environmental sciences proceedings

MDPI

Proceeding Paper

Assessment of Carbon Sequestration Potential of Tree Species in Amity University Campus Noida †

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† Presented at the 1st International Electronic Conference on Forests—Forests for a Better Future: Sustainability, Innovation, Interdisciplinarity, 15–30 November 2020; Available online: https://iecf2020.sciforum.net.

Abstract: Urban green spaces, particularly trees, have great potential to sequester carbon from the atmosphere and mitigate the impacts of climate change in cities. Large university campuses offer prominent space where such green spaces can be developed in order to offset the increasing greenhouse gas emissions, as well as other benefits. Amity University, Noida, is spread over 60 acres with dense tree plantations in and around the campus. The present study is a sustainability initiative to inventory the tree species on the campus and assess their total carbon sequestration potential (CSP). The above- and below-ground biomasses were estimated using the non-destructive sampling method. Individual trees on the campus were measured for their height and diameter at breast height (DBH), and estimates of carbon storage were performed using allometric equations. There is a total of 45 different tree species on the campus with the total CSP equivalent to approximately 139.86 tons. The results also reveal that Ficus benjamina was the predominant species on the campus with CSP equivalent to 30.53 tons, followed by Alstonia scholaris with carbon storage of 16.38 tons. The study reports that the ratio of native to exotic species is 22:23 or almost 1:1. The present work highlights the role of urban forests or urban green spaces, not only as ornamental and aesthetic plantations but also in mitigating the impacts of climate change at a local level. Higher education institutes have an important role in expanding their green cover so as to act as local carbon sinks.

Keywords: above-ground biomass (AGB); below-ground biomass (BGB); carbon sequestration potential (CSP); urban forests

Citation: Sharma, R.; Pradhan, L.; Kumari, M.; Bhattacharya, P. Assessment of Carbon Sequestration Potential of Tree Species in Amity University Campus Noida. *Environ. Sci. Proc.* **2021**, *3*, 52. https://doi.org/10.3390/IECF2020-08075

Academic Editors: Angela Lo Monaco, Cate Macinnis-Ng and Om P. Rajora

Published: 13 November 2020

1. Introduction

Cities are the hubs of economic growth and development. Urban areas contribute close to half of India's gross domestic product today, but the rapid urbanization is a major driver of global change, driving land use change, habitat loss, biodiversity decline, climate change, and pollution both within and outside the city [1]. A report published by International Council of Local Environmental Initiatives (ICLEI), South Asia, has stated that average per capita carbon emissions are higher in the metropolitan cities of India, being 1.19 tons per capita, as compared to only 0.90 tons per capita in the non-metropolitan cities. Reduction in carbon dioxide concentrations in the atmosphere can be achieved either by reducing the demand for energy, altering the usage of energy or increasing the rates of removal of CO_2 through the trees through carbon sequestration, which can decrease the atmospheric carbon dioxide naturally [2].

The term urban forest and urban green space includes trees in gardens, parks, and along the streets, roads, canal, etc., which contribute to verdancy in the city [3]. These spaces provide a variety of ecosystem services such as improving air quality [4], buffering of noise pollution, biodiversity conservation, mitigating Urban Heat Island effect, microclimate regulation, stabilization of soil, ground water recharge, prevention of soil erosion, and carbon sequestration [5]. Studies conducted by several scientists have claimed that urban green spaces can play a very important role in limiting the city's carbon footprint [6]. The vegetation and soil of a greenspace cannot only sequester carbon, directly contributing to a reduction in atmospheric CO_2 concentration, but also affect the carbon balance indirectly, through their effects on the urban energy balance and thus on CO_2 emissions related to energy use [7]. In addition, these upgrade the standards of urban living by facilitating the health and well-being of the people by alleviating stress and enabling relaxation. Such areas also deliver an array of cultural services such as spiritual and religious, recreation, ecotourism and aesthetics [8]. The maximum benefit of these spaces largely depends on judicious selection of an appropriate and diverse mix of tree species and their proper management in the urban areas [9,10].

According to the Intergovernmental Panel on Climate Change (2006), the major five carbon pools of a terrestrial ecosystem involving biomass are above-ground biomass, below-ground biomass, dead wood, litter and soil organic matter [11]. Therefore, there are three ways in which urban green spaces can repress atmospheric carbon. Firstly, autotrophs take up carbon dioxide from the atmosphere—a part of which is released back into the atmosphere and the remainder is stored in the plant tissues above and below ground, resulting in the plant growth in the form of biomass. Therefore, all autotrophs convert atmospheric carbon dioxide into biomass, but trees, specifically, are considered to be the major sinks or sponges of carbon. The carbon assimilated by trees is retained for longer duration with little leakage into the atmosphere. Annual rates of carbon sequestration largely depend on the tree size at maturity, life span and their growth rates [12]. After the trees die, the biomass either enters the food chain or the soil as soil carbon [13]. Secondly, the soils are also chief contributors to the carbon stocks. Litter and woody debris are not a major carbon pool as they contribute only a small fraction to the total carbon stocks. Thirdly, urban vegetation reduces the demand for cooling the building by providing shade and evapotranspiration, and demand for heating living spaces by reducing wind speed. This substantially reduces burden on fossil fuel burning for electricity generation, thus offsetting carbon emissions [14].

Though the importance of forested areas in carbon sequestration has been well established and documented, few attempts have been made to address the potential of trees in carbon sequestration in urban cities. It is important to study the carbon sequestration potential of urban centers so as to understand and highlight the role of urban green spaces in offsetting carbon emissions at a local level. Large university campuses provide large areas for urban tree plantations that can be a potential solution for climate change mitigation. Being aware of how much carbon an urban green space can sequester is helpful because it can help an institution or organization offset its emissions and value its green spaces.

There are a number of studies wherein carbon stock estimation is performed for University campuses in India. Gavali and Shaikh (2016) estimated tree biomass and carbon storage in the Solapur University of Maharastra and reported that urban green spaces are likely to have a wider impact per area of tree canopy cover in comparison to other non-urban forests due to faster growth rates and increased proportions of large trees [15]. Marak and Khare (2017) also estimated carbon sequestration potential of tree species in the Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS) campus, Allahabad, and identified the important species with maximum carbon sequestration potential [16]. Similar studies on carbon sequestration have been carried out in Jnanabharathi campus, Bangalore University [17], Bharathiar University campus at Coimbatore [18], Andhra University, Vishakhapatnam [19], North Maharashtra University Campus, Jalgaon [13], Golapbag campus of Burdwan University [20,21], various educational institutes in Vijaypur, Jammu and Kashmir [22] and Vellore Institute of Technology (VIT) campus [23]. However, a complete and recent analysis of CSP of Amity University

Noida campus has not yet been performed. Therefore, the main objective of the present work is to inventory the tree species present on the campus and calculate their total carbon sequestration potential.

2. Study Area

The present work was carried out in Amity University campus, located in Noida, Uttar Pradesh (Figure 1). The campus is spread over 60 acres with dense tree plantations in and around it. The total geographic area of the campus is 24 hectares. It is well connected to the national capital and is located on the Yamuna Expressway, connecting Greater Noida. The campus is divided into academic and administrative blocks, interspersed with plenty of green spaces.

The city experiences cold winters and warm summers, with a temperature ranging from a maximum of 48 °C to a minimum of 28 °C. It receives very little rainfall throughout the year with an average of around 728 mm per year. The city has witnessed extensive urbanization throughout the years, with a number of high-rise buildings, corporations and industries [24].

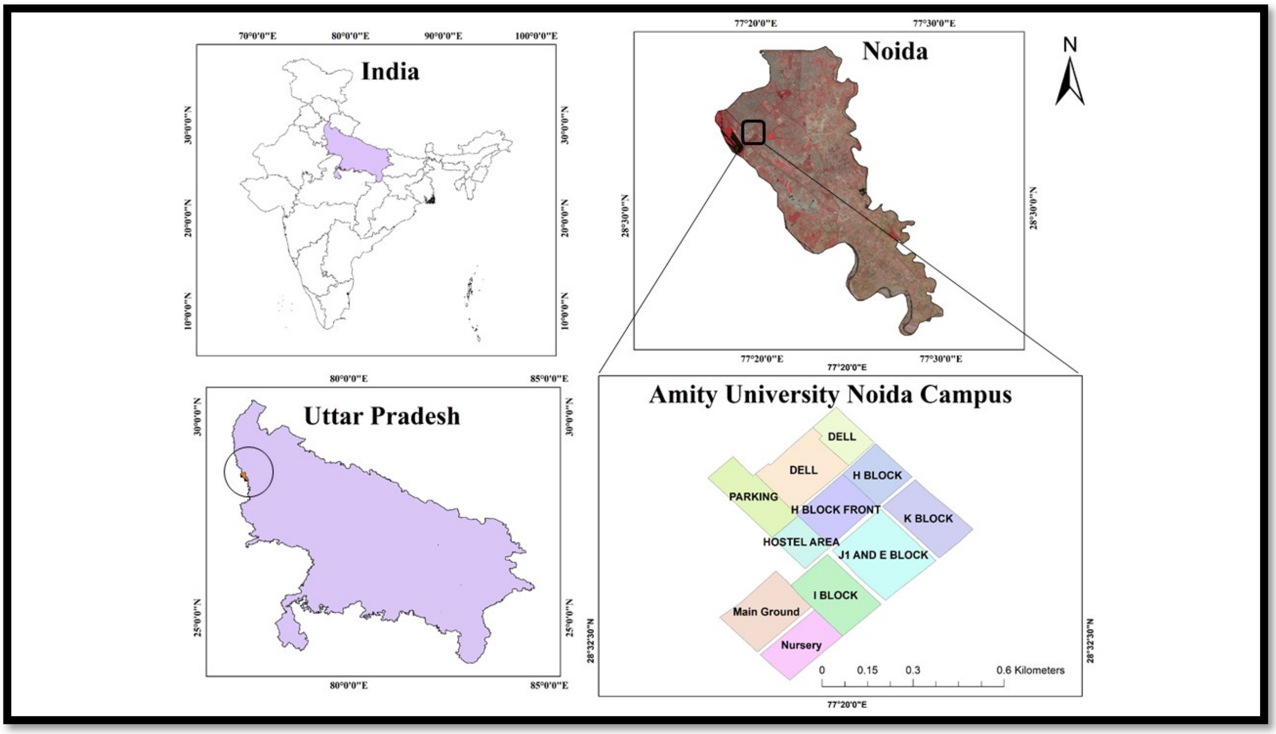

Figure 1. Study area.

3. Material and Methods

3.1. Tree Cover Mapping

Between March 2019 and March 2020, complete enumeration of the 1997 trees on the campus was performed block-wise (Figure 2).

3.2. Tree Height and Girth at Breast Height (GBH)

A non-destructive method of biomass estimation was used to measure the tree height and GBH of individual trees of the campus. Individual trees greater than or equal to 30 cm in girth at breast height (1.37 m) were enumerated. Tree height and girth were measured using clinometer/altimeter and measuring tape, respectively. Field data were recorded in spreadsheets. Species level identification of trees was obtained through visual observation, and the doubtful samples were collected and stored in herbarium for later identification by taxonomists. Shrubs and herbs were not recorded.

3.3. Estimation of Above-Ground and Below-Ground Biomass (AGB and BGB)

Above-ground and below-ground biomasses were estimated on the basis of field measurements of diameter at breast height (DBH) of the tree using allometric equations [25]. The below given equation is applicable to dry climates with annual rainfall < 1500 mm; hence, it can be used for Noida where the average annual rainfall ranges between 700 and 800 mm.

$$AGB = 34.4703 - 8.0671D + 0.6589D^2 \tag{1}$$

where D is the DBH (cm).

$$BGB = AGB \times (15/100) \tag{2}$$

3.4. Estimation of Total Biomass (TB)

Total biomass of individual trees will be the sum of their above- and below-ground biomasses, respectively, given by the following equation:

$$\text{Total Biomass} = AGB + BGB \tag{3}$$

3.5. Estimation of Carbon Content

Generally, for any plant species, 50% of its biomass is its carbon content [11].

$$\text{Carbon Content} = 0.5 \times \text{Total Biomass} \tag{4}$$

CO_2 equivalent is then calculated using the below given equation:

$$CO_2\ (\text{eq.}) = (\text{Carbon content} \times 44)/12 \tag{5}$$

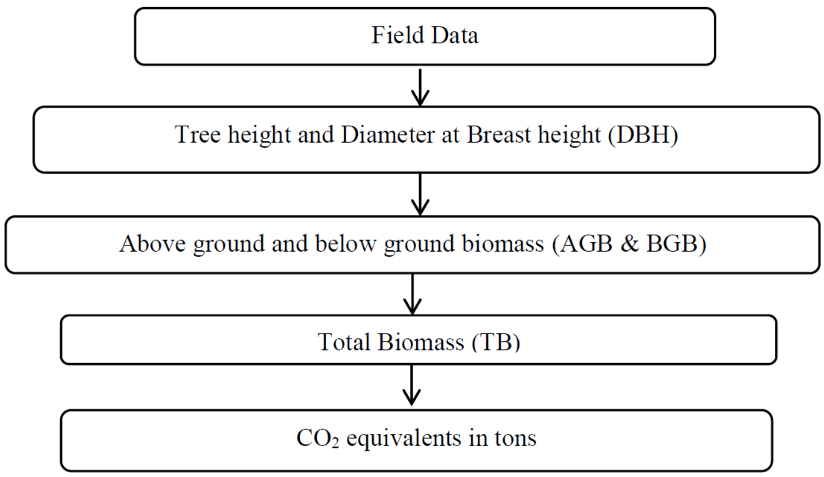

Figure 2. Methodology flowchart.

4. Results and Discussion

A total of forty-five different species of trees were enumerated on the campus (Figure 3, Table 1). The most dominant species on the campus is Ficus benjamina, with a total of 436 trees. This species is commonly used in urban plantations as it is shade tolerant, can survive drought conditions, requires very little maintenance and can thrive in a range of soil types. Its ability to regenerate by aerial roots, cuttings and by seeds, as well as its dense canopy cover that provides shade, makes it an ideal choice for avenue plantations.

One of the disadvantages of this non-native tree species is that its vigorous and invasive root system buckles up pavements and roads [26].

The second and the third most common tree species are *Alstonia scholaris* and *Plumeria obtusa*, with their individual tree number equal to 308 and 222, respectively. *Alstonia scholaris*, also known as the Devil's tree or the Blackboard tree, is prominently used in urban plantations because of its ability to survive dry conditions, hardy nature, and tolerance against air pollution [27]. It is the most common native tree species found on the campus. *Plumeria obtusa* also has evolved to be one of the most preferred ornamental trees in urban areas, as it requires little or no maintenance, can propagate easily and looks magnificent with beautiful clusters of flowers all year round [28]. *Delonix regia* and *Neolamarckia cadamba* also have over a hundred tree plantations on the campus.

The ratio of native to non-native species on the campus is approximately 1:1. The largest DBH is recorded for a *Ficus religiosa* tree measuring 298.7 cm, followed by *Bombax ceiba* and *Morus rubra* trees measuring 265.1 and 213.3 cm, respectively. The above-ground biomass (AGB) and below-ground biomass (BGB) of all the trees of the campus are equivalent to 63,136.8 and 9470.5 kg, respectively. The total biomass accumulated is 72,607.3 kg and the total carbon content of the campus trees is equal to 38,142.5 kg. The total carbon sequestered by all the trees in a year is 139.9 tons. In other words, on average, carbon sequestered by an individual tree on the campus is 70 kg or 0.07 tons. A similar study performed in California State University, Northridge (CSUN), reveals that the total carbon dioxide sequestered by campus trees was in the order of 154 tons per year [29]. Haghparast (2013) also reported a total of 1694.5 tons of sequestrated carbon for seventy-six plots of Pune University campus [30]. Analysis of CSP of New Zealand University gave the estimates that 4139 trees stored 5809 tons of CO_2 [31].

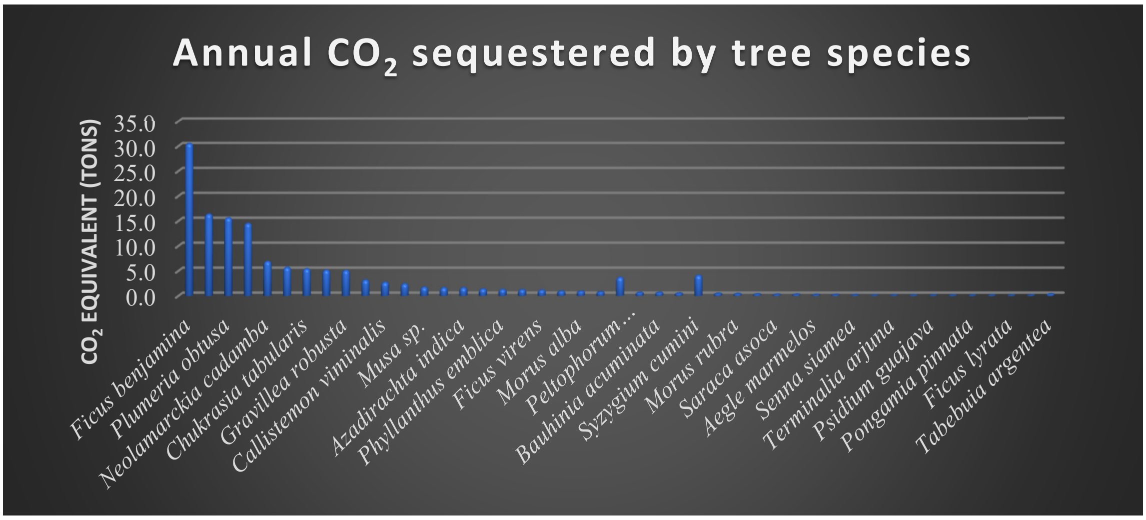

Figure 3. Annual CO_2 sequestered by different tree species in the campus.

Table 1. CO_2 Eq. (tons) of tree species in Amity University Campus.

S.N.	Species Name		Native/ Exotic Species	Total No. of Trees	AGB (kg)	BGB (kg)	TB (kg)	Carbon (kg)	CO_2 EQ (kg)	CO_2 EQ. (tons)
	Scientific Name	Common Name								
1	*Ficus benjamina*	Weeping fig	Exotic	436	14,481.29	2172.19	16,653.48	8326.74	30,531.39	30.53
2	*Alstonia scholaris*	Scholar's Tree	Native	308	7769.11	1165.37	8934.48	4467.24	16,379.87	16.38
3	*Plumeria obtusa*	White Frangipani	Exotic	222	7420.95	1113.14	8534.09	4267.04	15,645.83	15.65
4	*Delonix regia*	Flame Tree	Exotic	211	6883.30	1032.50	7915.80	3957.90	14,512.30	14.51
5	*Neolamarckia cadamba*	Kadam	Native	100	3274.72	491.21	3765.92	1882.96	6904.19	6.90
6	*Ficus microcarpa*	Laurel fig	Native	82	2716.93	407.54	3124.47	1562.24	5728.20	5.73
7	*Chukrasia tabularis*	Indian Mahogany	Native	78	2578.00	386.70	2964.70	1482.35	5435.28	5.44
8	*Phoenix dactylifera*	Date Palm	Exotic	77	2451.74	367.76	2819.50	1409.75	5169.09	5.17
9	*Gravillea robusta*	Silver Oak	Exotic	74	2430.46	364.57	2795.03	1397.51	5124.21	5.12
10	*Roystonea regia*	Royal Palm	Exotic	46	1515.21	227.28	1742.50	871.25	3194.58	3.19
11	*Callistemon viminalis*	Bottlebrush tree	Exotic	39	1303.96	195.59	1499.55	749.78	2749.18	2.75
12	*Eucalyptus sp.*	Eucalyptus	Exotic	36	1155.93	173.39	1329.32	664.66	2437.09	2.44
13	*Musa sp.*	Banana	Exotic	25	835.56	125.33	960.90	480.45	1761.64	1.76
14	*Mimusops elengi*	Spanish Cherry	Native	24	791.78	118.77	910.55	455.27	1669.34	1.67
15	*Azadirachta indica*	Neem	Native	24	784.78	117.72	902.50	451.25	1654.58	1.65
16	*Cassia fistula*	Indian Laburnum	Native	20	670.61	100.59	771.21	385.60	1413.88	1.41
17	*Phyllanthus emblica*	Indian Gooseberry	Native	19	615.51	92.33	707.84	353.92	1297.70	1.30
18	*Dalbergia sissoo*	Indian Rosewood	Native	18	592.21	88.83	681.04	340.52	1248.58	1.25
19	*Ficus virens*	White Fig	Exotic	17	556.52	83.48	640.00	320.00	1173.32	1.17
20	*Ficus religiosa*	Sacred Fig	Native	15	466.34	69.95	536.30	268.15	983.21	0.98
21	*Morus alba*	White Mulberry	Exotic	14	456.49	68.47	524.97	262.48	962.44	0.96
22	*Largestroemia speciosa*	Pride of India	Native	12	398.66	59.80	458.46	229.23	840.52	0.84
23	*Peltophorum pterocarpum*	Copper pod	Exotic	12	241.93	36.29	278.22	1020.15	3740.56	3.74
24	*Moringa oleifera*	Drumstick tree	Native	10	326.28	48.94	375.22	187.61	687.90	0.69
25	*Bauhinia acuminata*	Dwarf white orchid tree	Exotic	10	331.99	49.80	381.79	190.90	699.95	0.70
26	*Bambusa vulgaris*	Bamboo	Exotic	10	254.95	38.24	293.19	146.59	537.51	0.54
27	*Syzygium cumini*	Jamun	Native	9	296.08	44.41	340.49	1128.00	4135.99	4.14
28	*Jatropha Curcas*	Jatropha	Exotic	7	232.40	34.86	267.26	133.63	489.97	0.49

29	*Morus rubra*	Red Mulberry	Exotic	6	197.01	29.55	226.57	113.28	415.37	0.42
30	*Acacia auriculiformis*	Earleaf Acacia	Exotic	5	162.32	24.35	186.66	93.33	342.21	0.34
31	*Saraca asoca*	Sorrowless tree	Native	5	118.61	17.79	136.40	68.20	250.07	0.25
32	*Pterospermum acerifolium*	Maple-leaved Bayur tree	Native	4	129.22	19.38	148.60	74.30	272.44	0.27
33	*Aegle marmelos*	Stone apple tree	Native	3	98.48	14.77	113.26	56.63	207.64	0.21
34	*Bombax ceiba*	Silk cotton tree	Exotic	3	92.07	13.81	105.89	52.94	194.12	0.19
35	*Senna siamea*	Siamese Senna	Native	2	65.17	9.77	74.94	37.47	137.39	0.14
36	*Holoptelea integrifolia*	Indian Elm	Native	1	27.06	4.06	31.12	15.56	57.06	0.06
37	*Terminalia arjuna*	Arjun	Native	1	32.48	4.87	37.35	18.67	68.47	0.07
38	*Spathodea campanulata*	African Tulip Tree	Exotic	1	32.10	4.82	36.92	18.46	67.68	0.07
39	*Psidium guajava*	Guava	Exotic	1	27.06	4.06	31.12	15.56	57.06	0.06
40	*Cordia myxa*	Indian Cherry	Native	1	33.40	5.01	38.41	19.21	70.42	0.07
41	*Pongamia pinnata*	Indian Beech Tree	Exotic	1	31.73	4.76	36.49	18.25	66.90	0.07
42	*Ficus elastica*	Rubber Tree	Exotic	1	33.40	5.01	38.41	19.21	70.42	0.07
43	*Ficus lyrata*	Fiddle-leaf Fig	Exotic	1	33.62	5.04	38.66	19.33	70.87	0.07
44	*Magnifera indica*	Mango	Native	1	27.06	4.06	31.12	15.56	57.06	0.06
45	*Tabebuia argentea*	Yellow Trumpet Tree	Native	5	162.32	24.35	186.66	93.33	342.21	0.34
Total				**1997**	**63,136.81**	**9470.52**	**72,607.33**	**38,142.46**	**139,855.69**	**139.86**

5. Conclusions

The present work is a sustainability initiative to inventory the trees of Amity University campus and compute their carbon storage capacity. AGB and BGB were also estimated using the non-destructive method. A total of 1997 trees belonging to 45 different species have been recorded on the campus, with the carbon sequestration potential of 139.9 tons. The ratio of native to non-native species on the campus is approximately 1:1. The results of the study illuminate the value of urban trees, not only as ornamental and aesthetic plantations but also in mitigating the impacts of climate change at a local level. Higher education institutes have an important role in expanding their green cover so as to act as local carbon sinks. It is also imperative that more native species should be planted as compared to the exotic species. The results of the study can be used for future on-campus greening plans, and act as a baseline for future assessments of the campus carbon sink. Such education institutes can model themselves as agents of change and influence student behavior by undertaking such sustainable green practices on campus.

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