Estimation of Carbon Sequestration Potential of Urban Trees in Educational Institution: With Special Reference to Guru Gobind Singh Indraprastha University Campus, Delhi, India

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Abstract

Trees assimilate the atmospheric carbon through photosynthesis that stores tremendous CO_2 from the atmosphere in biomass. Urban trees play a significant role in accumulating atmospheric CO_2 in biomass and hence help climate change mitigation and biodiversity conservation. The study carried out on the campus of GGS IP University, Dwarka, Delhi. The living biomass stored in the trees of the campus calculated using allometric equations. The total area of campus is 60.436 acres that have 1657 trees in number. The diameter at Breast Height (DBH) of each tree was measured. The results reveal that Total Biomass and Carbon Stored are 248.29 tons and 124.14 tons, respectively. There is a total of 40 different species belonging to 21 families. *Ficus virens* is the dominant species followed by *Ficus benjamina* and *Putranjiva roxburghii*, respectively. In order to increase the carbon sinks, it is necessary to carry out the afforestation periodically. Therefore, a similar carbon sequestration study is required every ten years for green space planning, which is crucial in keeping ecosystem services optimal for the University Campus or educational institutes.

1. Introduction

Urban Green Spaces (UGSs), i.e., parks, gardens, avenue plantations, campus areas, uninhabited land and nature trails within the forests, provide indispensable Ecosystem Services (ESs) for the residents living in urban areas (McDonald and Marcotullio 2011; Cameron and Blanusa 2016; Elmqvist et al., 2015). The basis on earlier categorizations of ESs given by the Millennium Ecosystem Assessment (MEA 2005), The Economics of Ecosystem Services and Biodiversity (TEEB 2010) and Common International Classification of Ecosystem Services (Haines-Young, R. and M.B. Potschin 2018) arranged ESs in four divisions, i.e., provision, regulating, habitat, cultural and amenity services. UGSs generate provision services like food and freshwater (Bagdon et al., 2016; Alamgir et al., 2016), regulating services like air purification, microclimate regulation, carbon sequestration (Forman 2014; Nowak et al., 2006; Selmi et al., 2016), habitat services like home for biodiversity (Bagdon et al., 2016) and cultural services like recreation and health, environmental education (Chiesura 2004; Andersson et al., 2015).

UGSs are growing more than the population that is rapidly increasing in urban areas in the current decade (Fuller and Gaston 2009; Seto *et al.*, 2012). Therefore, it is vital to assess and quantify UGS ES. In the recent decade, many studies have been conducted to calculate the ES of urban forests (Nowak et al., 2013a; Liu and Li 2012; Nowak et al., 2002a), urban trees (Tang et al., 2016; Russo et al., 2014), urban parks and gardens (Buchel and Frantzeskaki 2015; Langemeyer et al., 2015; Breuste and Artmann 2015; Speak et al., 2015; Camps-Calvet et al., 2016), campuses (Hepcan and Hepcan 2018; Vishnu and Patil 2016).

Many methodologies have been developed to calculate ES around the globe by researchers such as InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs), UFORE (Urban Forest Effects Model), CUFR Tree Carbon Calculator (CTCC) and i-tree Eco (Tallis et al., 2011; CUFR, 2008; Pickard et al., 2015; USDA Forest Service, 2015).

Numerous researches (Liu and Li 2012; Park et al., 2018; Russo et al., 2014; Hepcan and Hepcan 2018; Sun et al., 2019; Nowak and Crane 2002) have explained that urban trees remove carbon dioxide from the atmosphere through the process of photosynthesis and store excess carbon as biomass in stems and roots. Indirectly, urban trees also help to reduce the energy demands of the building by providing shade and climate amelioration influences, thereby reducing CO_2 emissions from lowered energy production (Akbari et al., 2001). Carbon sequestration is one of the regulating services of the Ecosystem. Vegetation has been widely tabulated in different categories according to the capacity of generating provisioning (water and food production), regulating (climate change mitigation and carbon sequestration), supporting (Nutrient Cycle) and cultural (aesthetic benefits) ecosystem services (MEA, 2005). Most of the carbon storage and sequestration studies have been conducted in the United States (Rowntree and Nowak 1991; Nowak 1993, 1994; Jo and McPherson 1995; McPherson et al., 1997, 1999; McPherson 1998; Myeong et al., 2006; Mchale *et al.*, 2007, 2009, Escobedo et al., 2010). Despite this, there is an increasing interest in the quantification of carbon storage and sequestration by urban forests in both developing and developed nations (Brack 2002; Jo 2002; Yang et al., 2005; Gratani and Varone 2006; Myeong et al., 2006; Stoffberg et al., 2010; Zhao et al., 2010).

Guru Gobind Singh Indraprastha University situated in the southwest of Delhi, where the population is 2,292,958 and population density is 5,446 per km^2. During 2001−2011, southwestern Delhi recorded the highest growth rate of 30.65% compared to other city districts. Urban population is increasing rapidly, putting enormous pressure on existing green spaces, resulting in a decrease of green cover and degradation of ecosystem services. It has become imperative to estimate carbon storage and sequestration to assess the potential role of urban forests within the city. Such studies highlight the role of tree cover in carbon sequestration and emphasize the need for greater attention towards selecting trees in educational institutions, which supports biodiversity and maximizes environmental services.

2. Study Area

2.1. Delhi: Statistics

The present study was conducted at Guru Gobind Singh Indraprastha University (GGS IPU) campus (28°35'41.94"N and 77° 1'9.59"E), Dwarka, Delhi, located at the southwest of Delhi. The total area of GGSIPU campus is 60.436 acres (Fig. 1). Delhi, the capital of India, has an area of 1483 sq km, which is 0.05% of India's geographical area. Delhi lies between 28°22'N to 28°54'N latitude and 76°48'E to 77°23'E longitude and shares its boundaries with Haryana and Uttar Pradesh. The altitudes of Delhi ranges from 180m to 316m above mean sea level. Delhi receives rainfall from 400 mm to 600mm annually. The annual temperature ranges from 3°C to 45°C. Delhi has 11 districts and none, neither hill nor tribal. According to Census 2011, the population of Delhi is 16.79 million, out of which 97.25% is urban, and 2.50% is rural. Delhi has a population density of 11,320 people per kilometre.

2.2. Delhi: Urban Green Space Status

According to India State of Forest Report 2019, forest cover in the Delhi is 195.44 sq km which is 13.18% of Delhi's total area. Table 1 shows the distribution of forest class and area covered by these classes in the state.

The Forest Department under Delhi government administers and promote conservation activities to promote and encourage the participation of public educational institutes and carries out "Greening Delhi Campaign" every year. In Delhi, there is no forest land conversion to non-forestry purposes under the Forest Conservation Act, 1980 in the last four years (MoEF & CC, 2019).

Apart from forest cover, Delhi has a significant number of parks and gardens. Delhi has more than 18,000 parks and gardens with about 8000 ha in different locations throughout Delhi. These parks, gardens, avenue plantations etc., are potential sites to enhance green cover within the state without the demand for extra land. These green spaces are managed by different department like CPWD, PWD, MCD, DDA, RWA etc.

To manage the parks and gardens in the state, the Delhi government has formed a society, namely Delhi Parks and Garden Society, to coordinate with the different department within the state and ensure the proper maintenance of the parks and gardens.

3. Materials And Method

GGSIPU campus map was obtained with the help of Google Earth. Tree census was done on the campus in February 2019, and tree data, i.e. GBH (Girth at Breast Height) and diameter of each tree, was measured at 1.37 m (approx 4.5 ft) above the ground using a measuring tape to get GBH of each tree. The methodology is to enumerate the total number of trees within the GGSIPU campus and measure the diameter at breast height (DBH) to estimate carbon sequestration potential. The sample comprised 'trees' as defined by the Delhi Preservation of Tree Act, 1994. According to the Delhi Preservation of Tree Act, 1994 under Sect. 2(i) 'a "tree" means any woody plant whose branches spring from and are supported upon a trunk or body is not less than five centimeters in diameter at a height of thirty centimeters from the ground level and is not less than one meter in height from the ground level'. Trees that fell under the above act only considered.

3.1. Carbon Storage and sequestration

The process by which trees remove the carbon from the atmosphere is called carbon sequestration. The amount or weight of carbon accumulated by a tree is called carbon storage (Nowak et al., 2012). Carbon store in a tree is directly proportional to its biomass, increasing its diameter, height, and canopy spread (McPherson 1998). The amount of carbon sequestration depends on the growth characteristics of the tree species, the condition for growth where the tree is planted and the density of the tree's wood (Jana et al., 2010).

There are many methods to estimate carbon sequestration and storage. In most of the methods and models, different attributes of an individual tree are considered age, DBH, height, tree species and geographic location. In this research, carbon sequestration and storage were calculated by using the non-destructive method, i.e. Allometric Equations; (1) calculated AGB and BGB of the trees, (2) Estimated Total

biomass of the trees (TB), (3) Estimated Carbon Storage (CS) of the trees. Equations are given below in Table 2, where D is DBH in cm.

4. Results & Discussion

4.1. Structure of GGS IP University Campus's Trees

A total of 1657 trees that belong to 40 species from 21 families were measured. The dominant species is *Ficus virens* which has 569 individuals and accounts for 34.33% of the total tree population. The second and third most common species are *Ficus benjamina* and *Putranjiva roxburghii*, respectively. The campus has 812 deciduous and 845 evergreen, which represents 21 families. 93.60% of trees are native and 5.01% and 1.39% are introduced and naturalized, respectively. The largest DBH is recorded in *Ficus benghalensis* measured 280 cm followed by *Ficus religiosa* measured 264 cm. These dominant species are very common to urban plantation as these can survive drought conditions, not require any specific soil type and significantly less maintenance.

Out of the total tree population, 93.60% are native, and 5.01% and 1.39% are introduced and naturalized respectively. According to tree census of the GGS IP University campus suggested that 63.55% (1053) trees belong to 0-50cm category and 31.38% (520), 4.04% (67), 0.60% (10) and 0.42% (07) to following category 50–100, 100–150, 150–200 and > 200 respectively. This data shows tree population is very young and has great carbon sequestration potential. Generally, at an early stage or smaller DBH, trees sequester more carbon and larger tree store more carbon than small or young trees (Nowak, 1994).

4.2. Carbon Storage and Sequestration of GGS IP University Campus

To acknowledge research question, results showed that total biomass and total carbon stored in GGSIP University campus is 248.29 tons and 124.14 tons, respectively. Total biomass stored by evergreen and deciduous trees is 46.01% (114.23t), 53.99% (134.05t), respectively (Fig. 4). Similarly, total carbon stored by evergreen and deciduous trees is 46.01% (57.11t), 53.99% (67.02t), respectively. Family Moraceae found to be the dominant family, followed by Putranjivaceae and Bombacaceae.

Characteristics like species type, age, growth pattern, rainfall and most importantly, geographical conditions affect the carbon storage and sequestration potential. Thus, it is very challenging to compare the results of different studies (Aguaron and McPherson, 2012). The alike study was conducted at Amity University, Noida and published that the total carbon sequestered by all the trees in a year is 139.9 tons (Sharma et al., 2020).

Table 1 shows that the carbon sequestered by each trees species within the GGS IP University campus. The above and below ground biomass 215.89 tons and 32.37 tons, respectively.

5. Conclusion

Urban Trees play an important role in moderating climate change by sequestering or reducing atmospheric carbon. Hence, it is crucial to estimate the potential of carbon sequestration and storage of urban forests or trees. This research primarily provides a case study of the estimation of carbon sequestration and storage potential of urban trees planted in educational institutes situated in urban areas. Regulating ES is one of the most critical functions of green spaces. There is it essential to assess and map ES in planning a smart city or green space management.

Horticulture department of the GGS IP University taking care of the green spaces within the campus. These green spaces provide a learning environment to students and faculty and space for recreational activities. However, adjacent colonies to campus do not have access to these green spaces but still experience many benefits.

It is essential to accurately measure Carbon Storage and Sequestration values of urban trees therefore, site and species-specific allometric equations needed. More studies to be conducted to develop an allometric equation and monitor Urban ES provided by trees to understand the role of trees in Carbon Sequestration and storage.

Declarations

Availability of data and material

Not Applicable

Code Availability

Not Applicable

Author's Contributions

Not Applicable

Ethics Approval

Not Applicable

Consent to Participate

Not Applicable

Consent for publication

Not Applicable

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Tables

Table 1
Area covered by different forest class in Delhi

| Class	Area (sq.km)	% of Delhi's Land
Very Dense Forest (VDF)	6.72	0.45
Moderately Dense Forest (MDF)	56.42	3.81
Open Forest (OF)	132.30	8.92
Total	195.44	13.18
Source: ISFR, 2019		

Due to technical limitations, table 2 is only available as a download in the Supplemental Files section.

Table 1 Carbon Sequestered by Different Trees Species in GGS IP University Campus, Dwarka, Delhi

S.No.	Scientific Name	Family	No. of Trees	AGB (kg)	BGB (kg)	TB (kg)	CS (kg)
1	*Acacia auriculiformis*	Mimosaceae	10	204.6	30.69	235.28	117.64
2	*Acacia nilotica*	Mimosaceae	2	378.12	56.72	434.84	217.42
3	*Aegle marmelos*	Rutaceae	2	104.04	15.61	119.65	59.82
4	*Albizia lebbeck*	Mimosaceae	5	764.06	114.61	878.67	439.33
5	*Alstonia scholaris*	Apocynaceae	44	8005.6	1200.84	9206.44	4603.22
6	*Azadirachta indica*	Meliaceae	82	8326.51	1248.98	9575.49	4787.74
7	*Bauhinia racemosa*	Caesalpiniaceae	2	20.17	3.03	23.2	11.6
8	*Bombax ceiba*	Bombacaceae	38	9786.57	1467.99	11254.56	5627.28
9	*Callistemon viminalis*	Myrtaceae	2	21.89	3.28	25.17	12.59
10	*Carica papaya*	Caricaceae	1	13.82	2.07	15.89	7.95
11	*Caryota urens*	Arecaceae	1	281.61	42.24	323.85	161.93
12	*Cassia fistula*	Caesalpiniaceae	20	773.23	115.98	889.21	444.61
13	*Cordia dichotoma*	Boraginaceae	2	195.76	29.36	225.13	112.56
14	*Dalbergia sissoo*	Fabaceae	44	4855.3	728.3	5583.6	2791.8
15	*Delonix regia*	Caesalpiniaceae	8	869.58	130.44	1000.02	500.01
16	*Ficus benghalensis*	Moraceae	15	8672.03	1300.8	9972.84	4986.42
17	*Ficus benjamina*	Moraceae	334	47374.67	7106.2	54480.87	27240.44
18	*Ficus religiosa*	Moraceae	25	14620.99	2193.15	16814.14	8407.07
19	*Ficus virens*	Moraceae	569	76385.89	11457.88	87843.78	43921.89
20	*Grevillea robusta*	Proteaceae	10	365.24	54.79	420.03	210.01

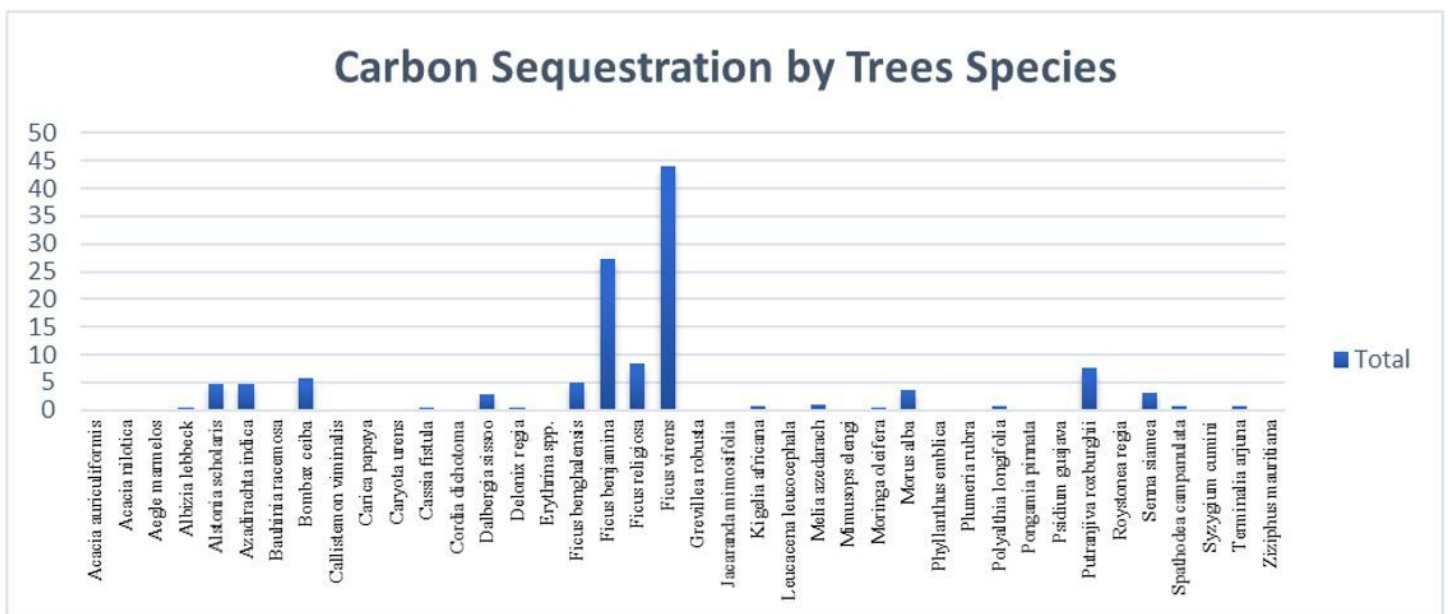| 21	*Jacaranda mimosifolia*	Bignoniaceae	2	167.99	25.2	193.19	96.59
22	*Kigelia africana*	Bignoniaceae	7	1011.9	151.79	1163.69	581.84
23	*Leucacena leucocephala*	Mimosaceae	6	244.67	36.7	281.37	140.68
24	*Melia azedarach*	Meliaceae	14	1778.87	266.83	2045.7	1022.85
25	*Mimusops elengi*	Sapotaceae	7	81.41	12.21	93.62	46.81
26	*Moringa oleifera*	Moringaceae	9	644.45	96.67	741.11	370.56
27	*Morus alba*	Moraceae	51	6304.87	945.73	7250.6	3625.3
28	*Phyllanthus emblica*	Phyllanthaceae	4	150.95	22.64	173.59	86.79
29	*Plumeria rubra*	Apocynaceae	15	204.45	30.67	235.11	117.56
30	*Polyalthia longifolia*	Annonaceae	48	1349.57	202.44	1552.01	776
31	*Pongamia pinnata*	Fabaceae	17	413.71	62.06	475.76	237.88
32	*Erythrina spp.*	Fabaceae	10	109.64	16.45	126.09	63.05
33	*Psidium guajava*	Myrtaceae	5	71.14	10.67	81.81	40.91
34	*Putranjiva roxburghii*	Putranjivaceae	134	13149.76	1972.46	15122.22	7561.11
35	*Roystonea regia*	Arecaceae	1	30.9	4.64	35.54	17.77
36	*Senna siamea*	Caesalpiniaceae	28	5562.26	834.34	6396.6	3198.3
37	*Spathodea campanulata*	Bignoniaceae	38	1282.17	192.33	1474.5	737.25
38	*Syzygium cumini*	Myrtaceae	3	60.7	9.1	69.8	34.9
39	*Terminalia arjuna*	Combretaceae	37	1004.19	150.63	1154.82	577.41
40	*Ziziphus mauritiana*	Rhamnaceae	5	263.55	39.53	303.08	151.54

Figures
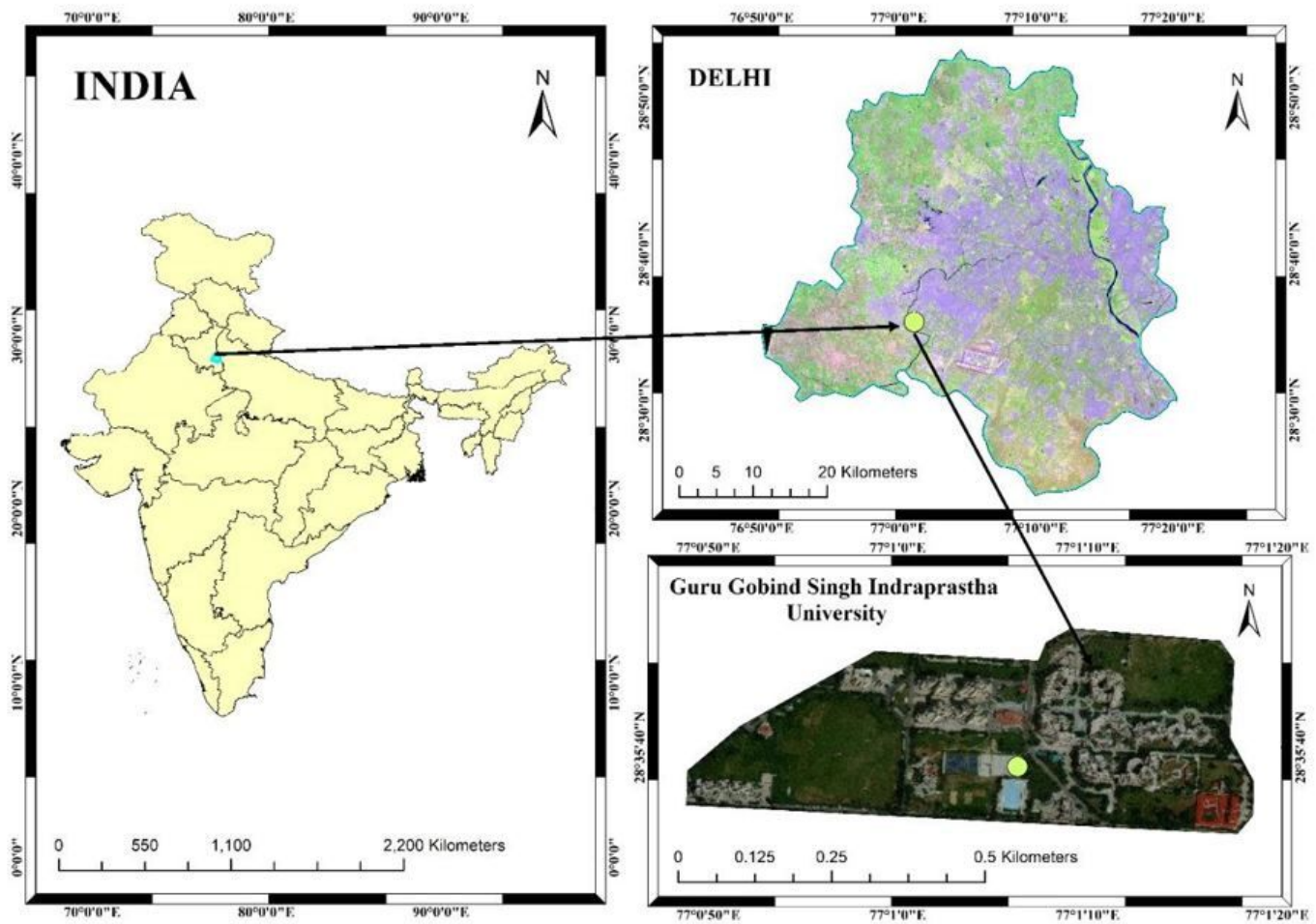
Figure 1

Location of Guru Gobind Singh Indraprastha University, Delhi Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Tree DBH distribution of GGS IP University

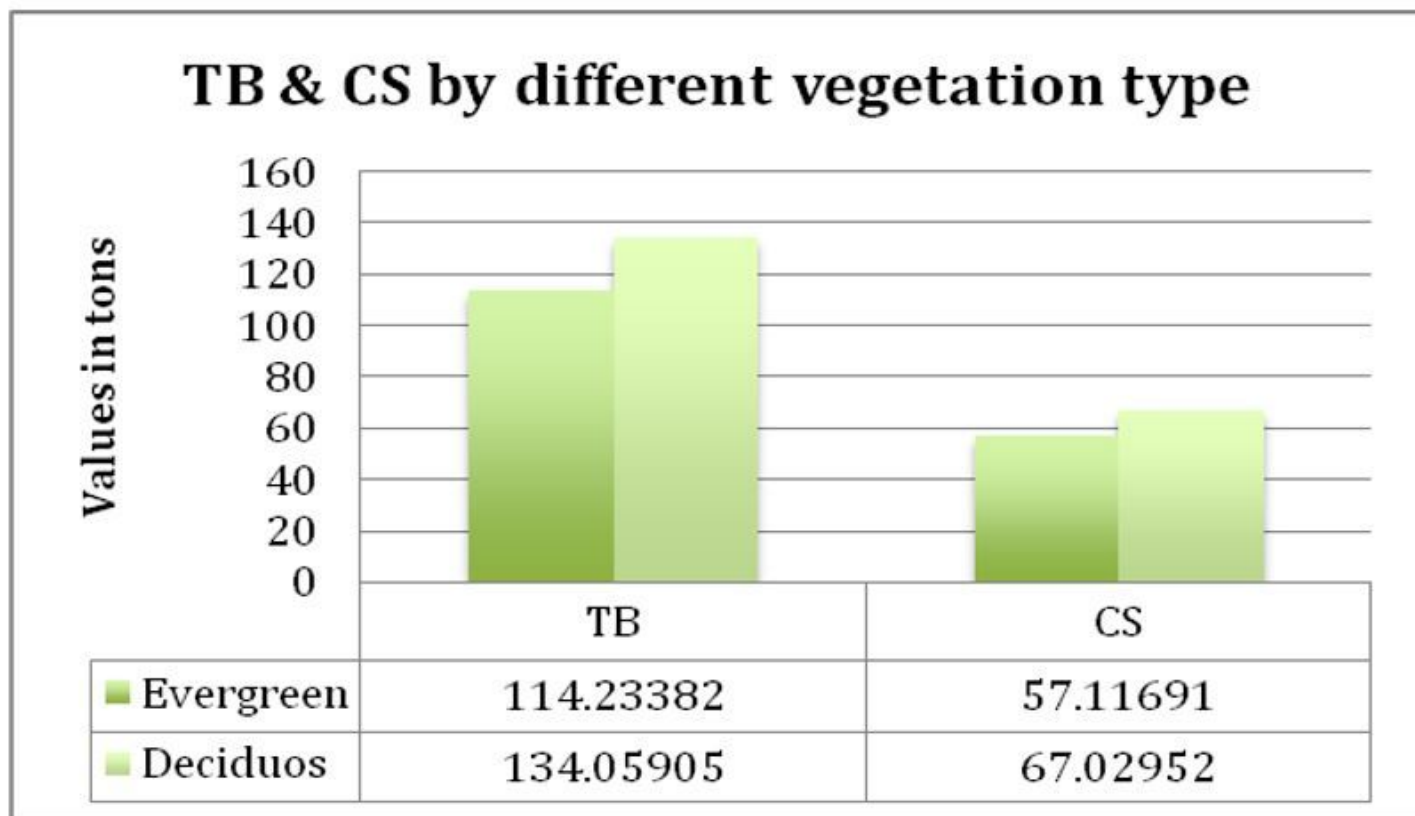|	0-50	50-100	100-150	150-200	>200
No of Trees	1053	520	67	10	7
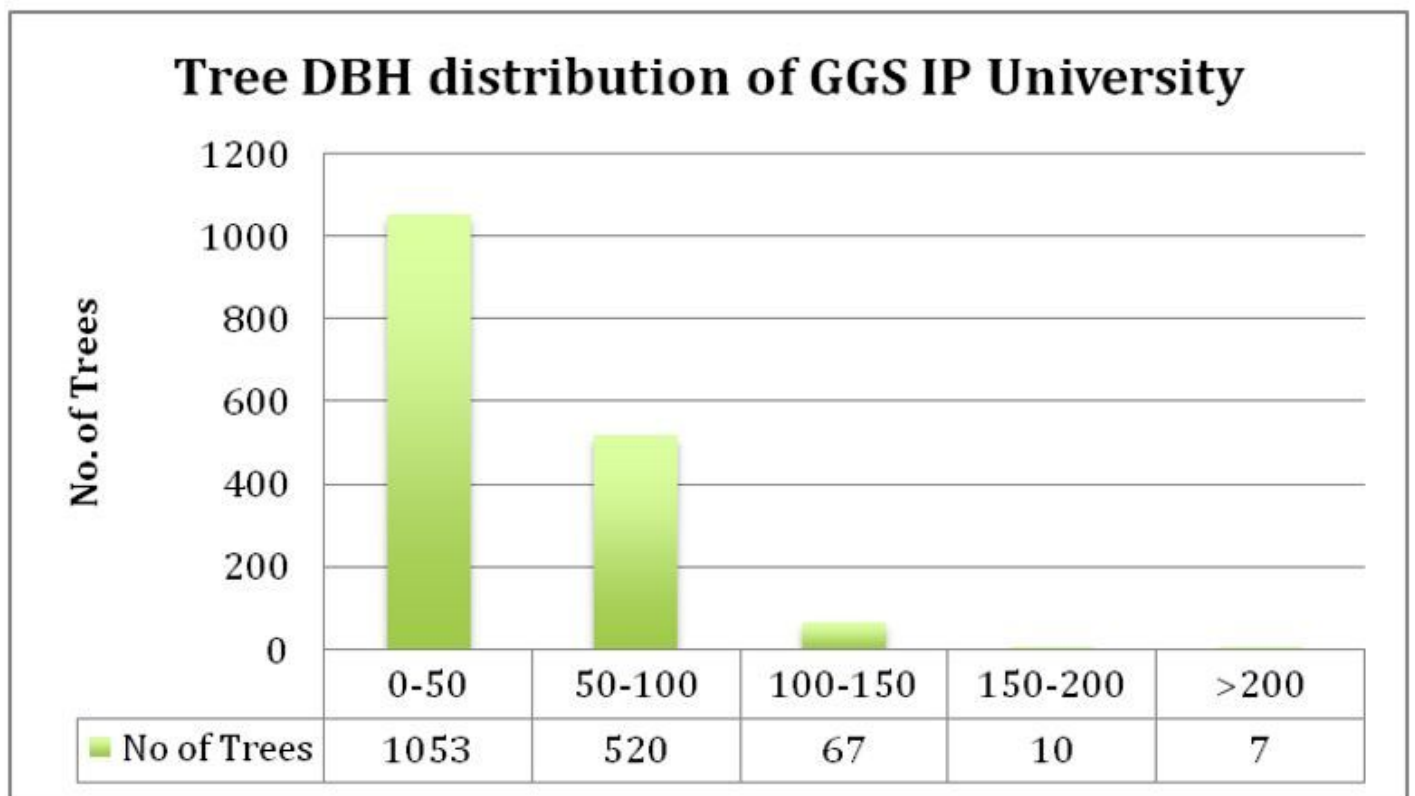
Figure 2

Distribution of trees on the basis of DBH

Figure 3

Carbon Sequestered by Tree Species at GGS IP University, Dwarka, Delhi

TB & CS by different vegetation type

	TB	CS
■ Evergreen	114.23382	57.11691
■ Deciduos	134.05905	67.02952

Values in tons — Y-axis scale: 0, 20, 40, 60, 80, 100, 120, 140, 160

Figure 4

Total Biomass & Carbon Storage by different Vegetation Type

AGB, BGB & CS distribution

	0-50	50-100	100-150	150-200	>200	Total
■ AGB	26.95	103.15	46.75	14.8	24.24	215.89
■ BGB	4.04	15.47	7.01	2.22	3.63	32.37
■ CS	15.5	59.31	26.88	8.51	13.94	124.14
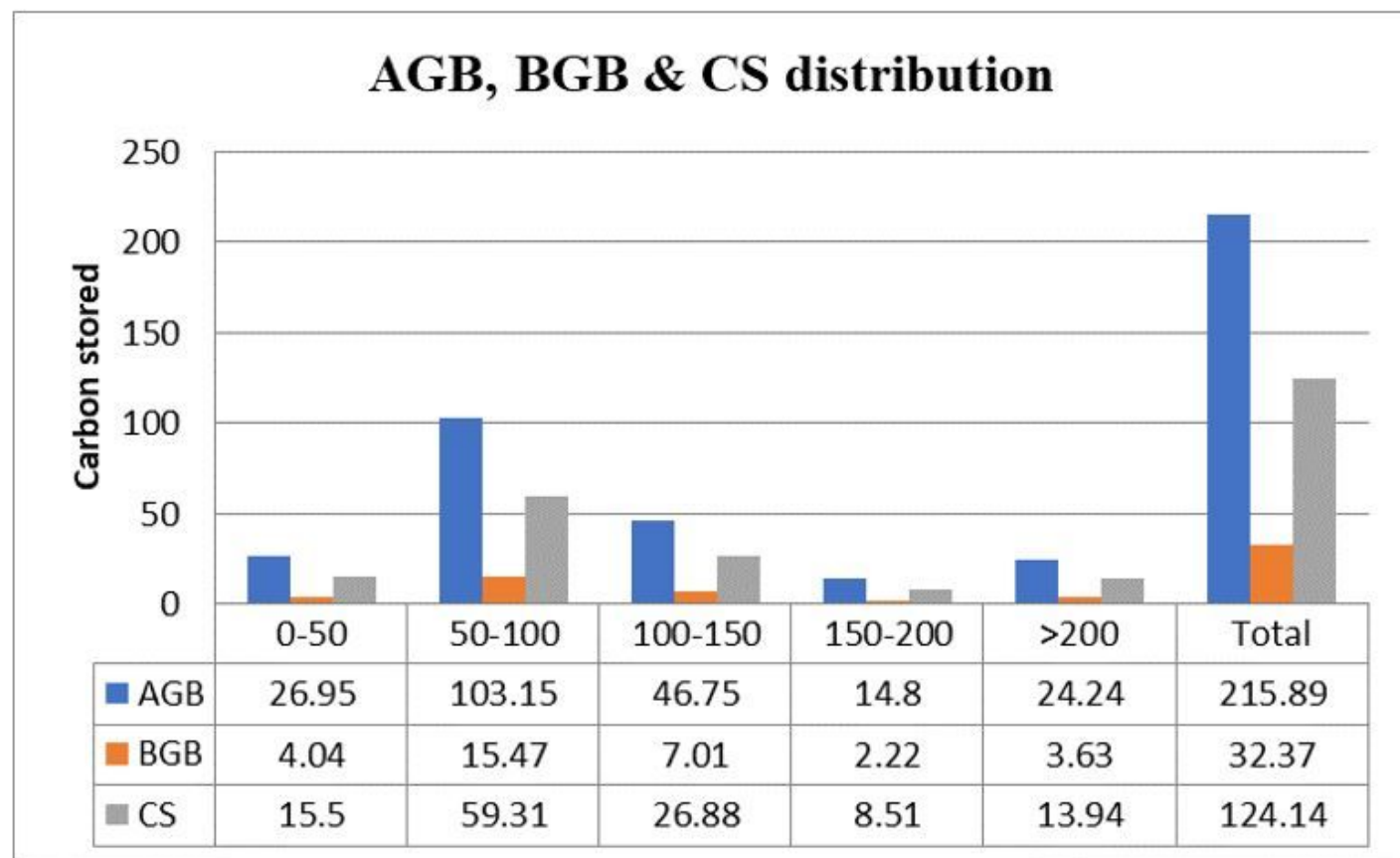
Figure 5

Above & Below Ground Biomass & Carbon Storage Distribution

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table2.jpg