0.6047	21..4
8	*Tecoma stans*	60	19.09	0.1909	12.3
9	*Holoptelea integrifolia*	78	24.82	0.2482	18.6
10	*Cresentia cujete*	56	17.82	0.1782	08.0
11	*Callistemon viminalis*	60	19.09	0.1909	09.1
12	*Bauhinia purpurea*	50	15.91	0.1591	10.4
13	*Butea monosperma*	101	31.83	0.3183	13.3
14	*Albezia lebbek*	86	27.05	0.2705	12.6
15	*Tectona grandis*	90	28.64	0.2864	28.1
16	*Mimusop elangi*	76	23.87	0.2387	14 .7
17	*Delonix regia*	61	19.09	0.1909	14.2
18	*Grevelia Robusta*	55	17.50	0.1750	28.1
19	*Dalbergia sissoo*	131	41.38	0.4138	22.2
20	*Syzygium cumini*	70	22.28	0.2228	17.3
			25.34		

The values of the estimated total biomass and carbon stock of identified species of the trees within the campus of IGNOU are demonstrated in Table 4 as 75.26446 t/tree and 37.63223 tC/tree respectively (Table 4).

The maximum value of the total biomass 13.01 t/tree was found to be of *Ficus recemosa.* This was followed by 12.26 t/tree found to be of *Dalbergia sissoo and* 10.14 t/tree with the *Azadirachta indica.* The minimum 0.45998 t/tree was found to be of *Phyllanthus emblica* which was followed by 0.85784 t/tree found to be of *Cresentia cujete.* The maximum value of the carbon stock was found to be of *Ficus recemosa* having (6.50 tC/tree) which was followed by *Dalbergia sissoo* (6.13 tC/tree), and *Azadirachta indica* (5.07 tC/tree) respectively as the top three carbon content species of the trees within the campus. Majority of the species of the trees, however, had carbon content <1.5 tC/tree as per the values demonstrated in Table 4. Figure 2 demonstrates the contributions of the identified individual trees in terms of carbon stock.

Table 4: Estimated Values of Biomass and Carbon Stock of the Trees within IGNOU Campus

	Species	AGB	BGB	TB	Carbon
1	*Azadirachta indica*	6.24616	1.62400	10.14379	5.07189
2	*Casurina equistifolia*	3.35730	0.872899	4.23019	2.11509
3	*Cassia fistula*	0.89376	0.23237	1.12613	0.56306
4	*Phyllanthus emblica*	0.36507	0.09491	0.45998	0.22999
5	*Acacia nilotica*	2.48384	0.64579	3.12964	1.56482
6	*Zizyphus jujube*	1.17671	0.30594	1.48204	0.74102
7	*Ficus recemosa*	10.32922	2.68559	13.01482	6.50741
8	*Tecoma stans*	0.69926	0.18180	0.88107	0.44053
9	*Holoptelea integrifolia*	2.74996	0.71499	3.46496	1.73248
10	*Cresentia cujete*	0.68083	0.17701	0.85784	0.42892
11	*Callistemon viminalis*	0.79591	0.20693	1.00284	0.50142
12	*Bauhinia purpurea*	0/70818	0.18412	0.89230	0.44615
13	*Butea monosperma*	2.58717	0.67266	3.25984	1.62992
14	*Albezia lebbek*	1.95452	0.50817	2.46269	1.23134
15	*Tectona grandis*	5.07078	1.31840	6.38918	3.19459
16	*Mimusop elangi*	2.41220	0.62717	3.03938	1.51969
17	*Delonix regia*	1.24197	0.32291	1.56488	0.78244
18	*Grevelia Robusta*	2.0727	0.5389	2.61160	1.30580
19	*Dalbergia sissoo*	9.73136	2.53015	12.26152	6.13076
20	*Syzygium cumini*	2.37020	0.61625	2.98645	1.49322
	Total			75.26446	37.63223

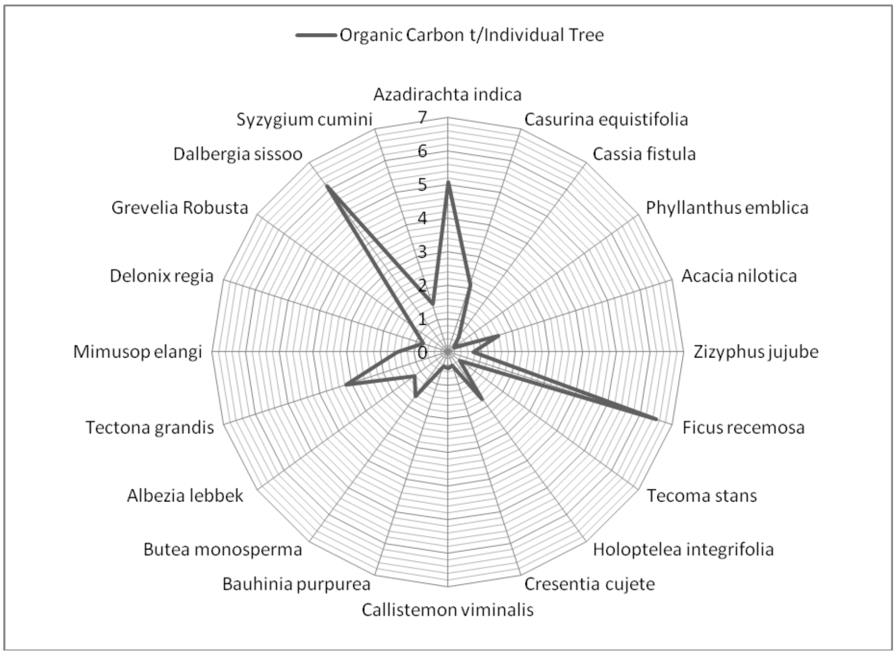

Figure 2: Contributions of the Selected Individual Trees in terms of Carbon Stock

Within the campus of IGNOU, *Azadirachta indica* species were found to be the most dominant species and therefore the sample in the study had 110 trees which were found to be able to sequester 537.526 tons of carbon in their standing biomass. They were followed by the trees of the species *Acacia nilotica and Albezia lebbek* with 287.776 tons and 257.27 tons respectively. The other major carbon sequestrating species were found to be *Tectona grandis* (245.93 tons), *Dalbergia lsissoo* (208.420 tons), *Casurina equistifolia* (129.015 tons), *Ficus recemosa* (97.60 tons), *Holoptelea integrifolia* (58.90 tons), *Grevelia Robusta* (54.81 tons), *Tecoma stans* (48.40 tons), *Mimusop elangi* (30.38 tons), *Syzygium cumini* (29.86 tons), and *Cassia fistula* (29.86 tons) in a decreasing order. It is notable that the remaining species of the trees in the studied sample were found to be having organic carbon content below 20 tons/species. The trees of the species *Phyllanthus emblica* had the lowest carbon sequestration potential with 10.9 tons whereas the lowest but second carbon sequestrating species were *Bauhinia purpurea* having carbon content 14.04 tons, and the lowest but third carbon sequestrating species were *Cresentia cujete* having 18.83 ton carbon (Table 55).

Table 5: Estimated Values of Carbon Stock of Selected Species of the Trees within IGNOU Campus

	Species Name	Organic Carbon t/Individual Tree	No. of Individual Tree	Organic Carbon t/Species
1	*Azadirachta indica*	5.07189	106	537.526
2	*Casurina equistifolia*	2.11509	61	129.015
3	*Cassia fistula*	0.56306	53	29.839
4	*Phyllanthus emblica*	0.22999	48	10.992
5	*Acacia nilotica*	1.56482	184	287.776
6	*Zizyphus jujube*	0.74102	37	27.417
7	*Ficus recemosa*	6.50741	15	97.605
8	*Tecoma stans*	0.44053	110	48.400
9	*Holoptelea integrifolia*	1.73248	34	58.888
10	*Cresentia cujete*	0.42892	44	18.832
11	*Callistemon viminalis*	0.50142	63	31.563
12	*Bauhinia purpurea*	0.44615	33	14.718
13	*Butea monosperma*	1.62992	32	52.128
14	*Albezia lebbek*	1.23134	209	257.279
15	*Tectona grandis*	3.19459	77	245.938
16	*Mimusop elangi*	1.51969	20	30.380
17	*Delonix regia*	0.78244	38	29.732
18	*Grevelia Robusta*	1.30580	42	54.810
19	*Dalbergia sissoo*	6.13076	34	208.420
20	*Syzygium cumini*	1.49322	20	29.860
	Total	37.63223	1,260	2201.118

*Organic Carbon is synonymous to Carbon

Figure 3 demonstrates the contributions of the identified individual species in terms of carbon stock.

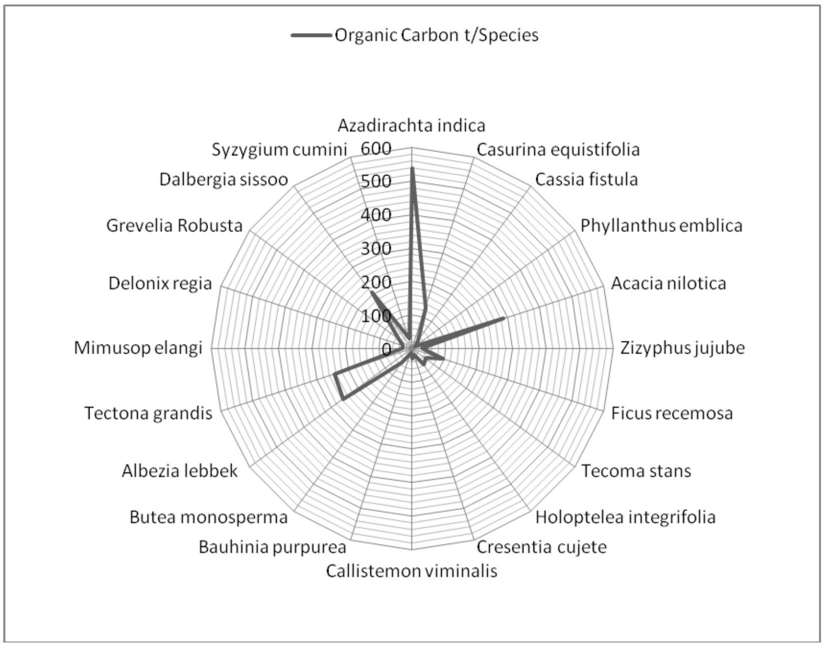

Figure 3: Contributions of the Selected Species in terms of Carbon Stock

As conclusion, this study, as per its primary objective, made an assessment of the biomass and carbon stock of the identified species of the trees within the campus of IGNOU at New Delhi using non-destructive method. This method was found suitable for the measurement of the different parameters of the trees useful in carbon sequestration process with the help of allometric equations. Trees in the educational institution campuses are highly vulnerable to the anthropogenic disturbances because of being at the receiving end of all the developmental activities. The findings of the study suggest that different species of the trees within the campuses possess huge potential in terms of accumulation of substantial biomass and contributions to the environmental health. There is a need to harness their huge potential in terms of non-tangible services offered by these trees in the campuses by storing and sequestrating carbon despite the limitedness of the quantity of planted trees as compared to natural forest. The findings of the current study support the studies such as Poonia (2020) that for the purpose of enhancing diversity in trees in terms of biomass and carbon allocation, there is a need to plant above ground and below ground diverse varieties of native and evergreen trees in different species.

The findings hint that the highest amount of biomass is contained in the above ground parts of the trees which retain greater share of carbon and are followed by below ground parts. The study hints at the necessity to maintain the baseline data related to their species, genera and families along with the data of carbon to make their optimum utilization for protecting these important species of trees in campuses especially in urban areas which are under the threat of urbanization. These data would be useful in facilitating future researchers to undertake appropriate studies focused on the trees in the campuses of educational institutions and other urban areas. The findings also help in concluding that trees with higher diameter posses higher carbon content indicating thereby that they can be considered to be significant carbon reservoirs underscoring the significance of the sustainable management of trees within the campuses to negate the negative irreversible effect of climate change and global warming. This study offers valuable insight with respect to the carbon sequestration potential of university campus situated in urban settings by assessing the above- and below- ground carbon storage potential of the trees.

This study might be immensely useful for different stakeholders associated with the planning and decision-making of urbanization and future researchers in conducting more such studies. Here, it is notable that the study had limitations in the form of keeping itself confined to the assessment of the potentials of tress only amongst the terrestrial carbon pools excluding soil and litter biomass. However, the findings suggest that the trees species found in the campus of IGNOU at New Delhi make significant contributions in climate change mitigation, helping also in conserving the biodiversity, maintaining the carbon stock within the campus of IGNOU, and offering many significant ecosystem services to the society. This study provides further underpinnings to the huge contributions that trees along with their biodiversity within the campuses of educational.

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