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Carbon dioxide sequestered by trees in an urban institution: A case study

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ABSTRACT

The geographical location, climate, topography and most important human interference has contributed to the characteristic flora of the old campus of University of Jammu. A total of 24 tree species having 153 individuals belonging to 14 families have been recorded. Out of 24, 23 species belong to Angiosperms (22 dicots and 1 monocot) whereas, only 1 species belong to Gymnosperms. Overall, Moraceae was found to be the dominant family. The total growing stock, total biomass, total carbon content within university campus has been assessed to be 215663.99cm^{3,} 107.83kg, 50.68kg respectively. The total CO_2 sequestered by trees and net oxygen produced have been estimated to be 185.84kg and 495.65kg, respectively. Thus, the old campus of University of Jammu with lot of built-up area, roads, lawns, parking places, garden, etc. has sequestered considerably good amount of carbon and also produced considerable amount of oxygen as compared to its size, and its potential for sequestration can be enhanced with the help of management practices and plantation of more trees/shrubs within the permissible areas.

Introduction

The Urban Forest structure i.e., tree species composition, size and location, etc. provide the basis for understanding its functions that can affect urban inhabitants and also help to improve the management system to maximize the environmental and social benefits. As urban forests sequester and affect the emission of CO_2 from urban areas, which have 50% of global population across the globe, consume up-to 75% of total energy and 60% of water sources and contribute about 80% of GHG emissions despite being concentrated only on 2.5% of world geographical area (McGranahan *et al.,* 2005), thus, can play a critical role in combating increasing levels of atmospheric carbon dioxide. They also play an important role in affecting atmospheric concentration of CO_2, act as sink of atmospheric carbon, modulate earth's carbon balance and help in mitigation of climate change (Chavan and Rasal, 2010; Eneji *et al*., 2014; Marak and Khare, 2017). Tree vegetation constitutes an important natural resource having productive, protective, aesthetic and regulatory functions of tangible and intangible nature. Growth of tree vegetation in an urban area is a function of several simultaneous factors. Higher population density, more fossil fuel and other resources consumption, presence of more concretised and artificial surfaces in urban regions have led to accelerated climatic differences and their impacts on vegetation in urban environment than rural. Tree canopies provide a cooling effect on the microclimate of the region, reduces vehicular pollution and also capture large-size particulate matter (Beckett *et al.,* 2000) which have far reached implications towards air quality standards along with sequestration in mitigation strategies. Trees simultaneously sequester carbon as they grow and emit the carbon to the atmosphere after their death/decay, there by influencing air

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temperatures and building energy use and consequently alter carbon emission and absorption from urban sources. The net carbon sequestration can be achieved by urban plantings up to 18 kg CO_2 per year per tree which will correspond to 3 to 5 forest trees of similar size as well as health (Ferrini and Finni, 2011).

Therefore, effective management and manipulation of the urban tree cover in a planned and cost-effective way by understanding its structure and function can potentially yield a wide range of benefits to the urban region (McPherson *et al.,* 1994). Many studies related to tree biomass and carbon content have been conducted across the world by Nowak and Crane (2002), Nowak *et al.* (2013), Fares *et al.* (2017), Brack (2002), Kiran and Kinnary (2011), Ugle (2010), Velasco *et al.* (2016), Nowak *et al.* (2007) and Zhao (2015) etc. Similarly, few studies in Jammu and Kashmir on forest biomass and carbon have been carried out by Dar and Sundarapandian (2015), Wani *et al.* (2017), Handa *et al.* (2017), Dar and Sahu (2018), Gairola *et al.* (2020) while, few studies on biomass and carbon sequestration potential of trees of forest area, outside forest area, urban and of sacred grooves were investigated by Jasrotia and Raina (2017), Sharma *et al.* (2020), Mahajan *et al.* (2021), Devi (2017), Kour and Sharma (2017), Ahmed and Sharma (2018), Bhat *et al.* (2019) and Priya and Sharma (2018). So, keeping in view the importance of tree vegetation in urban habitat our main aim of the study was to evaluate the carbon content and sequestration potential of urban trees especially in an institution to understand and to comply with aim of sustainable living.

Material and Methods

Study area

The Old Campus of University of Jammu (Lat. 32°43'28.59" and Long. 74°50'58.61", Altitude: 336m above msl and Area: 410.5 acres) located near Canal Road, Nawabad, Jammu, J&K (UT) and is now utilized only for residential accommodation of teaching, non-teaching staff and students (Boy's hostel). It lies in the foot-hills of outer Shivaliks with climate typically of sub-tropical type having hot summers and cold winters with an average summer and winter temperature of 30.7 °C and 10.5 °C, respectively. June is the warmest and January is the coldest months of the year with average yearly precipitation of 42 inches (1,100 mm) where the bulk of the rainfall is contributed by monsoon in the months from June to September.

Data collection

Field surveys for total enumeration of trees with diameter of ≥ 10cm [at breast height (dbh) i.e., 1.37m above from the ground] were conducted within area of university campus. Circumference (in cm) at dbh was measured and recorded (Ravindranath and Ostwald, 2008).

Data analysis

Volume was calculated using volumetric equation based on diameter (FSI,2013) (Table 1). The volume (kg) was converted into above-ground biomass (kg) by multiplying it with wood density (g/cm^3) (FAO 1993) (Table1) and biomass expansion factor (BEF) which is calculated using Exp {3.213-0.506*Ln (Volume)}. The below ground biomass (kg) of the trees was calculated using root to shoot ratio of 0.26 (Mokany *et al*., 2006). Above-ground biomass (kg) and belowground biomass (kg) were added to get the Total Biomass(kg). Finally, the carbon storage (kg) was estimated by multiplying total biomass using the default value of carbon fraction of 0.47 (IPCC, 2006). The estimated carbon stock was converted into CO_2 sequestrated by multiplied it with 3.667. The oxygen production (kg) was calculated by multiplying CO_2 sequestered with 2.667.

Results and Discussion

Floristic analysis

A total of 24 species belonging to 14 families have been recorded from the area. Moraceae has been found to be the dominant family. Total number of individuals of all the tree species has been observed to be 153 within the campus, *Mangifera indica* being the most dominant species with 21 individuals followed by *Alstonia scholaris* (20 individuals) and *Morus alba* (14 individuals). List of the observed species has been presented in alphabetical order with their common name and family in **Table 1**.

Biomass C stocks, CO_2 sequestered and O_2 produced by trees.

Live biomass includes both the aboveground biomass and below ground biomass. This pool is likely to change frequently, even annually, much faster than other pools and is an important indicator of the impact on benefits related to carbon

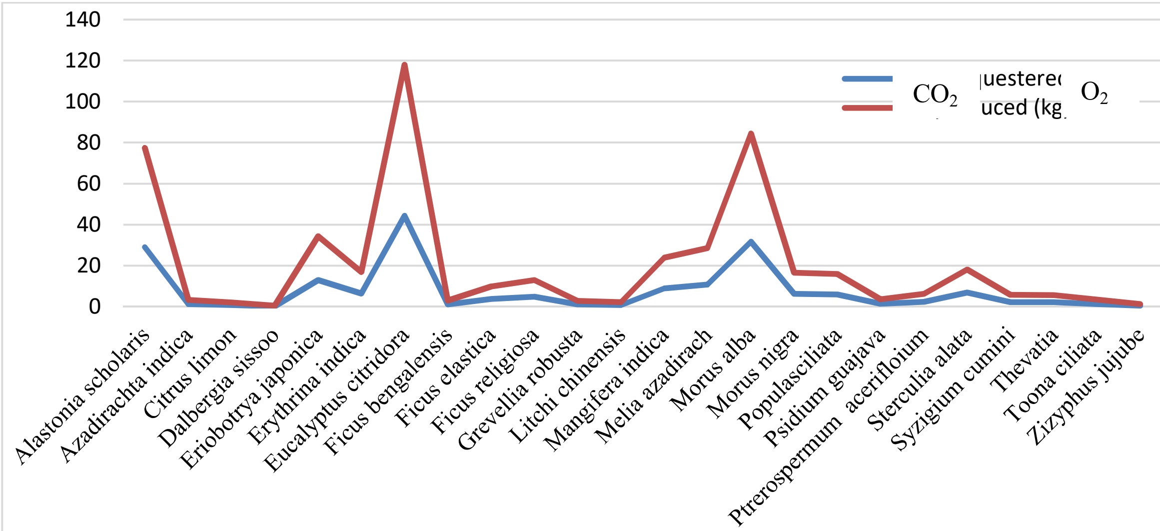

Figure 1: CO_2 Sequestered and O_2 produced by tree Species

mitigation and other matters (Ravindranath and Ostwald, 2008). Globally, live forest biomass in aboveground tissues and belowground contributes ~80% and ~20%, respectively while, in the Indian forests, aboveground and belowground biomass contributes 79% and 21% (Chhabra *et al.,* 2002). In the present investigation, total live tree biomass within the campus has been estimated to be 107.83kg contributed by aboveground (85.58kg i.e., 79%) and belowground (22.25kg i.e., 21%) and thus, is in line with the reports of above and below ground biomass of Indian forests.Total carbon content possessed by trees in the present study area has been recorded as 50.68kg which has been contributed by 40.22kg of aboveground and 10.45kg of belowground biomass carbon, respectively. From this, it has been estimated that 185.84kg of CO_2 has been sequestered by trees in the study area. Dubal *et al.* (2013) in their studies at Shivaji university campus with an area of 874 acres reported that 1314 individuals of trees (belonging to 38 species) have sequestered 158268kg of carbon. Though the area is little more than double, the number of individuals of trees and sequestered carbon is ~8.5 times more, thereby reflecting that almost same amount of carbon has been sequestered by individual trees.While, Chavan and Rasal (2012) reported 1650kg (1.65t) of carbon stock among 1658 individuals (belonging to 20 species) within university campus of Dr. B.A.M. University, Aurangabad. Though the number of individuals studied was ~10times more than the present investigation, the carbon stock was ~33 times higher. Similarly, Villiers *et al.* (2014) and Sarel *et al.* (2017) and Flora *et al.* (2018) reported 15000kg (15ton), 580900kg and 4565.928 kg carbon content in their university campuses which is ~80, 3000, 24 times higher than present study, respectively. Whereas, Gulcin *et al.* (2021) reported 5.2kg C/m^2 above ground biomass which was ~60 times higher in an area i.e., 2.5 times (988.425 acres) more than study area. Over all, the comparative studies were found to have more carbon content because of larger area as well as a greater number of individuals within their study area. Since, one ton of carbon storage in the tree species represents removal of 44/12 or 3.67t of carbon from the atmosphere and the releasing of 2.67t of oxygen back. Net oxygen produced by trees within the study area has been workout to be 495.65kg which is lower than 2959.68 t ha^{-1} y^{-1} of oxygen produced by the 28 tree species in Konnagar Municipality estimated by Abhijit *et al.* (2017). While, Sharma *et al.* (2019) reported 5777818.399 kg in Jiwaji University campus. As the O_2 produced is affected by the density of trees, the less amount of O_2 produced in the present area may be due to the smaller area as maximum area is covered as built-up area in the campus. The total biomass, carbon content, carbon sequestered as well as oxygen produced was recorded maximum for *Eucalyptuscitridora* having 6 individuals followed by *Morus alba* (14), *Alastonia scholaris* (20), *Eriobotrya*

Table1: List of the observed tree species within the campus of University of Jammu.

SCIENTIFIC NAMES	LOCAL NAME	FAMILY	VOLUMETRIC EQUATION	WOOD DENSITY (g/cm^3)
Alastonia scholaris(L.) R. Br.	Satpatra	Apocynaceae	$V=0.193297-2.267002D+10.679492 D^2$	0.629
Azadirachta indica A.Juss.	Neem	Meliacea	$V/D^2=0.007602/D^2 0.033037/D+1.868567+4.483454D$	0.69
Citrus limon (L.) Osbeck	Lemon	Rutaceae	$V/D^2=0.007602/D^2 0.033037/D+1.868567+4.483454D$	0.6
Dalbergia sissoo Roxb. ex DC.	Indian rosewood	Fabaceae	$V=0.25412D^2H-1.83911D^2+0.07907H-1.40296$	0.34
Eribotrya japonica (thunb.) Lindl.	Laquat	Rosaceae	$V=0.00471+1.79326 D^2$	0.7758
Erythrina variegate L.	Parijat	Fabaceae	$V=0.00471+1.79326 D^2$	0.6
Eucalyptus citriodora(Hook.) K.D. Hill & L.A.S. Johnson	Safeda	Myrtaceae	$V=0.02894-0.89284*D+8.72416*D^2$	0.64
Ficus benghalensis Linn.	Bargad	Moraceae	$V=0.00471+1.79326 D^2$	0.49
Ficus elastica Roxb. ex Hornem.	Rubber tree	Moraceae	$V=0.00471+1.79326 D^2$	0.6071
Ficus religiosa Linn.	Peepal	Moraceae	$V=0.00471+1.79326 D^2$	0.443
Grevillea robusta A.Cunn.ex R.Br.	Silver oak	Protoaceae	$V/D^2=0.007602/D^2 0.033037/D+1.868567+4.483454D$	0.6
Litchi chinensis Sonn.	Litchi	Sapindoideae	$V/D^2=0.007602/D^2 0.033037/D+1.868567+4.483454D$	0.88
Mangifera indica L.	Mango	Anarcardiaceae	$V=0.193297-2.267002D+10.679492 D^2$	0.37
Melia azedarach L.	Dreank	Meliacea	$V=-0.0351+5.32981D^2$	0.4629
Morus alba L.	Shahtoot	Moraceae	$V=0.167174-1.735312D+12.039017D^2$	0.6224
Morus nigra L.	Toot	Moraceae	$V=0.00471+1.79326 D^2$	0.6156
Populus ciliate Wall. ex Royle	Poplar	Salicaceae	$V=0.193297-2.267002D+10.679492 D^2$	0.3887
Psidium guajava L.	Guava	Myrtaceae	$V/D^2=0.007602/D^2 0.033037/D+1.868567+4.483454D$	0.6
Pterospermuma cerifolium (L.) Willd.	Kanankchampa	Sterculiaceae	$V=0.00471+1.79326 D^2$	0.6
Pterygotaalata (Roxb.) R. Br.		Malvaceae	$V=0.00471+1.79326 D^2$	0.6
Syzigium cumunii L.	Jamun	Myrtaceae	$V/D^2=0.2421/ D^2 2.68191/D+14.77955$	0.468
Thevetia peruviana (Pers.) K. Schum.	Luckynut	Apocynaceae	$V=0.00471+1.79326 D^2$	0.6
Toona ciliate M. Roem.	Toon	Meliacea	$V=0.193297-2.267002D+10.679492D^2$	0.427
Ziziphus jujuba Mill.	Baer	Rhamnaceae	$V/D^2=0.007602/D^2 0.033037/D+1.868567+4.483454D$	0.597

Table 2: Biomass and Carbon stocks in observed tree species within the campus of University of Jammu.

Species	Total Individuals	Total Volume (cm^3)	Basal area (cm^2)	Total ABG (kg)	Total BGB (kg)	Total Biomass (kg)	Total Carbon (kg)	Total CO2 Sequestered (kg)	Total O2 produced (kg)
Alastonia scholaris	20	134392.00	46422.00	13.38	3.48	16.85	7.92	29.05	77.47
Azadirachta indica	3	391.12	3391.20	0.57	0.15	0.72	0.34	1.24	3.30
Citrus limon	3	194.07	1657.90	0.35	0.09	0.44	0.21	0.76	2.03
Dalbergia sissoo	4	6.33	7134.10	0.08	0.02	0.10	0.05	0.17	0.45
Eriobotrya japonica	8	22821.40	9507.90	5.93	1.54	7.47	3.51	12.88	34.36
Erythrina indica	4	13438.00	6003.70	2.90	0.75	3.65	1.71	6.29	16.77
Eucalyptus citridora	6	327794.00	18275.00	20.38	5.30	25.68	12.07	44.25	118.02
Ficus bengalensis	3	624.58	1256.00	0.50	0.13	0.63	0.30	1.09	2.91
Ficus elastica	4	3503.56	3454.00	1.70	0.44	2.14	1.01	3.69	9.84
Ficus religiosa	4	11411.70	6267.40	2.23	0.58	2.81	1.32	4.85	12.94
Grevellia robusta	4	255.91	2185.40	0.46	0.12	0.58	0.27	1.01	2.69
Litchi chinensis	2	146.52	1256.00	0.36	0.09	0.46	0.22	0.79	2.11
Mangifera indica	21	5640.68	49273.00	4.11	1.07	5.18	2.43	8.93	23.81
Melia azadirach	9	23790.20	7661.60	4.92	1.28	6.20	2.91	10.69	28.50
Morus alba	14	78075.00	11317.00	14.57	3.79	18.36	8.63	31.65	84.40
Morus nigra	8	4982.08	5727.40	2.86	0.74	3.61	1.70	6.22	16.58
Populas ciliata	3	30108.40	3629.80	2.74	0.71	3.45	1.62	5.95	15.87
Psidium guajava	5	347.73	2976.70	0.60	0.16	0.76	0.36	1.31	3.49
Ptrerospermuma cerifloium	3	1867.00	2172.90	1.06	0.28	1.33	0.63	2.30	6.13
Sterculia alata	7	6909.87	6414.40	3.12	0.81	3.93	1.85	6.77	18.05
Syzigiumcumini	8	594.07	10035.00	0.99	0.26	1.24	0.58	2.14	5.72
Thevatia peruviana	3	1519.44	1984.50	0.97	0.25	1.22	0.57	2.10	5.61
Toona ciliata	4	728.53	6342.80	0.58	0.15	0.73	0.34	1.26	3.36
Zizyphus jujuba	3	225.35	1318.80	0.21	0.06	0.27	0.13	0.47	1.24
Total	**153**	**669767.40**	**215663.99**	**85.58**	**22.25**	**107.83**	**50.68**	**185.84**	**495.64**

japonica (8) and the minimum values was recorded for *Dalbergia sisoo* (4) followed by *Zizyphus jujube* (3), *Citrus limon* (3) and *Litchi chinensis* (2).

Conclusion

Thus, the old campus of University of Jammu with lot of built-up area, roads, lawns, parking places, garden, etc. has sequestered considerably good amount of carbon and also produced considerable amount of oxygen ascompared to its size, and its potential for sequestration can be enhanced with the help of management practices and plantation of more trees/shrubs within the permissible areas.

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Conflict of interest

The authors declare that they have no conflict of interest.

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