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Optimization for Carbon Footprint in an Institutional Campus

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ABSTRACT

Development of environmentally sustainable cities is the need of today's fast urbanizing India. By 2050 nearly half the Indian population will be living in urban areas. Urban activities have increased the atmospheric Carbon Dioxide (CO2), and will continue to increase. Indian cities are major producers of CO2, but are not planned for enough Carbon Storage to compensate their own Carbon Footprints. It is imperative to maintain the ''balance'' between the Carbon emission and Sequestration to achieve environmental sustainability. Any process that removes CO2 from the atmosphere and deposits it in a reservoir of any particular type (plant material, wood, soil, etc) is termed as 'Carbon Sequestration'. The Trees make the withdrawal of CO2 from the atmosphere with the process of photosynthesis and store it in the form of growing plant material. Around 5%-21% of total photosynthetically fixed Carbon is transferred into the rhizosphere through root exudates. This study constitutes an estimation of standing biomass in the form of Plants and Trees, and the Carbon Sequestration by them at the institutional campus – 'Udhaji Maratha Boarding Campus, Nasik'. Objective is to find their value in environmental optimization w.r.t. CO2 footprint of the campus. This study tries to estimate (i) CO2 Sequestration by existing plant material, (ii) required Sequestration as per the current Carbon footprint of the users. Further this research projects the Carbon Sequestration in the future by the current vegetation after its 100% growth.

Key words *: Carbon sequestration, Urban ecosystem, Standing biomass*

Introduction

Carbon emissions have serious effects on the natural environment as well as on human health; by displacing oxygen in the atmosphere (Manisalidis I.). Tropical deforestation and activities like burning petroleum products for vehicular transportation; besides burning of the fossil fuels such as coal, oil, and natural gas; have caused a substantial increase in the concentration of atmospheric CO2 over the last 2 centuries. Global CO2 emissions increased by 63% from 1990 (22,200 Mt CO2) to 2017 (36,200 Mt CO2) with an average annual increase of 1.8% (Harald, 2021). This has caused global warming and high air pollution levels. Even the oceans are becoming acidic, since high atmospheric CO2 gets absorbed by the seawater.

Carbon Sequestration is a natural or artificial process by which CO2 is removed from the atmosphere and held in solid or liquid form. Carbon is stored in various natural storages like oceans, fossil fuel deposits, soil (forestland, grassland, & agricultural land), terrestrial system (rocks, sediments, wetlands, & forests), and the atmosphere. Tree biomass (tree trunks, branches, foliage, and roots) is the terrestrial Carbon storage (Akhlaq, 2012).

Plants and Trees store Carbon for as long as they live, in the form of the live biomass. Carbon Sequestration rates differ based on the species of tree, soil type, regional climate, topography, and management practices. Plants take CO2 from the atmosphere, and turn it into sugars that become leaves, stems, roots, & woody trunks. When Trees mature, Carbon accumulation reaches saturation point where additional Sequestration is no longer possible. Once they die, the biomass becomes a part of the food chain and enters in the soil as 'Soil Carbon'. Subsequently, it re-enters into the atmosphere upon either decomposition or burning.

India's emissions have increased by 300% since 1990. From 1990 to 2017, the annual increase in percentage was 5.3 pa **%** as given in Table 1.

Table 1. Rise in CO2 Emissions in India

CO2 emissions (Mt)		Growth 1990 – 2017(%)	
Yr. 1990	Yr. 2017	Total (%)	(pa %)
617	2,467	300	5.3

Source: Global Carbon Atlas (2019)
Mt = million tons; pa = per annum

Table 2. Per Capita Emission in India

CO2 emissions in Yr. 2017(Mt) and (pc %)	
Total	(pc %)
2,467	1.8

Source: Global Carbon Atlas (2019)
t = Ton (1 Ton = 1,000 kilograms); Mt = million tons; pc = per capita

Among highly populous countries, India with population 1.34 billion has a tree population of only 35 billion; leading to just 28 Trees/person; as against the countries such as –Brazil with 301 billion Trees has 1494 Trees/person, Russia with 641 billion Trees has 4461 Trees/person, Canada with 318 billion Trees has 8953 Trees/person, and China with 139 billion Trees has 102 Trees/person (Crowther, 2015).

Since 2010, India's total greenhouse gas emissions increased by 34%, consisting of 48% increase in CO2 emissions and 9% increase in non-CO2 greenhouse gas emissions (Olivier J.G.J.). The per capita CO2Emission in India is 1.8%as compared to USA-16%, Saudi Arabia 19%, China 7%which is comparatively less (McKinsey *Quarterly* - JAN 25, 2022). The target set by the Paris Agreement 2015 is to limit the temperature rise by 2.0 degree Centigrade, for which amongst the GHG Reduction of Carbon emissions is targeted. India has to take the responsibility in any which way to reduce the emissions. Increasing the Green cover is one of the strategies that can be deployed.

Study Site : Udhaji Maratha Boarding Campus, Nasik

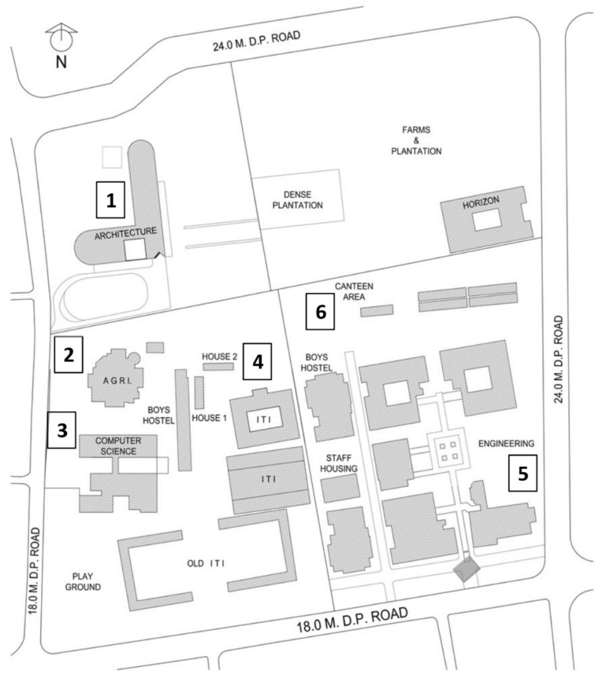

Fig. 1. MVPS's Udhaji Maratha Boarding Campus, Nasik (Showing the built-up and non-built-up areas)

The study site is 'Udhaji Maratha Boarding Campus' of MVPS's Educational Institute; is located in Nasik city. Nasik is the 4th largest urban area of Maharashtra State and one of the fastest growing Tier-2 city of India. Urban population of the city was 11,52,326 in 2001; 15,62,769 in 2012, and is estimated to be 24,00,000 in 2023.The ongoing Tree Census done in Nov 2016 shows over 46,50,000 Trees within the civic body's jurisdiction. That makes it approximately 2.1 tree per person, which is far less.

The campus area of 1,38,945 sq.m. is comprised of various educational institutes and ancillary buildings like hostels, etc. Total building footprint measures 23,655 sq.m. as in Table 6.

Methodology

The research is carried out on the following steps – [**A**] Documentation of the existing Trees and calculating the Carbon Sequestration done by them in the status of Growth.

[B] Calculating the Carbon Emissions by the users –

a) Carbon given out in Exhalation

b) Carbon emission from the travel - home to institute and back home.

Travel is considered on 2 wheelers and 4 wheelers for an average distance of 10 kms (both ways).

[C] Calculating the no. of Trees required for sequestering Carbon from the above information.

[D] Working out a phase wise proposal for developing the Trees for the current no. of users.

[A] Existing Trees and Carbon Sequestration

The counting of Trees (765 Trees) is done according to the species. Trees having the girth at breast height (GBH) of above 150 mm were considered. Existing Trees are classified in four Growth Categories, based on GBH as in Table 3.

To estimate the stocks of Live Tree Carbon in the campus site, the biomass of all sampled Trees is first estimated. Tree heights are estimated by visually comparing it to the closest buildings with known heights.

Table 3. Tree Classification as per their growth

Tree		Growth	
100%	75%	50%	25%
GBH 0.95 m	GBH 0.75 m	GBH 0.55 m	GBH 0.35 m
No. of Trees in each Growth Category			
215	96	156	298
Fully Grown	Grown	Half Grown	Young

The 'Carbon Storage' is calculated for both the above and below ground plant components (i.e. sum of the biomass of roots, trunk, branches, leaves, & reproductive organs – flowers & fruits) (See Table-5).

[B] Calculating the Carbon Emissions by the users.

The users considered are Students, Teaching Staff, Administrative Staff, and Visitors. CO2 production by the users due to breathing activity and vehicle use is calculated.Total Carbon Storage is then compared with estimated CO2 produced by the human population on the campus.

(a) A typical Human exhales

approx 1.0 kg CO2 / day (Brian Palmer)

= approx 365 kg CO2 / yr

= approx 100kg Carbon / yr

. . . . . [1 Ton CO2 = 0.273 Ton Carbon]

Hence, Carbon produced by 5205 humans

= approx 520500 kg Carbon / yr

= approx **520.50 Ton** Carbon / yr

. . . . . [1 Ton = 1000 kg]

(b) Carbon Emissions from on-campus vehicles

- Average distance of 10 kms is considered.
- Petrol vehicles are considered based on the sample survey conducted (for coming to institute and going back home)
- 22 working days per month and 11 months are considered for the use of vehicles by the users in relation to all the institutes in the campus.

Table 4. Abbreviations, Definitions, Formulas

Abbreviations and Formulas	Unit
GBH = Girth measured at breast height *(Approx 1.3 m above ground)*	
Tree Diameter	m
= GBH / Pie value	
= GBH / 3.14	m
$\mathbf{T_{BV}}$ = Tree Bio-Volume	m^3
= Diameter × Height × factor 0.4	
= D × H × 0.4	
AGB = Above Ground Biomass	kg
= T_{BV} × Green Wood Density	
. . . . (Vashum K T)	
BGB = Below Ground Biomass	kg
= AGB X Root : Shoot Ratio	
= AGB × 0.26	
TB = Total Biomass = AGB + BGB	Kg
P = Potential for Carbon Storage (OR Carbon Sequestration Potential)	
= TB / 2	kg

Table 5. Biomass and Carbon Sequestration Potential (**P**) of the existing Trees

Campus		No. of Trees	AGB (Kg)	BGB (Kg)	TB (Kg)	P (kg)
1	Architecture	150	65720.37	9519.09	75239.46	37619.73
2	Agriculture	123	109057.25	13288.82	122346.06	61173.03
3	Computer Sci.					
4	Industrial	40	19080.81	2475.22	21556.03	10778.02
5	Engineering	231	124921.79	9139.99	134061.78	67030.89
6	Canteen	221	112696.26	1527.18	114223.44	57111.72
	Total =	765	431476.5	35950.3	467426.77	233713

Table 6. Number of Users and Vehicles

	Campus	Built up Area(sq.m.)	Population	Motor Bikes	Cars
1	Architecture	2750	550	350	40
2	Agriculture	2100	480	250	30
3	Computer Sci.	2535	1725	200	20
4	Industrial	5500	330	50	10
5	Engineering	10570	2100	1150	100
6	Canteen	200	20	Nil	Nil
	Total =	23655	5205	2000	200

Carbon Emissions from 2 wheelers

Fleet Average of CO2 Emissions = 41.2 g CO2 / km (Anup S.)

For 10 kms	41.2 X 10	=412.0 gCO_2
Total CO_2 Emission	2000 X 412	= 824000 gCO_2/day
For 22 days	824000 X 22	= 18128000 gCO_2/ month
For 11months	18128000 X 11	= 199408000 g CO_2/ year

Total CO2 Emission from 2 wheelers = 199.408 Ton/ Year

Carbon Emissions from 4 wheelers

Fleet Average of CO2 Emissions = 122.6 g CO2 / km (Deo A.)

For 10 kms	122.6 X 10	= 1226.0 g CO2
Total CO2 Emission	200 X 1226.0	= 245200 g CO2/day
For 22 days	2452000 X 22	= 5394400 g CO2/ month
For 11months	53944000 X 11	= 59338400 g CO2 / year

Total CO2 Emission from 4 wheelers = 59.338 Ton / Year

Thus, Total CO2 emission from 2 Wheelers and 4 Wheelers	199.408 +59.338	258.746 Ton / Year

Hence Carbon Emission from 2 and 4 wheelers

= 258.746 X 0.273

= 70.637 Ton Carbon / year

Carbon Emission from Exhalation and Vehicles

= (a) + (b) = 520.50 + 70.63

= 591.13 Ton Carbon / year

Carbon Sequestration By Existing Trees

From Table 3, only **28 % Trees** are fully grown. Full Carbon Sequestration Potential (**P**) of the existing 765 Trees is yet to be reached; considering the fact that **72 % Trees** are yet to be grown fully.

Currently Sequestered Carbon *(Yr. 2021)*

= 2,33,713 kg Carbon (from Table-5)

= **233.71 Ton** Carbon

Following Table 7 shows the Carbon Sequestration potential (**P**) according to their growth. The proportion of 298 Young Trees (25% Growth category) which are recently planted in last 3 to 5 years is comparatively largest (39%). The proportion of 311 Grown Trees (100% & 75% Growth category) is 28% + 13% = 41%; and has implications on the proposal for optimization of the Carbon Emission.

Findings

Shortage of required Carbon Sequestration

= Current '**P**' Deficit

= (Carbon Production / yr) – (Existing Carbon Sequestration Potential / yr)

= 591.13 – 233.71 Ton Carbon / yr

= **357.42 Ton** Carbon / yr

Table 7. Carbon Sequestration Potential (**P**) of 765 Trees according to their Growth

Growth of Tree (%)	No. of Trees (No.)	% of Trees (%)	GBH (Avg.)(m)	P (Yr 2021)(kg)	P(Yr 2021) (Ton)
100%	215	28%	0.95	65439.75	65.44
100%	215	28%	0.95	65439.75	65.44
75%	96	13%	0.75	30382.74	30.38
50%	156	20%	0.55	46742.68	46.74
25%	298	39%	0.35	91148.23	91.15
Total =	765	100%	- - -	233713	233.71

Table 8. Carbon Sequestration Target phases to optimize the Carbon Footprint of the campus

Tree Growth / Year	Fully Grown	Grown	Half Grown	Young	New
2021	215	96	156	298	- - -
2022	215	96	156	298	**165 (New-a)**
2023	215	96	156	298	**165 (New-b)**
2026	311	156	298	**165 (a)**	- - -
2027	311	156	298	**165 (b)**	- - -
2031	467	298	**165 (a)**	- - -	- - -
2032	467	298	**165 (b)**	- - -	- - -
2036	765	**165 (a)**	- - -	- - -	- - -
2037	930	**165 (b)**	- - -	- - -	- - -
2038	**1095**	- - -	- - -	- - -	- - -

Discussion

- Despite seemingly plenty of plantation on the site, 'Carbon Production' VS 'Carbon Sequestration' is not being balanced out yet. The total Deficit of Carbon Sequestration based on the existing status of Trees is **357.42 Ton** Carbon / yr.
- To fulfil the deficit, first strategy that can be considered is to calculate the Carbon emission after the full growth of **550** under-grown Trees (total 765 Trees – fully grown 215 Trees = under-grown 550 Trees). These Trees will attain their full growth after 15 years on an average (i.e. In Year 2036 as shown in Table-8) (depending upon the speed of growth of varied species).
- The Carbon sequestered after the 765 Trees are fully grown is **367.81** Ton. Carbon/Year (worked out on the formula given in Table 4).
- Hence the Deficit after the full growth of 765 Trees is 591.13–367.81 = **223.32** Ton Carbon/year
- To fulfill the requirement of Carbon Sequestration in the Campus,

$$\frac{\text{Deficit of Carbon Seq.} \times \text{Full grown Trees in 15 years}}{\text{Total Carbon to be Sequestered}} = \text{No. of Trees Required}$$

$$\frac{223.32 \times 765}{591.13} = 290 \text{ Trees Required}$$

- Considering that there will be mortality of 5%, additional 40 new Trees will have to be newly planted and to be grown fully. i.e. 290 required Trees + 40 additional Trees = **330 new Trees** have to be newly planted and to be grown fully.

Recommendations

- Following stages of maturing of existing Trees and becoming full grown for maximum Carbon Sequestration are considered.
- 75% grown Trees will mature in coming 5 yrs (i.e. 2027), 50% grown Trees will mature in 10 yrs (i.e. 2032), and 25% grown Trees will be mature and full grown in 15 yrs (i.e.2037).
- Currently 17% of the Site is a Built-Up Area (23655 sq. m.) (i.e. 83% of 115290 sq. m. campus) is open with plenty of scope for additional plantation.
- Additional required plantation can be done in 2 phases to reach the on-site Carbon Footprint Mitigation.
- New Tree plantation of the first phase (in 2022) will become matured and full grown in 15 yrs (i.e. 2037).
- New Tree plantation of the second phase (in 2023) will become matured and full grown in the year 2038.
- This shall fulfill the Sequestration required to compensate for the CO2 produced from two activities of -Exhalation and vehicular use (within 10 kms).
- A combination of Indigenous fast growing and medium pace growing Trees should be planted. The following species not observed in the Campus and can enrich various environmental aspects should be planted such as: Mangifera In-

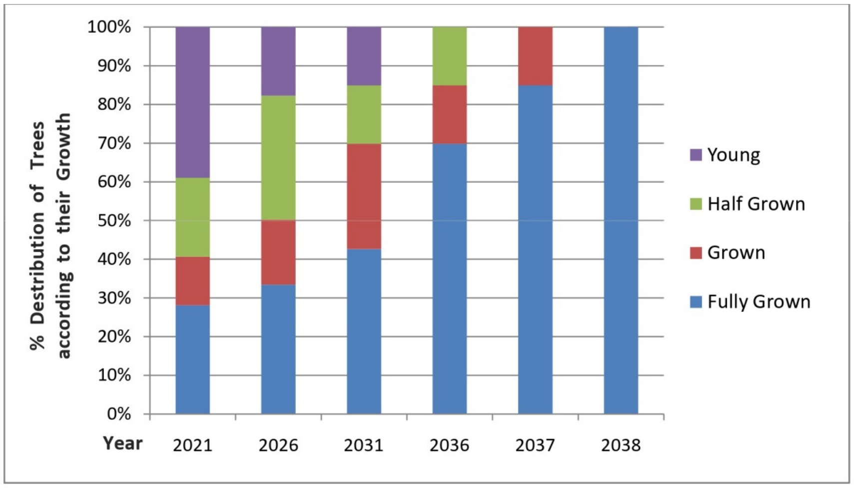

Fig. 2. Growth of Trees in next 17-Years

dica (Mango), Anthocephalus Kadamba (Kadam), Ficus Religiosa (Peepal), Ficus Benghalensis (Banyan), Millettia Pinnata (Karanj), Inga Dulcis (Vilayati Chinch), Psidium Guajava (Guava), Bambusa Vulgaris (Bamboo), Emblica Officianalis (Amla), Sapindus Mukorossi (Reetha- Indian Soapberry), Madhuca Longifolia (Madhukar), Terminalia Catappa (Badam), Dalbergia Sissoo (Shisham), Kigelia Pinnata (Kigelia), Michelia Champaca (Champak), Aegle Marmelos (Indian Bael), Terminalia Arjuna (Arjun), Holarrhena Pubescens (Indrajav), Erythrina Variegata (Indian Coral Tree), Varieties of Bauhinia, (Bose T. K.).

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