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EVALUATION OF TREES AND THEIR CARBON SEQUESTRATION POTENTIAL USING NON-DESTRUCTIVE METHODS IN SURAT, GUJARAT

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Abstract

One important tactic for reducing climate change is carbon sequestration, which involves absorbing and storing carbon dioxide (CO_2) from the atmosphere. Abrama Road, Umbhel Garden, Sarthana Nature Park, Gorat, and Sneh Rashmi Botanical Garden are the five locations chosen for this study, which evaluates the carbon sequestration capability of urban trees in Surat city of Gujarat. A non-destructive technique based on girth at breast height (GBH), height, and biomass estimations was used to examine 73 different tree species. The study evaluates biomass buildup and carbon storage capability in several tree species across diverse urban environments using methods including remote sensing, allometric equations, and ground-based observations. The study contributes to climate resilience and sustainable urban planning by shedding light on the best tree species for sequestering carbon. These calculations emphasize how crucial afforestation is to improve carbon absorption. Policymakers may use the study's useful data to create sustainable urban forestry plans that will reduce CO_2 emissions. Future studies should examine the effects of climate change and long-term sequestration trends on the growth of urban trees.

Key words: *Carbon sequestration, Climate, Afforestation, Urban trees*

INTRODUCTION:

There has been an increase in global heat and carbon emission over the past few years as a result of both biotic and abiotic factors and climate change. Since Earth's mean temperature is expected to rise by 1.5–5.88°C throughout the course of the twenty-first century, global surface temperatures have risen by 0.88°C (Change, 2001; Lal, 2008). From 280 ppmv in 1850 to 380 ppmv in 2005, the concentration of carbon dioxide (CO_2) rose 31%, and it is currently rising at a rate of 1.7 ppmv yr^{-1} or 0.46 yr^{-1} (Lal, 2008). One of the primary gases contributing to global warming is carbon dioxide (CO_2), CFC (chlorofluorocarbon), and NO_2 (nitrogen oxide), carbon monoxide (CO), methane (CH_4), sulfur dioxide (SO_2), water vapor (H_2O), and dust particles, but methane (CH_4) and nitrous oxide (NO_2O), two more dangerous gases, are seen to raise atmospheric CH_4, which in 2013 reached 253% of its pre-industrial level (~722 ppb) (Prather, 2001). Global warming is defined as the excessive increase in the mean temperature of the earth's atmosphere. This phenomenon is thought to be irreversibly changing the planet's climate and poses a significant challenge to scientists worldwide (Kumar et al., 2022). The primary cause of global warming is the rise in greenhouse gases brought on by human activity. Fossil fuel combustion, deforestation, industrial emissions, waste management, and agriculture are major contributors, releasing nitrous oxide, methane, and carbon dioxide into the atmosphere (Singh, 2024).

Combating climate change requires the use of mitigation methods. Adopting CCS technology, investing in reforestation, switching to renewable energy, increasing energy efficiency, and encouraging sustainable urban planning and transportation are important steps. These initiatives, when coupled with international collaboration, have the potential to build a more resilient and sustainable future (Singh, 2024). Three methods exist for reducing CO_2 emissions in order to slow down climate change. (i) Cutting down on the amount of energy used worldwide, (ii) Creating fuel with little or no carbon, and (iii) Using engineering and natural methods to sequester CO_2 from point sources or the atmosphere (Lal, 2008; Schrag, 2007).

Carbon Sequestration:

Emissions from burning fossil fuels increased by 40% between 1980 and 2000 (Wofsy, 2001). However, during this time, the quantity of CO_2 building up in the atmosphere was constant due to the excess oceans, trees, soils, and other ecosystems are removing the CO_2 that has been emitted (Lal, 2008). There are two primary forms of carbon sequestration: geologic and biologic (also known as bio-sequestration). The act of storing carbon in a carbon pool, or carbon sequestration, is essential for minimizing climate change because it lowers the atmospheric concentration of carbon dioxide (Masson-Delmotte et al., 2021). A National Academy of Sciences research states

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that "10 billion metric tons of CO_2 need to be extracted out of the air per year" (Chhabra, 2020; National Academies of Sciences, 2019).

Aim & Objective:

The aim of a carbon sequestration research in Surat district is to evaluate and improve the district's potential to absorb and store atmospheric carbon dioxide (CO_2) in order to increase environmental sustainability and slow down climate change.

Detailed objectives might be as follows: (1) It identifies high-potential locations for carbon storage while assessing how industry and urbanization affect sequestration capability. (2) mapping and identifying high-potential for carbon capture regions and increasing green cover through agroforestry, afforestation, and coastal area restoration. (3) The results will help guide planning for sustainable industrial and urban growth as well as climate policy.

Site selection:

The city of Surat is located in the southern region of Gujarat, a state in western India. The city is situated on the banks of the Tapi River, close to where it meets coastal location on the Arabian Sea. Its approximate coordinates are 21°12′18″N 72°50′24″E. One of India's cleanest cities, Surat is also referred to as "The SILK CITY," "The Diamond City," and "The Green City". Moreover, Surat is a significant economic and industrial hub, renowned for its textile and diamond sectors (sours- https://surat.nic.in/). Being a significant economic and industrial hub, it adds to worldwide environmental problems such as industrial pollution and greenhouse gas emissions.

Air pollution and carbon emissions have been rising as a result of construction, automobile traffic, and industrial pollutants. Residents may experience respiratory disorders as well as other health concerns as a result. Winter temperatures vary from 10° to 15° Celsius, while summer temperatures range from 37° to 44° Celsius (Vasanthawada et al., 2023). According to the 2011 census, there are 44,61,002 (4.46 million) people living in Surat, and the Surat Municipal Corporation occupies 326.515 km² (Patel & Bhatt., 2016). According to pollution and population Carbone study are most important. Five sites of Surat are selected for the study of carbon sequestration- Abrama Road, Umbhel Graden, Sarthana Nature Park, Gorat, and Sneh Rashmi Botanical Garden.

Figure 1: Map of India

Source: https://www.theguardian.com/cities/2014/sep/15/indian-cities-climate-change-surat

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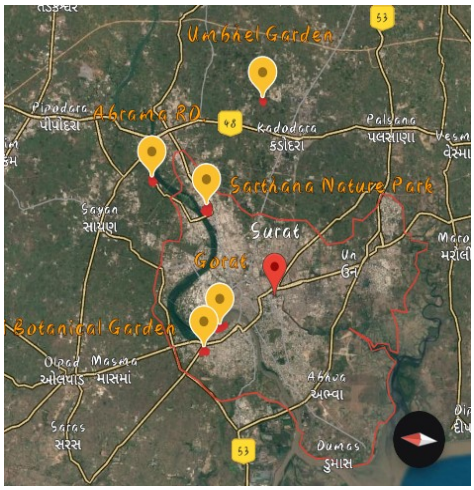

Figure 2: Selected sites of Surat

The rainy season is oppressive, windy, and mainly overcast, whereas the dry season is humid and mostly clear. It is hot all year around. Throughout the year, the temperature ranges from 62°F to 99°F, seldom falling below 58°F or rising over 103°F.

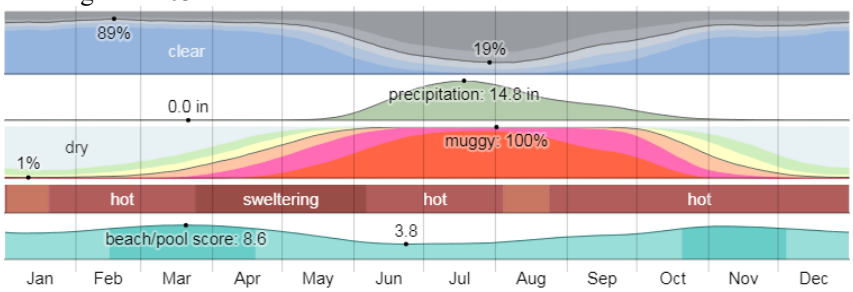

Figure 3: Climate of Surat

Source: https://weatherspark.com/y/107304/Average-Weather-in-S%C5%Abrat-Gujarat-India-Year-Round#Sections-Temperature

MATERIAL & METHODOLOGY:

For the non-destructive approach of estimating biomass and carbon sequestration, the height of certain tree species and their girth at breast height (GBH) were assessed. GBH and height were measured methodically in order to estimate biomass and carbon sequestration using a nondestructive approach (Maitreya & Modi, 2024)

The chosen region is enormous and dispersed over a considerable area. Thus, the quadrant approach is the most effective for this carbon sequestration investigation. A random sample of 10×10 meters was obtained as part of the sampling procedure. 10 and 15 quadrants were laid and studied in each selected site.

Material:

A list of tools utilized for this study:

- Measurement tape
- Clinometer
- Field journal
- Datasheets
- Pen or pencil
- Camera (DSLR or high-resolution mobile camera)
- Map
- Books for identifying flora

Flow chart of methodology:

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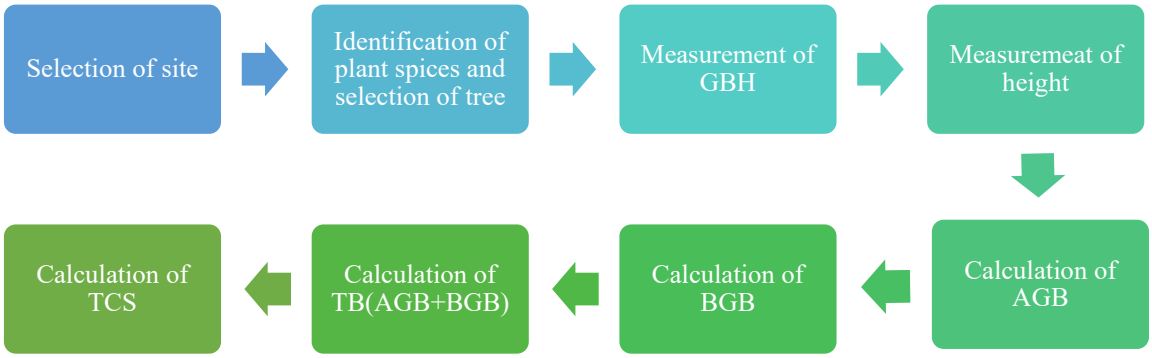

Carbon sequestration estimation:
The following formula was used to estimate the tree's volume:
$V=r^2h$
Where, (V = Volume, r = Radius, h = Height) in cubic meter (cm^3)
Calculation of Above Ground Biomass (AGB):
All live biomass found above the soil is referred to as above-ground biomass. By dividing the biomass volume by the density of the wood, the volume of the expected aboveground biomass based on diameter and height was calculated.
The estimate of the species' wood density from the web (www.fao.org)
AGB (kg/tree) = Volume of tree (m3) × Wood density (g/m3)
Note: The standard average value of 0.6 gm/cm3 is considered for computation in the event that the wood density is unavailable.
The Below Ground Biomass (BGB):
The total biomass of living roots, excluding fine roots with a diameter of less than 2 mm, is included in the below-ground biomass. According to Ravindranath and Ostwald's (2008) technique, the below-ground biomass was determined by multiplying the above-ground biomass by 0.26 factors.
BGB (kg/tree) or (ton/tree) = AGB (kg/tree) or (ton/tree) × 0.26
Where, 0.26 = Root to Shoot ratio
Total Biomass:
According to Sheikh & Wang, the sum of the above-ground and below-ground biomass is the total biomass.
Total Biomass (kg/tree) = AGB + BGB
Total Carbon:
TC = TB/2 or TB × 50%
Calculating the mass of carbon dioxide stored in the tree:
One carbon molecule and two oxygen molecules make up the three molecules that make up carbon dioxide. The atomic weights of carbon and oxygen are 10 and 14, respectively. Carbon dioxide's molecular weight is 38.
CO_2= 1C + 2O = 1(10) + 2(28) = 38
The ratio of CO_2 to carbon is 44/12 = 3.667 (Maitreya et al., 2023)
The current study used the non-destructive approach to assess the total carbon sequestration in woody vegetation, particularly tree species, utilizing the FAO-recommended wood density of tree species. Additionally, the standard average value of 0.6 gm/cm^3 was taken into consideration for the computation of carbon sequestration in the event that the wood density was unavailable.

Table 1: Vernacular name & wood density of tree species

Sr. No.	Scientific Name	Vernacular Name	Family	Wood Density G/CM^3 or T/M^3
1	Acacia auriculiformis Benth.	Australian Baval	Mimosaceae	0.68
2	Acacia nilotica (L.) Delile	Babool, Kalo Baval	Mimosaceae	0.67
3	Acacia 51enegal (L.) Willd	Goradiyo Baval	Mimosaceae	0.6
4	Aegle marmelos (L.) Correa	Bili, Stone apple	Rutaceae	0.75
5	Ailanthus excelsa Roxb.	Arduso	Simaroubaceae	0.83
6	Albizia lebbeck (L.) Benth	Kaliosaras, Shirish	Mimosaceae	0.55
7	Albizia saman (Jacq.) Merr.	Rato Shirish	Mimosaceae	0.45
8	Anacardium occidentale L.	Kaju, Cashew	Anacardiaceae	0.52
9	Annona squamosa L.	Sitaphal	Annonaceae	0.52
10	Azadirachta indica A. Juss.	Limbdo, Neem	Meliaceae	0.69
11	Bauhinia variegata L.	Kanchan	Fabaceae	0.68

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12	Bismarckia nobilis Hildebr. & H. Wendl.	Bismarkia Palm	**Arecaceae (Palmae)**	0.6
13	Butea monosperma (Lam.) Taub.	Khakhro	Papilionaceae	0.48
14	Carica papaya L.	Papaiyu	Caricaceae	0.52
15	Caryota mitis Lour.	Clustered fishtail palm	Arecaceae	0.48
16	Casuarina equisetifolia L.	Sharu	Casuarinaceae	0.83
17	Cocos nucifera L.	Nariyal, Coconut	Arecaceae (Palmae)	0.5
18	Cordia dichotoma G. Forst.	Mota Gunda	Boraginaceae	0.38
19	Corymbia citriodora (Hook.) K. D. Hill & L. A. S. Johnson	Nilgiri	Myrtaceae	0.64
20	Couroupita guianensis Aubl.	Kailashpati	Lecythidaceae	0.52
21	Dalbergia lanceolaria subsp. Paniculata (Roxb.) Thoth.	Sitsal, Dandosi	Fabaceae	0.75
22	Dalbergia latifolia Roxb.	Shisham, Sitsal	Fabaceae	0.75
23	Delonix regia (Hook.) Raf.	Gulmohar	Caesalpiniaceae	0.52
24	Dypsis lutescens (H. Wendl.) Beentje & J. Dransf.	Areca Palm	Arecaceae (Palmae)	0.52
25	Eucalyptus globulus Labill.	Blue gum	Myrtaceae	0.52
26	Ficus amplissima Sm.	Piper, Pipali	Moraceae	0.39
27	Ficus arnottiana (Miq.) Miq.	Paras Pipal	Moraceae	0.6
28	Ficus benghalensis L.	Vad, Banyan	Moraceae	0.39
29	Ficus benjamina L.	Golden Fig	Moraceae	0.65
30	Ficus hispida L. f.	Dhed Umbar	Moraceae	0.6
31	Ficus racemosa L.	Goolar, Umardo	Moraceae	0.36
32	Ficus religiosa L.	Pipalo	Moraceae	0.44
33	Gmelina arborea Roxb	Sevan, Shivan	Verbenaceae	0.41
34	Grevillea robusta A. Cunn. Ex R. Br.	Silver Oak	Proteaceae	0.52
35	Haldina cordifolia (Roxb.) Ridsdale	Haldu, Haldavan	Rubiaceae	0.58
36	Hevea brasiliensis (Willd. Ex A.Juss.) Müll. Arg.	Rubber Tree	Euphorbiaceae	0.53
37	Holoptelea integrifolia (Roxb) Planch	Kanjo, Palpaliya	Ulmaceae	0.6
38	Hyphaene petersiana Klotzsch ex Mart.	Real fan palm	Arecaceae	0.6
39	Latania loddigesii Mart.	Latan palm	Arecaceae	0.6
40	Latania lontaroides (Gaertn.) H. E. Moore	Red Latan Palm	Arecaceae	0.6
41	Madhuca longifolia var. latifolia (Roxb.) A. Chev.	Mahua, Mahudo	Sapotaceae	0.74
42	Mangifera indica L.	Mango	Anacardiaceae	0.52
43	Manilkara hexandra (Roxb.) Dubard	Rayan	Sapotaceae	0.89
44	Manilkara zapota (L.) P. Royen	Chikoo	Sapotaceae	0.87
45	Mimusops elengi L.	Borsalli, Bakul	Sapotaceae	0.72
46	Moringa oleifera Lam.	Saragvo	Moringaceae	0.52
47	Neolamarckia cadamba (Roxb.) Bosser	Kadamb	Rubiaceae	0.52
48	Phoenix dactylifera L.	Date palm	Palmaceae	0.48
49	Phyllanthus acidus (L.) Skeels	Star Goose Berry, Khata amla	Euphorbiaceae	0.52
50	Phyllanthus emblica L.	Amla	Euphorbiaceae	0.64
51	Pithecellobium dulce (Roxb.) Bth.	Sweet Tamarind	Mimosaceae	0.52
52	Plumeria rubra L.	Champo	Apocynaceae	0.5
53	Polyalthia longifolia (Sonn.) Thw.	Asopalav	Annonaceae	0.56

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54	Pongamia pinnata (L.) Pierre	Karanj	Papilionaceae	0.82
55	Prosopis cineraria (L) Druce	Khijado	Mimosaceae	0.78
56	Prosopis juliflora (Sw) DC	Gando Baval	Mimosaceae	0.73
57	Psidium guajava L.	Guava, Peru	Myrtaceae	0.52
58	Pterocarpus marsupium Roxb.	Biyo, Kino Tree	Papilionaceae	0.67
59	Roystonea regia (Kunth) O. F. Cook	Bottle Palm, Royal Palm	Arecaceae (Palmae)	0.6
60	Sapindus trifoliatus L.	Aritha	Sapindaceae	0.7
61	Saraca asoca (Roxb.) Willd.	Ashok Tree	Caesalpiniaceae	0.6
62	Semecarpus anacardium L.	Oriental Cashew Nut	Anacardiaceae	0.7
63	Senna siamea (Lam.) H. S. Irwin & Barneby	Kasheed, Kasood	Caesalpiniaceae	0.52
64	Swietenia macrophylla G. King	Mahogani	Meliaceae	0.49
65	Syzygium cumini (L.) Skeels	Jambu	Myrtaceae	0.7
66	Tamarindus indica L.	Amli, Chineli	Caesalpiniaceae	0.75
67	Tectona grandis L.	Teak, Saag	Verbenaceae	0.5
68	Terminalia arjuna (Roxb) W. & A.	Arjun Sadad	Combretaceae	0.68
69	Terminalia bellirica (Gaertn) Roxb.	Behda	Combretaceae	0.72
70	Terminalia catappa L.	Badam	Combretaceae	0.52
71	Terminalia chebula Retz.	Harde	Combretaceae	0.96
72	Thespesia populnea (L.) Soland ex. Corr.	Paras Pipado	Malvaceae	0.52
73	Ziziphus jujuba Mill.	Mota Bor	Rhamnaceae	0.52

RESULT & DISCUSSION:

Five sites were chosen for this study in Surat including Abrama Road, Umbhel Graden, Sarthana Nature Park, Gorat, and Sneh Rashmi Botanical Garden. Of them, Sneh Rashmi Botanical Garden and Sarthana Neture Park have larger areas than the others. Among the 73 trees species, 60 quadrans are present.

1. Abrama road:

In this site, total of 44 individual tree species were found in 10 quadrates. Azadirachta indica A. Juss. Has been found highest at 8 in 6 quadrates, Acacia 53enegal (L.) Willd and Ficus hispida L. f. have 7 trees and found in respectively 5 and 3 quadrates. Prosopis juliflora (Sw) DC has 4 species found in 4 quadrates. While Acacia nilotica (L.) Delile, Ficus benghalensis L., Pithecellobium dulce (Roxb.) Bth. Have 3 individuals, which were found in 3, 3 and 2 quadrates respectively.

Total five families were found in this site, out of which Mimosaceae had the largest species recorded of total 19 trees, Moraceae was second large family and highest carbon is stored by Moraceae family- 5.45 tonnes. Total 30.88 tonnes carbon is sequestered from this site.

Table 2: Abrama road Tree species' physiological details.

Sr. No.	Scientific Name	No. of Trees	Average GBH (CM)	Average Height (M)	Average Organic Carbon			Total CS (Tonnes)
					AGB	BGB	TB	
1	Acacia nilotica (L.) Delile	3	58.82	8.65	39.92	10.37	50.29	0.39
2	Acacia senegal (L.) Willd.	7	51.66	6.35	20.24	5.26	25.50	0.20
3	Aegle marmelos (L.) Correa	1	76.2	8.00	69.40	18.04	87.45	0.64
4	Ailanthus excelsa Roxb.	2	163.54	14.13	624.35	162.33	786.68	5.9
5	Azadirachta indica A. Juss.	8	78.21	8.08	679.51	176.67	856.18	1.06
6	Ficus amplissima Sm.	2	31.76	3.75	29.42	7.65	37.08	0.02
7	Ficus benghalensis L.	3	399.28	13.05	1615.1	419.94	2035.1	16.81
8	Ficus hispida L. f.	7	54.16	7.15	25.08	6.52	31.60	0.30
9	Ficus religiosa L.	2	176.47	13. 29	494.44	128.55	623.00	4.67

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10	Pithecellobium dulce (Roxb.) Bth.	3	58.89	8.03	288.33	74.96	363.29	0.29
11	Prosopis cineraria (L) Druce	2	61.26	6.79	39.61	10.30	49.91	0.37
12	Prosopis juliflora (Sw) DC	4	45.26	7.40	22.03	5.73	27.77	0.23
Total Carbon Sequestration								**30.88**

Table 3: Abrama road family based physiological details

Sr No.	Family Name	No of Species	No. of Trees	Average GBH (CM)	Average Height (M)	Average Organic Carbon			Total CS (Tonnes)
						AGB	BGB	TB	
1	Meliaceae	1	8	78.21	8.08	679.51	176.67	856.18	1.06
2	Mimosaceae	5	19	55.17	7.44	82.02	21.32	103.35	0.29
3	Moraceae	4	14	165.41	7.98	541.01	140.66	681.69	5.45
4	Rutaceae	1	1	76.2	8.00	69.40	18.04	87.45	0.64
5	Simaroubaceae	1	2	163.54	14.13	624.35	162.33	786.68	5.9
Total carbon sequestration									**13.34**

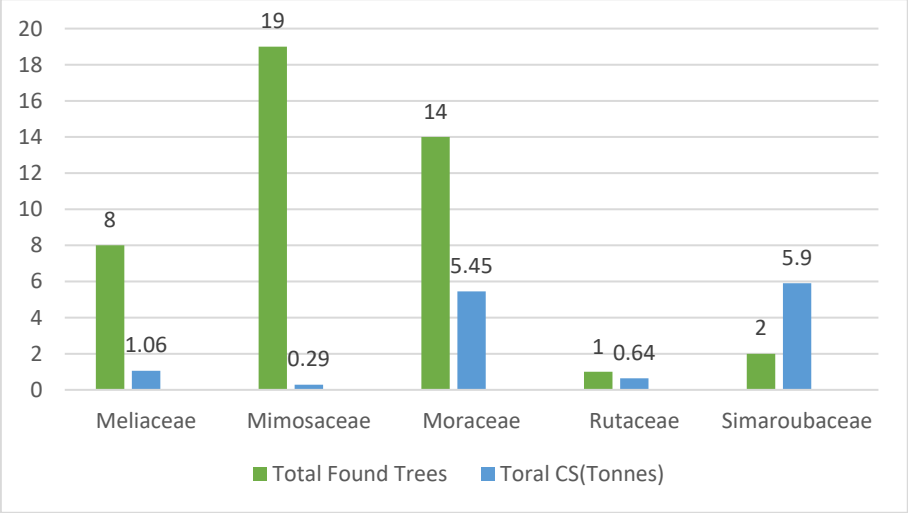

Figure 3: Abrama road Comparison of Total found trees in Family and Total Carbon Sequestration.

2. Umbhel Garden:

Umbhel garden recorded 41 tree species. With highest number of individuals of Delonix regia (Hook.) Raf. 8 occurring in 6 quadrates. Corymbia citriodora (Hook.) K. D. Hill & L. A. S. Johnson has 5 individuals found in 4 quadrates. Casuarina equisetifolia L. was found in 3 quadrates with 4 individuals. Semecarpus anacardium L. was has 3 individuals found in 3 quadrates.

Total of 13 families were found in this site, out of which Caesalpiniacea had a greater number of tree species of 10, while Moraceae stored highest amount of carbon- 3.36 tonnes. Arecacea, Boraginaceae, Euphorbiaceae, Rutaceae had only one species. Total 11.96 tonnes carbon is sequestered from this site.

Table 4: Umbhel Garden tree species' physiological details.

Sr No.	Scientific Name	No. of Trees	Average GBH (CM)	Average Height (M)	Average Organic Carbon			Total CS (Tonnes)
					AGB	BGB	TB	
1	Aegle marmelos (L.) Correa	1	98.75	9.30	135.52	35.23	170.75	1.25
2	Azadirachta indica A. Juss.	2	32.91	9.24	13.76	3.57	17.34	0.12
3	Casuarina equisetifolia L.	4	90.44	13.23	178.85	46.5	225.35	1.76
4	Cocos nucifera L.	1	74.67	7.88	45.51	11.83	57.34	0.42

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5	Cordia dichotoma G. Forst.	1	36.88	7.69	7.91	2.05	9.97	0.07
6	Corymbia citriodora (Hook.) K. D. Hill & L. A. S. Johnson	5	109.84	17.31	266.1	69.18	335.28	2.51
7	Delonix regia (Hook.) Raf.	8	125.04	13.97	226.14	58.79	284.94	2.12
8	Ficus benghalensis L.	2	291.08	9.71	639.12	166.17	805.29	6.20
9	Ficus religiosa L.	2	149.96	14.98	402.50	104.65	507.16	0.52
10	Mangifera indica L.	2	66.21	8.02	38.5	10.01	48.52	0.35
11	Neolamarckia cadamba (Roxb.) Bosser	2	103.63	11.17	124.22	32.29	156.52	1.28
12	Phyllanthus emblica L.	1	60.99	9.24	43.82	11.39	55.21	0.4
13	Polyalthia longifolia (Sonn.) Thw.	2	31.58	6.00	6.68	1.73	8.41	0.06
14	Semecarpus anacardium L.	3	68.58	4.11	269.64	70.1	339.75	0.25
15	Syzygium cumini (L.) Skeels	1	70.71	6.7	34.72	9.02	43.74	0.32
16	Tamarindus indica L.	2	71.32	7.37	56.02	14.56	70.59	0.52
17	Terminalia catappa L.	2	49.83	9.2	23.66	6.15	29.81	0.21
Total Carbon Sequestration								**18.39**

Table 5: Umbhel Garden Family based physiological details.

Sr No.	Family Name	No of Species	No. of Trees	Average GBH(CM)	Average Height (M)	Average Organic Carbon			Total CS (Tonnes)
						AGB	BGB	TB	
1	Anacardiaceae	2	5	67.39	6.06	154.07	40.05	194.13	0.30
2	Annonaceae	1	2	31.58	6.00	6.68	1.73	8.41	0.06
3	Arecaceae	1	1	74.67	7.88	45.51	11.83	57.34	0.42
4	Boraginaceae	1	1	36.88	7.69	7.91	2.05	9.97	0.07
5	Caesalpiniaceae	2	10	98.18	10.67	141.08	36.67	177.76	1.32
6	Casuarinaceae	1	4	90.44	13.23	178.85	46.5	225.35	1.76
7	Combretaceae	1	2	49.83	9.2	23.66	6.15	29.81	0.21
8	Euphorbiaceae	1	1	60.99	9.24	43.82	11.39	55.21	0.4
9	Meliaceae	1	2	32.91	9.24	13.76	3.57	17.34	0.12
10	Moraceae	2	4	220.52	12.34	520.81	135.41	656.22	3.36
11	Myrtaceae	2	6	90.27	12.00	150.41	39.10	189.51	1.41
12	Rubiaceae	1	2	103.63	11.17	124.22	32.29	156.52	1.28
13	Rutaceae	1	1	98.75	9.30	135.52	35.23	170.75	1.25
Total Carbon Sequestration									**11.96**

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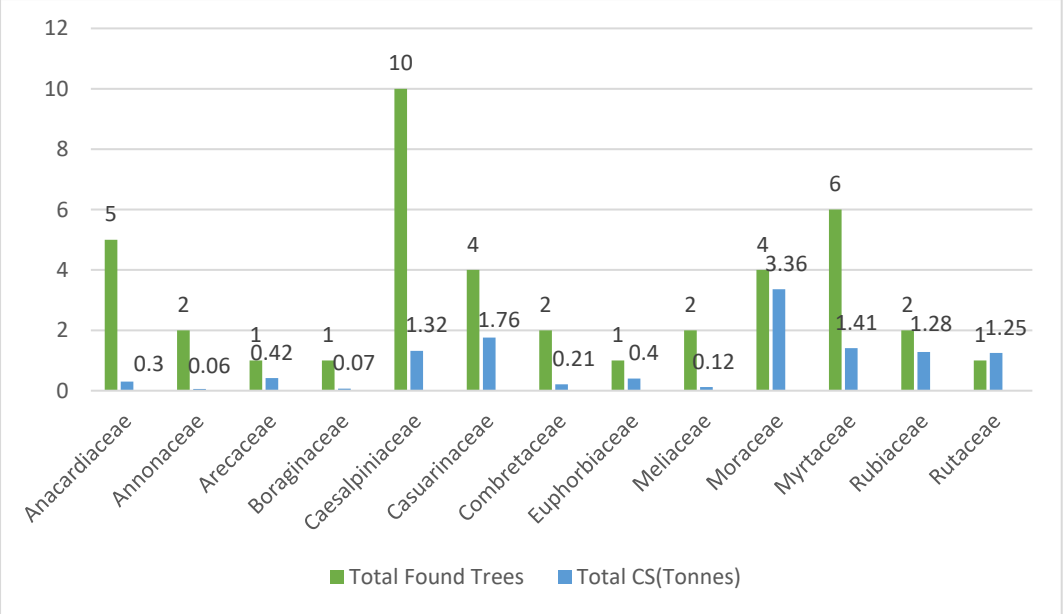

Figure 4: Umbhel garden comparison of total found trees in family and total carbon sequestration

3. Gorat:

Total of 40 individual trees were found in 10 quadrates. Prosopis juliflora (Sw) DC has 10 individuals found in 6 quadrates. Cocos nucifera L. and Pithecellobium dulce (Roxb.) Bth. have 4 individuals found in 2 and 4 quadrates respectively. Azadirachta indica A. Juss. was found in 2 quadrates with 3 individuals.

Total 13 families were found in this site, out of which Mimosaceae family had been recorded as largest species in total 17 tree and 4 species. Moraceae family stored highest carbon- 7.54 tonnes. Caesalpiniaceae, Moraceae, Moringaceae had only one tree. Total 20.35 tonnes carbon is sequestered by this site.

Table 6: Gorat Tree species' physiological details

Sr No.	Scientific Name	No. of Trees	Average GBH(CM)	Average Height (M)	Average Organic Carbon			Total CS (Tonnes)
					AGB	BGB	TB	
1	Acacia nilotica (L.) Delile	1	41.14	5.62	12.69	3.3	15.99	0.11
2	Azadirachta indica A. Juss.	3	72.84	6.89	50.27	13.07	63.35	0.48
3	Carica papaya L.	2	39.16	9.23	14.66	3.81	18.47	0.13
4	Cocos nucifera L.	4	80.84	8.76	57.03	14.82	71.86	0.54
5	Ficus religiosa L.	1	246.88	15.27	815.50	212.03	1027.53	7.54
6	Hyphaene petersiana Klotzsch ex Mart.	1	73.85	8.85	57.66	14.99	72.66	5.33
7	Mangifera indica L.	2	53.18	7.42	21.73	5.65	27.38	0.23
8	Moringa oleifera Lam.	1	94.48	9.89	91.39	23.76	115.16	0.84
9	Phoenix dactylifera L.	2	147.21	9.76	202.28	52.59	254.87	1.87
10	Pithecellobium dulce (Roxb.) Bth.	4	58.83	3.86	12.77	3.32	16.1	0.11
11	Prosopis cineraria (L) Druce	2	63.62	8.04	33.7	8.76	42.46	0.35
12	Prosopis juliflora (Sw) DC	10	87.93	9.29	111.56	29	140.57	1.03
13	Psidium guajava L.	2	47.77	7.13	23.64	6.14	29.79	0.24
14	Senna siamea (Lam.) H. S. Irwin & Barneby	1	39.24	7.55	12.04	3.13	15.17	0.11
15	Syzygium cumini (L.) Skeels	2	73.52	8.27	46.28	12.03	58.31	0.42
16	Ziziphus jujuba Mill.	2	87.17	9.38	99.31	25.82	125.13	0.97
Total Carbon Sequestration								**20.35**

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Table 7: Gorat tree family-based details

Sr No.	Family Name	No. of Species	No. of Trees	Average GBH(CM)	Average Height (M)	Average Organic Carbon			Total CS (Tonnes)
						AGB	BGB	TB	
1	Anacardiaceae	1	2	53.18	7.42	21.73	5.65	27.38	0.23
2	Arecaceae	2	5	77.34	8.80	57.34	14.90	72.26	2.93
3	Caesalpiniaceae	1	1	39.24	7.55	12.04	3.13	15.17	0.11
4	Caricaceae	1	2	39.16	9.23	14.66	3.81	18.47	0.13
5	Meliaceae	1	3	72.84	6.89	50.27	13.07	63.35	0.48
6	Mimosaceae	4	17	62.88	6.70	42.68	11.09	53.78	0.4
7	Moraceae	1	1	246.88	15.27	815.5	212.03	1027.53	7.54
8	Moringaceae	1	1	94.48	9.89	91.39	23.76	115.16	0.84
9	Myrtaceae	2	4	60.645	7.7	34.96	9.085	44.05	0.33
10	Palmaceae	1	2	147.21	9.76	202.28	52.59	254.87	1.87
11	Rhamnaceae	1	2	87.17	9.38	99.31	25.82	125.13	0.97
Total Carbon Sequestration									**15.83**

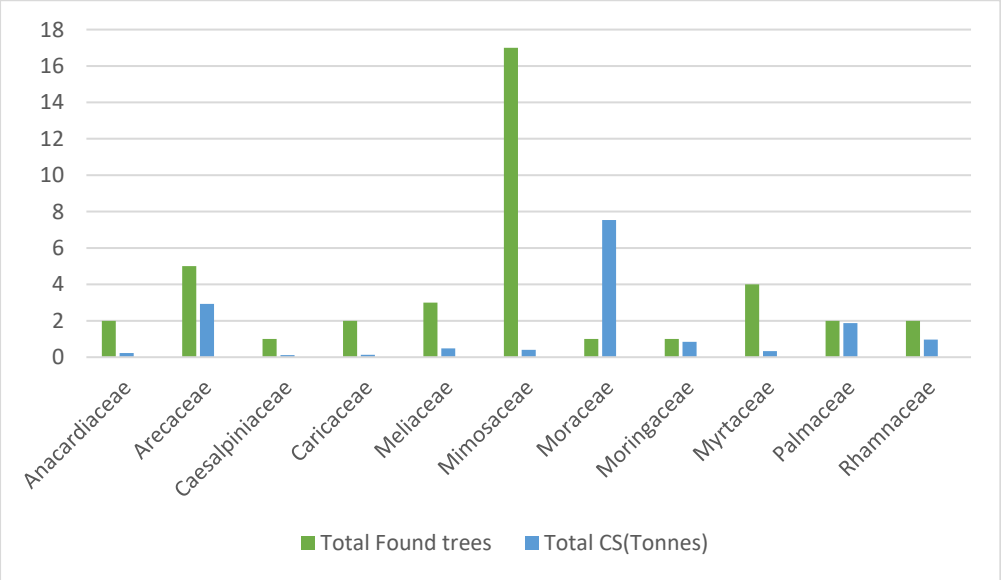

Figure 5: Gorat comparison of total found trees in family and total carbon sequestration

4. Sarthana Nature Park:

Total of 57 trees were found in 15 quadrates at Sarthana Nature Park. Ficus benghalensis L. has been found in 4 quadrates with 4 individuals. Albizia lebbeck (L.) Benth, Bauhinia variegata L., Butea monosperma (Lam.) Taub., Cordia dichotoma G.Forst., Dalbergia latifolia Roxb., Ficus racemosa L., Gmelina arborea Roxb, Mangifera indica L., Moringa oleifera Lam., Phyllanthus acidus (L.) Skeels have 2 individuals found in 2, 2, 2, 2, 2, 2, 2, 2, 1 and 2 quadrates respectively.

Total of 20 families were found in this site, in which Moraceae had recorded largest species of total 8 trees and 4 species. But Meliaceae family stored highest carbon- 4.92 tonnes. Myrtaceae, Malvaceae, Lecythidaceae, Sapindaceae, and Ulmaceaeare had only one tree present. 81.52 tonnes of carbon sequestration calculated in this site.

Table 8: Sarthana nature park tree species' physiological details

Sr No.	Scientific Name	No. of Trees	Average GBH(CM)	Average Height (M)	Average Organic Carbon			Total CS (Tonnes)
					AGB	BGB	TB	
1	Albizia lebbeck (L.) Benth	2	112.13	12.59	173.31	45.06	218.38	1.63
2	Albizia saman (Jacq.) Merr.	1	138.37	16.95	290.81	75.61	366.42	2.68
3	Anacardium occidentale L.	1	64	7.49	31.78	8.26	40.04	0.29
4	Annona squamosa L.	1	65.73	8.67	38.81	10.09	48.9	0.35

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5	Azadirachta indica A. Juss.	1	135.94	11.75	298.29	77.55	375.85	2.75
6	Bauhinia variegata L.	2	34.82	7.81	12.83	3.33	16.17	0.12
7	Butea monosperma (Lam.) Taub.	2	45.7	7.79	15.55	4.04	19.6	0.15
8	Cordia dichotoma G. Forst.	2	92.5	9.03	58.48	15.2	73.68	0.57
9	Couroupita guianensis Aubl.	1	30.78	9.3	9.12	2.37	11.5	0.08
10	Dalbergia lanceolaria subsp. paniculata (Roxb.) Thoth.	1	87.47	9.98	114.06	29.65	143.72	1.05
11	Dalbergia latifolia Roxb.	2	130.91	15.64	400.25	104.06	504.32	3.7
12	Ficus arnottiana (Miq.) Miq.	1	120.7	15.2	264.46	68.76	333.23	2.44
13	Ficus benghalensis L.	4	180.97	10.88	276.84	71.97	348.82	2.86
14	Ficus racemosa L.	2	110.33	11.44	99.83	25.95	125.78	0.93
15	Ficus religiosa L.	1	147.03	15.95	411.9	107.09	518.99	3.8
16	Gmelina arborea Roxb	2	181.57	16.6	446.79	116.16	562.96	4.15
17	Haldina cordifolia (Roxb.) Ridsdale	1	135.94	11.41	243.59	63.33	306.92	2.25
18	Holoptelea integrifolia (Roxb) Planch	1	98.45	11.65	134.88	35.06	169.95	1.24
19	Madhuca longifolia var. latifolia (Roxb.) A. Chev.	1	128.93	14.12	345.93	89.94	435.87	3.19
20	Mangifera indica L.	2	94.8	9.31	86.62	22.52	109.14	0.8
21	Manilkara hexandra (Roxb.) Dubard	1	175.26	11.23	611.59	159.01	770.61	5.65
22	Mimusops elengi L.	1	90.98	9.98	118.42	30.78	149.21	1.09
23	Moringa oleifera Lam.	2	66.29	8.18	37.24	9.68	46.92	0.35
24	Neolamarckia cadamba (Roxb.) Bosser	1	98.75	16.1	162.6	42.27	204.88	1.5
25	Phyllanthus acidus (L.) Skeels	2	35.35	8.35	10.8	2.8	13.61	0.09
26	Phyllanthus emblica L.	1	99.6	16.02	202.56	52.66	255.22	1.87
27	Pithecellobium dulce (Roxb.) Bth.	1	160.93	10.93	293.13	76.21	369.35	2.71
28	Polyalthia longifolia (Sonn.) Thw.	1	80.46	13.74	99.2	25.79	125	0.91
29	Pongamia pinnata (L.) Pierre	1	161.11	17.2	729.08	189.56	918.64	6.74
30	Prosopis cineraria (L) Druce	1	61.56	5.62	33.1	8.6	41.71	0.3
31	Pterocarpus marsupium Roxb.	2	125.57	13.97	293.99	76.43	370.43	2.73
32	Sapindus trifoliatus L.	1	120.24	11.72	236.15	61.4	297.55	2.18
33	Saraca asoca (Roxb.) Willd.	1	78.94	13.91	103.55	26.92	130.48	0.95
34	Senna siamea (Lam.) H. S. Irwin & Barneby	2	87.32	10.3	81.33	21.14	102.47	0.79
35	Swietenia macrophylla G. King	1	206.65	18.42	767.52	199.55	967.08	7.09
36	Syzygium cumini (L.) Skeels	1	108.81	13.25	218.66	56.85	275.51	2.02
37	Tamarindus indica L.	1	114.14	11.8	229.7	59.72	289.43	2.12
38	Tectona grandis L.	2	95.7	15.56	141.84	36.88	178.72	1.31

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39	Terminalia arjuna (Roxb) W. & A.	1	109.72	12.29	200.39	52.1	252.5	1.85
40	Terminalia chebula Retz.	1	90.83	14.73	232.29	60.39	292.69	2.14
41	Thespesia populnea (L.) Soland ex. Corr.	1	122.22	11.88	183.74	47.77	231.51	1.69
Total Carbon Sequestration								**81.52**

Table 9: Sarthana nature park family based physiological details

Sr No.	Family Name	No. of Species	No. of Trees	Average GBH(CM)	Average Height (M)	Average Organic Carbon			Total CS (Tonnes)
						AGB	BGB	TB	
1	Anacardiaceae	2	3	79.4	8.4	59.2	15.39	74.59	0.545
2	Annonaceae	2	2	73.09	11.20	69.00	17.94	86.95	0.63
3	Boraginaceae	1	2	92.5	9.03	58.48	15.2	73.68	0.57
4	Caesalpiniaceae	3	4	93.47	12.00	138.19	35.93	174.13	1.29
5	Combretaceae	2	2	100.27	13.51	216.34	56.24	272.59	1.99
6	Euphorbiaceae	2	3	67.47	12.18	106.68	27.73	134.41	0.98
7	Fabaceae	3	5	84.4	11.14	175.71	45.68	221.40	1.62
8	Lecythidaceae	1	1	30.78	9.3	9.12	2.37	11.5	0.08
9	Malvaceae	1	1	122.22	11.88	183.74	47.77	231.51	1.69
10	Meliaceae	2	2	171.29	15.08	532.90	138.55	671.46	4.92
11	Mimosaceae	4	5	118.25	11.52	197.59	51.37	248.96	1.83
12	Moraceae	4	8	139.75	13.37	263.26	68.44	331.70	2.51
13	Moringaceae	1	2	66.29	8.18	37.24	9.68	46.92	0.35
14	Myrtaceae	1	1	108.81	13.25	218.66	56.85	275.51	2.02
15	Papilionaceae	3	5	110.79	12.99	346.21	90.01	436.22	3.21
16	Rubiaceae	2	2	117.34	13.75	203.09	52.8	255.9	1.87
17	Sapindaceae	1	1	120.24	11.72	236.15	61.4	297.55	2.18
18	Sapotaceae	3	3	131.72	11.78	358.65	93.24	451.90	3.31
19	Ulmaceae	1	1	98.45	11.65	134.88	35.06	169.95	1.24
20	Verbenaceae	1	4	138.63	16.08	294.31	76.52	370.84	2.73
Total Carbon Sequestration									**35.56**

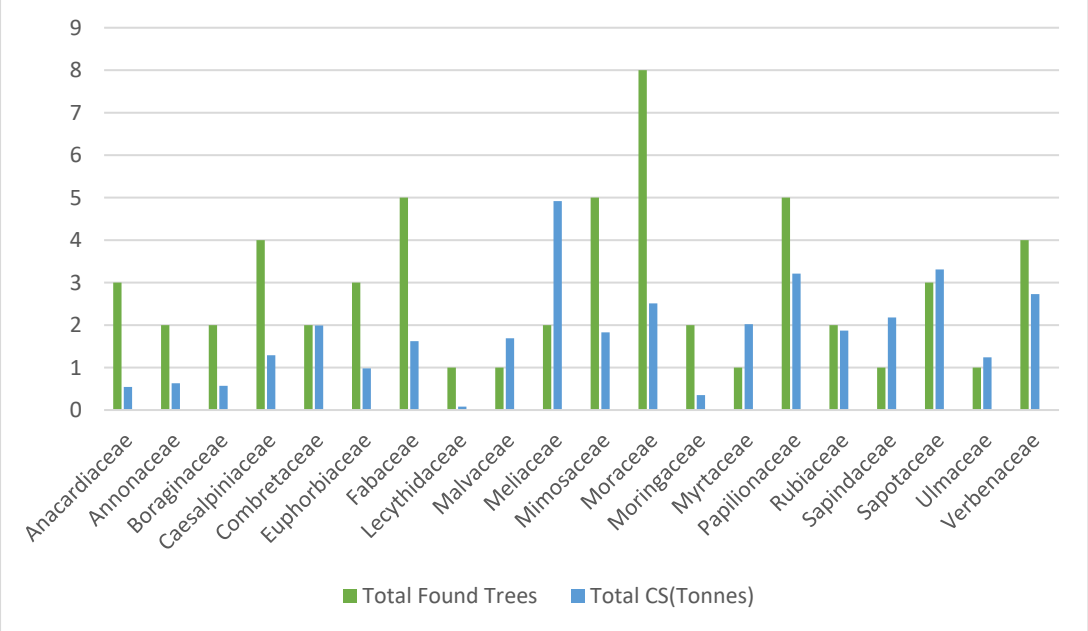

Figure 6: Sarthana Nature Park comparison of total found trees in family and total carbon sequestration

5. Sneh Rashmi Botanical Garden

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Total of 57 individuals were found in 15 quadrates of Sneh Rashmi Botanical Garden. Dypsis lutescens (H.Wendl.) Beentje & J. Dransf. was found highest in 4 quadrates with 5 individuals. Eucalyptus globulus Labill. was found in 4 quadrates with 4 individual trees.

Total 18 families were found in this site, in which Arecaceae was the largest species in total 15 tree and 7 species. But Myrtaceae stored highest carbonn of 4.96 tonnes. Casuarinaceae, Euphorbiaceae, Fabaceae, Meliaceae, Proteaceae, and Rutaceae had only one tree. In this site, all found families and tree species sequester 35.24 tonnes carbon.

Table 10: Sneh rashmi botanical garden tree species' physiological details

Sr No.	Scientific Name	No. of Trees	Average GBH(CM)	Average Height (M)	Average Organic Carbon			Total CS (Tonnes)
					AGB	BGB	TB	
1	Acacia auriculiformis Benth.	2	138.37	14.12	366.21	95.21	461.43	3.41
2	Aegle marmelos (L.) Correa	1	119.78	11.56	247.64	64.38	312.02	2.29
3	Albizia saman (Jacq.) Merr.	1	127.4	11.87	172.65	44.89	217.54	1.59
4	Azadirachta indica A. Juss.	1	117.04	10.77	202.75	52.71	255.47	1.87
5	Bauhinia variegata L.	1	79.85	8.82	76.13	19.79	95.93	0.7
6	Bismarckia nobilis Hildebr. & H. Wendl.	2	119.02	7.94	134.33	34.92	169.26	1.24
7	Butea monosperma (Lam.) Taub.	2	142.64	13.88	269.90	70.17	340.08	2.5
8	Caryota mitis Lour.	1	32.7	6.77	6.92	1.8	8.72	0.06
9	Casuarina equisetifolia L.	1	96.62	16.4	253.08	65.8	318.88	2.34
10	Cocos nucifera L.	2	107.89	18.24	211.39	54.96	266.35	1.96
11	Delonix regia (Hook.) Raf.	2	123.13	12.3	193.04	50.19	243.23	1.79
12	Dypsis lutescens (H. Wendl.) Beentje & J. Dransf.	5	30.45	8.18	7.85	2.04	9.89	0.07
13	Eucalyptus globulus Labill.	4	151.87	22.37	534.18	138.88	673.07	4.96
14	Ficus benghalensis L.	2	169.92	9.92	222.4	57.82	280.23	2.14
15	Ficus benjamina L.	1	75.59	8.63	63.87	16.6	80.47	0.59
16	Ficus racemosa L.	1	146.6	13.04	200.96	52.25	253.22	1.85
17	Ficus religiosa L.	1	152.7	12.81	261.68	68.03	329.72	2.42
18	Grevillea robusta A. Cunn. ex R. Br.	1	147.82	16.44	371.93	96.7	468.64	3.43
19	Hevea brasiliensis (Willd. ex A. Juss.) Müll. Arg.	1	68.82	14.31	71.55	18.6	90.15	0.66
20	Latania loddigesii Mart.	1	56.08	4.43	16.66	4.33	21	0.15
21	Latania lontaroides (Gaertn.) H. E. Moore	2	79.85	10.76	81.95	21.3	103.26	0.76
22	Madhuca longifolia var. latifolia (Roxb.) A. Chev.	2	76.35	9.35	80.34	20.89	101.23	0.75
23	Manilkara zapota (L.) P. Royen	2	33.98	5.63	11.27	2.93	14.21	0.1
24	Mimusops elengi L.	2	119.86	12.28	252.91	65.75	318.66	2.34
25	Neolamarckia cadamba (Roxb.) Bosser	2	131.67	14.03	251.82	65.47	317.3	2.32

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26	Pithecellobium dulce (Roxb.) Bth.	2	144.68	10.73	232.68	60.49	293.18	2.19
27	Plumeria rubra L.	2	37.15	6.87	9.44	2.45	11.9	0.08
28	Polyalthia longifolia (Sonn.) Thw.	2	36.14	6.23	9.08	2.36	11.44	0.08
29	Roystonea regia (Kunth) O. F. Cook	2	129.99	12.86	259.71	67.52	327.24	2.4
30	Saraca asoca (Roxb.) Willd.	2	83.66	11.98	100.16	26.04	126.21	0.94
31	Senna siamea (Lam.) H. S. Irwin & Barneby	2	116.19	11.15	155.76	40.49	196.26	1.48
32	Tectona grandis L.	2	131.67	16.29	281.16	73.1	354.26	2.6
33	Terminalia arjuna (Roxb) W. & A.	2	151.18	16.99	525.78	136.7	662.49	4.91
34	Terminalia bellirica (Gaertn) Roxb.	1	129.54	12.57	302.36	78.61	380.97	2.79
Total Carbon Sequestration								**59.91**

Table 11: Sneh Rashmi Botanical Garden family based physiological details

Sr No.	Family Name	No of Species Found	No. of Trees	Average GBH(CM)	Average Height (M)	Average Organic Carbon			Total CS (Tonnes)
						AGB	BGB	TB	
1	Annonaceae	1	2	36.14	6.23	9.08	2.36	11.44	0.08
2	Apocynaceae	1	2	37.15	6.87	9.44	2.45	11.9	0.08
3	Arecaceae	7	15	79.42	9.88	102.69	26.69	129.39	0.95
4	Caesalpiniaceae	3	6	107.66	11.81	149.65	38.91	188.57	1.40
5	Casuarinaceae	1	1	96.62	16.4	253.08	65.8	318.88	2.34
6	Combretaceae	2	3	140.36	14.78	414.07	107.65	521.73	3.85
7	Euphorbiaceae	1	1	68.82	14.31	71.55	18.6	90.15	0.66
8	Fabaceae	1	1	79.85	8.82	76.13	19.79	95.93	0.7
9	Meliaceae	1	1	117.04	10.77	202.75	52.71	255.47	1.87
10	Mimosaceae	3	5	136.82	12.24	257.18	66.86	324.05	2.40
11	Moraceae	4	5	136.20	11.1	187.23	48.67	235.91	1.75
12	Myrtaceae	1	4	151.87	22.37	534.18	138.88	673.07	4.96
13	Papilionaceae	1	2	142.64	13.88	269.90	70.17	340.08	2.5
14	Proteaceae	1	1	147.82	16.44	371.93	96.7	468.64	3.43
15	Rubiaceae	1	2	131.67	14.03	251.82	65.47	317.3	2.32
16	Rutaceae	1	1	119.78	11.56	247.64	64.38	312.02	2.29
17	Sapotaceae	3	6	76.73	9.09	114.84	29.86	144.7	1.06
18	Verbenaceae	1	2	131.67	16.29	281.16	73.1	354.26	2.6
Total Carbon Sequestration									**35.24**

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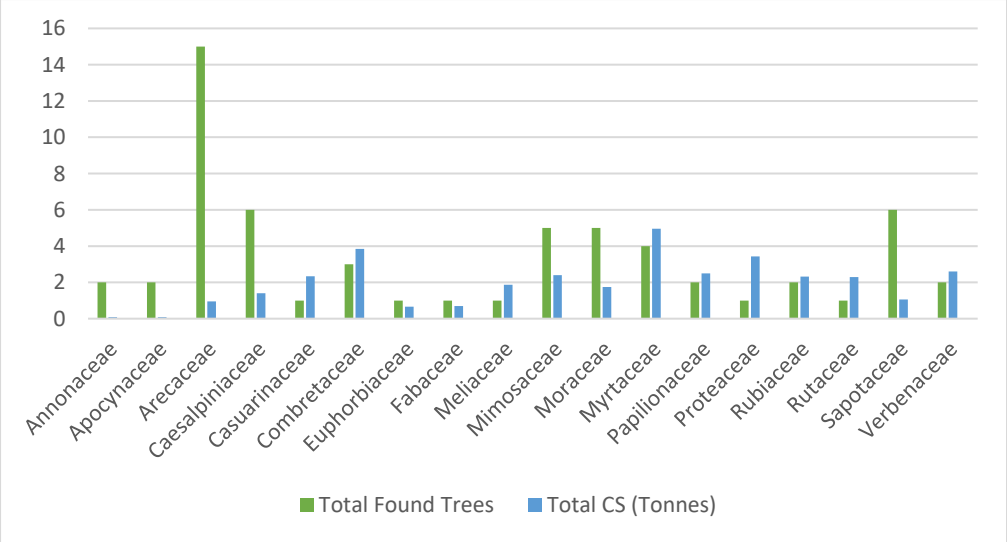

Figure 7: Sneh-Rashmi botanical garden comparison of total found trees in family and total carbon sequestration

Table 12: Surat trees family based physiological details

Sr No.	Family Name	No. of Species	No. of Site Trees Present	No. of Trees	Average GBH (CM)	Average Height (M)	Average Organic Carbon			Total CS (Tonnes)
							AGB	BGB	TB	
1	Anacardiaceae	3	3	10	66.66	7.293	78.33	20.36	98.7	0.36
2	Annonaceae	2	3	6	46.94	7.81	28.25	7.34	35.6	0.26
3	Apocynaceae	1	1	2	37.15	6.87	9.44	2.45	11.9	0.08
4	Arecaceae	8	3	21	77.14	8.85	68.51	17.81	86.33	1.43
5	Boraginaceae	1	2	3	64.69	8.36	33.195	8.625	41.82	0.32
6	Caesalpiniaceae	4	4	21	84.64	10.51	110.24	28.66	138.91	1.03
7	Caricaceae	1	1	2	39.16	9.23	14.66	3.81	18.47	0.13
8	Casuarinaceae	1	2	5	93.53	14.81	215.96	56.15	272.11	2.05
9	Combretaceae	4	3	7	96.82	12.50	218.02	56.68	274.71	2.02
10	Euphorbiaceae	3	3	5	65.76	11.91	74.02	19.24	93.26	0.68
11	Fabaceae	3	2	6	82.12	9.98	125.92	32.73	158.66	1.16
12	Lecythidaceae	1	1	1	30.78	9.3	9.12	2.37	11.5	0.08
13	Malvaceae	1	1	1	122.22	11.88	183.74	47.77	231.51	1.69
14	Meliaceae	2	5	16	94.46	10.01	295.84	76.91	372.76	1.69
15	Mimosaceae	8	4	46	93.28	9.47	144.87	37.66	182.53	1.23
16	Moraceae	7	5	32	181.75	12.01	465.56	121.04	586.61	4.12
17	Moringaceae	1	2	3	80.38	9.03	64.31	16.72	81.04	0.59
18	Myrtaceae	4	4	15	102.90	13.83	234.55	60.98	295.53	2.18
19	Palmaceae	1	1	2	147.21	9.76	202.28	52.59	254.87	1.87
20	Papilionaceae	3	2	7	126.71	13.43	308.05	80.09	388.15	2.85

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21	Proteaceae	1	1	1	147.82	16.44	371.93	96.7	468.64	3.43
22	Rhamnaceae	1	1	2	87.17	9.38	99.31	25.82	125.13	0.97
23	Rubiaceae	2	3	6	117.55	12.98	193.04	50.19	243.24	1.82
24	Rutaceae	1	3	3	98.24	9.62	150.85	39.22	190.07	1.39
25	Sapindaceae	1	1	1	120.24	11.72	236.15	61.4	297.55	2.18
26	Sapotaceae	4	2	9	104.22	10.43	236.74	61.55	298.3	2.18
27	Simaroubaceae	1	1	2	163.54	14.13	624.35	162.33	786.68	5.9
28	Ulmaceae	1	1	1	98.45	11.65	134.88	35.06	169.95	1.24
29	Verbenaceae	2	2	6	135.15	16.18	287.73	74.81	362.55	2.66
Total no. of Families		**73**		**242**	**Total Carbon Sequestration**					**47.59**

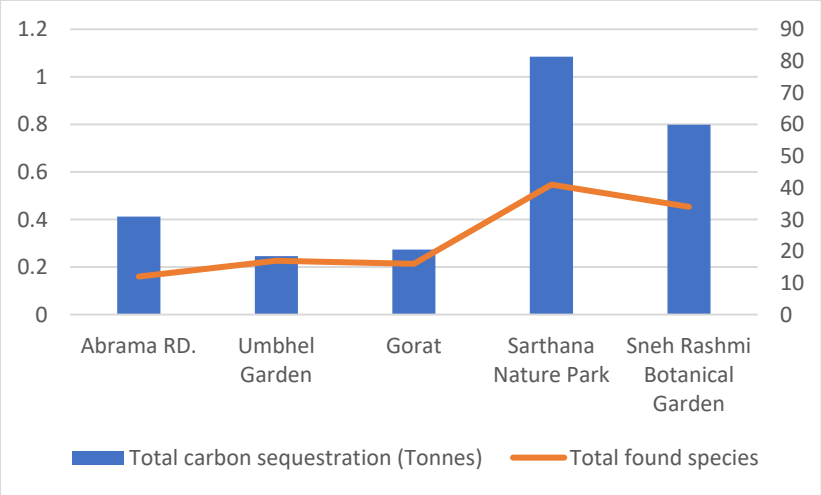

Figure 8: Comparison of total carbon sequestration and total found species.

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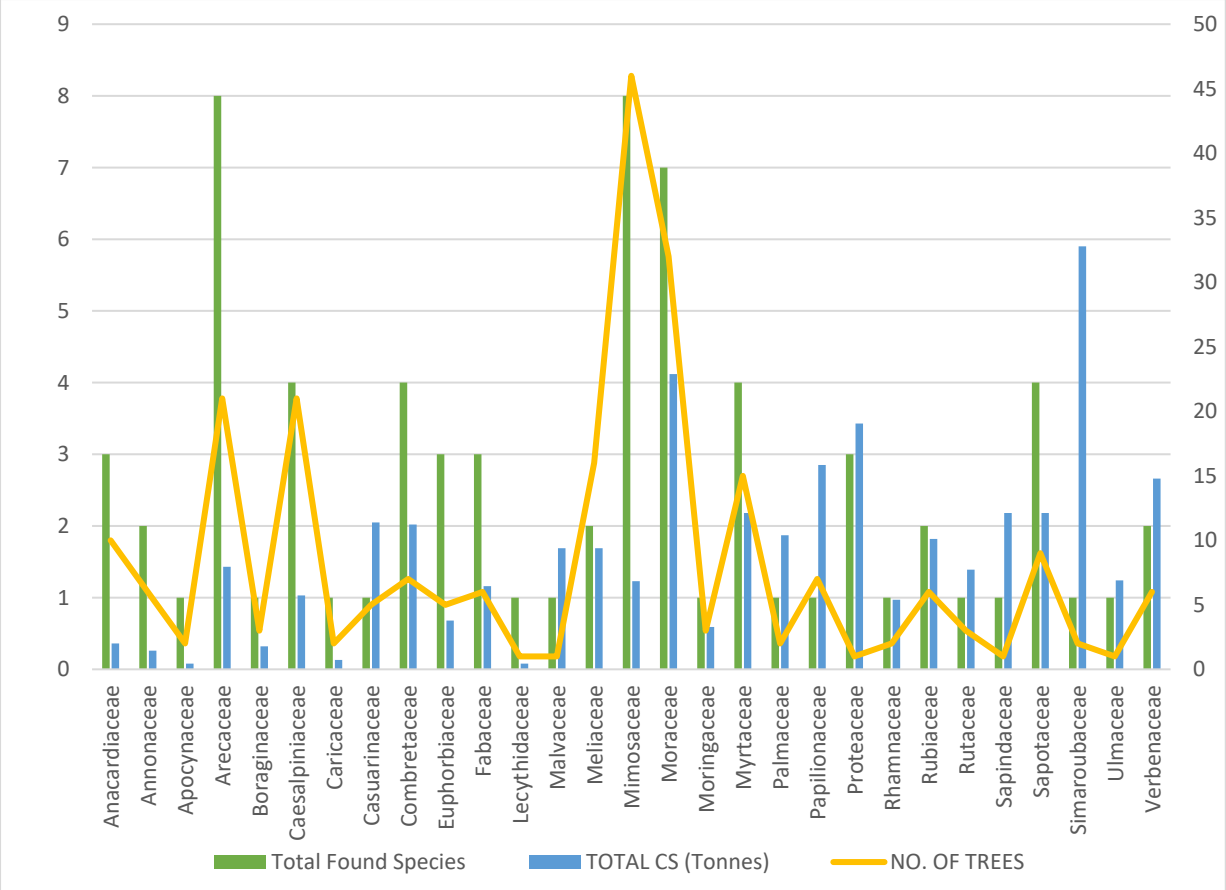

Graph 9: Comparison of total found species, trees and total carbon sequestration

CONCLUSION:

Planting a range of tree species is essential for biodiversity, the environment, humans, and climate change mitigation. Because of their large girth, height, and expansive canopies, species like Eucalyptus globulus Labill, Terminalia arjuna (Roxb) W. & A., Ficus benghalensis L., Swietenia macrophylla G. King, Ficus religiosa L. and Corymbia citriodora (Hook.) K. D. Hill & L. A. S. Johnson are perfect for planting in homes, parks, botanical gardens, schools, and along roadsides to help lower atmospheric CO_2 levels. Higher species were found in Arecaceae and Mimosaceae families but Simaroubaceae species have higher rate of carbon sequestration. Moraceae family has good combination balance of species distribution and carbon sequestration.

In addition to provide food for creatures like squirrels, monkeys, and other insects that consume their fruits, diverse tree plantations also maintain natural habitats by giving birds a place to nest. In addition to adding aesthetic value to landscapes, trees help create leisure areas that benefit mental health by reducing stress, anxiety, and elevating mood. They also support the tourism, forestry, and leisure sectors, creating jobs and economic possibilities for local populations. Planting a diverse range of trees benefits both the environment and humans by fostering a healthy ecosystem.

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