Nature Based Solutions: Carbon Sequestration by Standing Trees In Urban Parks and Gardens of Katni City in Madhya Pradesh, India

ABSTRACT

Aims: This study aims at estimating contribution of urban Parks and gardens by carbon sequestration and suggests suitable strategies that can be helpful in reducing climate change impacts in urban centres. The challenges of climate change can be efficiently overcome by the storage of carbon in terrestrial carbon sinks viz. plants, plant products and soils for longer periods. Selection of appropriate trees can help mitigate climate impact.

Study design: Non-destructive sampling method of biomass estimation was used to measure to GBH of individual trees.

Place and Duration of Study: The study was conducted in Katni city, Madhya Pradesh in 2020.

Methodology: The parks and gardens in Katni were categorized into three groups based on their sizes: (A) large parks/gardens, (B) medium parks/gardens, and (C) small parks/gardens. The height of the trees was estimated using a relascope, while the girth classes of the trees were measured at different heights, including the basal area at Diameter at Breast Height (DBH) and at a 2-meter height.

Results: 26 parks were systematically selected from a total of 62, encompassing small, medium, and large-sized areas, representing 42% of the city's green cover. The sampled parks sequestered 340 tons of carbon, projecting an annual sequestration of 414 tons by all parks combined. Among the planted trees in these spaces were (*Hyophorbe lagenicaulis*), Fishtailed palm (*Carota urens*) Ashok (*Polyalthia longifolia*), Neem (*Azardirachtaindica*), Amaltas (*Cassia fistula*), Champa (*Magnolia champaca*), Saptaparni (*Alstonia scholaris*), etc. Furthermore, the study identified ten suitable tree species—Bargad *(Ficus benghalensis),* Gulmohar *(Delonix regia),* Karanj *(Millettia pinnata),* Kassod *(Cassia siamea),* Mahaneem *(Ailanthus excelsa),* Neem *(Azadirachta indica),* Umar *(Ficus racemosa),* Peepal *(Ficus religiosa),* Peltaforum *(Peltophorum pterocarpum) and Shisham* (*Dalbergia sissoo)* ideal for planting in parks for climate mitigation. The study advocates for widespread planting of these identified indigenous species in urban areas to enhance environmental quality and contribute significantly to climate improvement efforts.

Conclusion: This study provides valuable insights into the nature of carbon sequestration in urban green spaces, stressing the need for selection of tree species based on multiple criteria discussed in the paper. Holistic approaches in environmental management and conservation will help mitigate climate impact.

*Keywords: Nature based solutions, urban parks, carbon sequestration, climate mitigation and plantation***.**

1. INTRODUCTION

Urban forestry means managing of trees for their contribution to the physiological, sociological and economic wellbeing of the urban society (FAO, 2010). In India, there is rapid increase in the population in urban centres. By 2030, urban areas are projected to increase by an estimated 50 percent. High population density will lead to several challenges and a significant impact on the environment is expected.

Green spaces in the form of gardens, parks and roadside plantations will have to be created on all available spaces to offset carbon emissions. Besides, tree canopies provide a cooling effect by shading the areas. In times of Ashoka, shade bearing trees were planted alongside roads to provide relief to travelers. The net saving in carbon emissions that can be achieved by urban planting can be up to 18 kg CO_2 per year per tree and this benefit corresponds to that provided by 3 to 5 forest trees of similar size and health (Ferrini and Fini, 2011).

Rapid urbanization in the country will be one of the most dominant trends in the coming years. It is expected that about 40% of the population in 2030 would be urban as against 30% currently. As population expands and incomes grow, this shift will likely be realized alongside demographic changes that will exponentially increase the demand for urban amenities like housing, energy, transport, water, waste and disposal (GoI, 2015).

As far as Madhya Pradesh is concerned, it has a total population of 72.63 million (Census, 2011) accounting for 6 percent of India's population. The rural and urban population stands at 72.37% and 27.63% respectively. (FSI, 2019). Cities perform an important role in the global carbon cycle by emitting larger amounts of CO_2 due to more energy consumption, transportation and conversion of natural land to the constructed environment (Churkina, 2008). Development of sustainable green cities is the need of today's fast urbanizing world. Nearly half of India's population will soon be living in urban areas.

Trees are an important basis for atmospheric carbon i.e., carbon dioxide, as 50% of their standing biomass is carbon itself. (Ravindranath *et al.,*1997).

Waran and Patwardhan (2005) estimated carbon sequestration potential in urban plantations of Pune city. The rate of carbon sequestration by the trees was estimated to be 15,000 tons per year.
Study by Kiran and Kinnary, (2011) on carbon sequestration by urban trees revealed that trees in Vadodara city sequestered 73.59 tons of carbon which amounted 22% of estimated total CO_2 production in the city. Total CO_2 emission at major roads was found around 159.47 tons.

Study by Gandherva and Bhattacharya, (2019) revealed that in parks and gardens of South Delhi, young trees stock more carbon. Parks and gardens also perform vital functions of biodiversity conservation.

Hardly any attempt has been made to study the potential of trees in carbon sequestration from urban areas besides a few studies in Pune by Shinde and Mahajan (2015) and Vadodara cities.

1.1 Earlier studies on carbon storage by parks and gardens

Studies conducted by Gandherva and Bhattacharya, (2019) in Delhi have estimated 66.93 tons of carbon stored in sample trees in Lodi garden and 14.49 tons of carbon in DDA park, Delhi. In their study, they have calculated the carbon content in tons only from sample trees in these two gardens of Delhi. Gill *et al.,* 2007 in conclusion of the study have suggested that specific policies might include creating new green spaces, maintaining existing green spaces, conserving natural lands through zone control and planting fast-growing species that have long life spans and mature into enormous plants.

Chavan and Rasal, (2010) in Aurangabad have calculated organic carbon stock in 1658 number of 20 trees species in Dr. B.A.M University. The average organic carbon in 20 well grown trees in University campus is about 1.65 ton /tree, Aurangabad.

Dadhich *et al.,* (2023) in Rajasthan, India have calculated carbon stored in 849 trees belonging to 43 tree species on the campus of Janki Devi Bajaj Government Girls College, Kota in Rajasthan, India. The total carbon sequestered by all the trees in a year is 788.38 tons. Average carbon sequestered by an Individual tree on the campus is 0.93 tons/year. The study suggested that the urban green islands are likely to have a wider impact on biomass accumulation in turn carbon storage and sequestration in comparison to other structural parameters like species richness or density.

Shinde and Mahajan, (2021) in Pune have calculated carbon sequestered in 65 gardens developed by Pune Municipal Corporation. Total number of trees was 5929. Out of total plant species, 3346 were exotic and 2583 native plants. The study suggested that the litter and dead wood biomass can be managed carefully from a viewpoint to increase the soil carbon content. It should not be burnt away; instead, it must be used as a source of increasing carbon content in soil.

Vasagadekar *et al.,* (2023) Maharashtra region to assess carbon sequestration potential of trees in selected green in the of Kolhapur city. This study estimated carbon sequestration in randomly selected green spaces of Kolhapur containing 638 trees belonging to 29 species. The total carbon sequestration of trees was 692.31 tons. This study highlights the value of urban trees not only for beauty and aesthetic purposes but also for their carbon sequestration potential in order to combat climate change at the local level

Sharma *et al.,* (2023) Noida have calculated carbon sequestered in Amity University Campus. There is a total of 45 different tree species on the campus with the total Carbon Sequestration Potential equivalent to approximately 139.86 tons. The results reveal that *Ficus benjamina* was the predominant species on the campus with Carbon Sequestration Potential equivalent to 30.53 tons, followed by *Alstonia scholaris* with carbon storage of 16.38 tons. The 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.

The above studies were confined to only estimating the carbon sequestration potential in various parks and gardens of different cities/campuses. Present study not only estimates the carbon potential but addressed research gap of criteria for selection of suitable species on environmental utilitarian, aesthetic and other values.

2. STUDY AREA

Katni district, spanning 4504 sq. km. and bordered by Satna, Umaria, Jabalpur, Damoh, and Panna districts, ranges from $23^{0}37'$ to $80^{0}58E$ with an average elevation of 392 meters above sea level and an annual rainfall of 1171.4 mm, peaking during the southwest monsoon. Positioned in the north-eastern part of Madhya Pradesh, Katni strikes a balance between agriculture-cultivating paddy, wheat, gram, and pulses-and industries, notably limestone extraction. Total area of Katni district is 4949.59 km^2 and total forest area is 711.55 sq km. The forest types in Katni as per the Champion and Seths classification are 1) 5A/C-1b Southern Tropical Dry Deciduous Teak Forest 2) 5A/C3- Southern Tropical Dry Mixed Deciduous Forest 3) 5B/C-1c Northern Tropical Dry Deciduous Peninsular Sal Forest and 4) 5B/C2-Northern Tropical Dry Mixed Deciduous Forest. (Source: Working Plan Katni (2015-16). With its industrial presence, urban parks and gardens in Katni are vital for their ability to mitigate industrial pollution, acting as green lungs for the cityscape. Recognizing their potential, a study was undertaken to assess the importance of trees within these spaces as nature-based solutions, gathering a comprehensive list of parks and gardens, including colony parks, across the area.

3. METHODOLOGY

The parks and gardens in Katni were categorized into three groups based on their sizes: (A) large parks/gardens, (B) medium parks/gardens, and (C) small parks/gardens as per given in table 1. This categorization helped in organizing and analysing the data effectively, allowing for a comprehensive understanding of the distribution and characteristics of trees within each category of urban green spaces in Katni.

Table-1: Classification of parks/gardens in Katni

S.N.	Classification	Size/area	Sampling	Total no. of	Sample

		(in ha.)	intensity	parks	selected
1.	Large parks/gardens	05 to 09	100%	02	02
2.	Medium parks/gardens	02 to 04	100%	01	01
3.	Small parks/gardens	02 and less	37%	59	22
	Total			**62**	**25**

The trees were evaluated using a specific methodology: all trees within these parks were of relatively small size. To gather accurate data, the GPS locations of these parks were recorded using a GPS essential mobile app.

3.1 Growth parameters measurements

In plantations of age up to 5 years or having average height upto 2 m, all the selected sample plants were measured for their collar diameter and height. Collar diameters (in two perpendicular directions) were measured with the help of vernier calliper. Height was measured by a tape.

In plantations having average height more than 2 m, the total height was measured with the help of a height measuring instrument, such as Haga altimeter and Relascope. Diameters at different heights at 2 m height interval were measured with the help of a relascope. Data of each sample tree was recorded separately and later on the recorded data were compiled stratum wise.

3.2 Calculation of stem volume

Shape of a tree is generally not perfectly cylindrical and there is invariably some taper. Therefore, stem volume of different imaginary segments of length ≤2m (the last segment toward tip of the tree may be of less than 2m in length) was calculated separately using the following formulae. $V_i = \pi(Di/2)^2 \times Li$,

where Vi = Volume for the i^{th} segment in m^3

Di= Mid diameter of the i^{th} segment in m

Li = Length of the i^{th} segment in m

Π = 3.14

And $V = \sum_{i=1}^{n} Vi$

Where, V= Total stem volume of the tree and

n = number of imaginary segments of length $\leq 2m$

It is clarified that only the aforementioned non–destructive method, without tree felling, employed for the estimation of stem volume with bark.

3.3 Calculation of stem biomass

Stem biomass has been calculated from the stem volume by multiplying it with the density or specific gravity of the wood. Values of wood density (gm cm-3 or MT m-3) for different species have already been worked out and published. In case of those species whose wood density was not known, it was determined by taking small wood samples and measuring its weight and volume (Reyes et al., 1992).

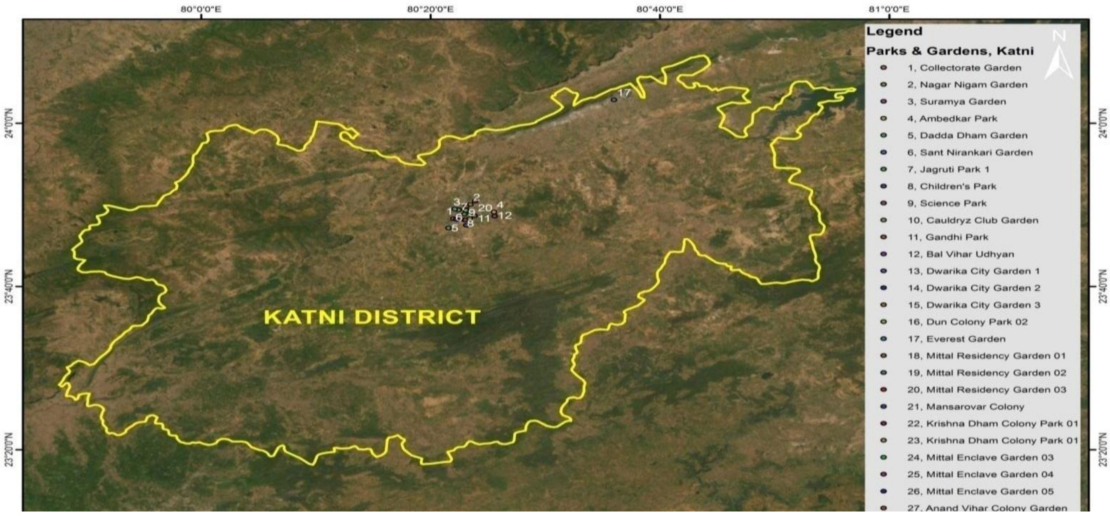
3.4 Calculation of sequestered carbon in different plant parts (above and below ground), leaf litter and soil

Amount of carbon sequestered in the stem is almost half of the stem biomass. For calculation of sequestered carbon in different plant parts (including roots), soil and leaf litter, allometric equations have been developed for a large number of tree species by the IPCC. These allometric equations were used for calculation of total carbon sequestered in trees of different species.

Table-2: List of sampled parks and gardens of Katni

S.N.	Name of parks/gardens and location	GPS location	Major tree species	Area in ha.	Total no. of

					trees
1.	Jaguriti Park, Bargawan, Katni	N-23.814 E-80.382	*Hyophorbe laginicaulis, Delonix regia, Albizia procera*	3	101
2.	Filter Park, Community Park-1, Kateyeghat, Katni	N-23.824 E-80.368	*Azadirachta indica, Phyllanthus emblica*	2.83	60
3.	SantNirankari Garden, Madhav Nagar, Katni	N-23.814 E-80.382	*Polyalthia longifolia, Tabernae Montana divaricata, Dalbergia sissoo*	0.805	65
4.	Baba Narayan Shah Colony Garden, Jhinjhari, Katni	N-23.814 E-80.382	*Dalbergia sissoo, Cassia siamea*	0.309	74
5.	Nagar Nigam Office Garden, Katni	N-23.834 E-80.391	*Hyophorbe laginicaulis, Thuja occidentatis*	0.05	22
6.	BalViharUdyan, NKJ, Katni	N-23.810 E-80.426	*Cassia siamea, Azadirachta indica*	0.105	17
7.	Caldryz Club Garden, OFK, Katni	N-23.805 E-80.390	*Polyalthia longifolia, Peltophorum pterocarpum*	0.300	48
8.	DaddaDham colony Park, Jhinjhari, Katni	N-23.786 E-80.359	*Polyalthia longifolia, Callistemon spp.*	0.167	44
9.	Dwarka city colony Park-1, Madhavnagar, Katni	N-23.821 E-80.386	*Hyophorbe lagenicaulis, Polyalthia longifolia*	0.125	30
10.	Dwarka city colony Park-2, Madhavnagar, Katni	N-23.820 E-80.386	*Hyophorbe lagenicaulis, Polyalthia longifolia*	0.126	22
11.	Dwarka city colony Park-3, Madhavnagar, Katni	N-23.820 E-80.386	*Alstonia scholaris, Phyllanthus emblica*	0.129	16
12.	Everest industry Admin garden, Kymore, Katni	N-24.047 E-80.599	*Azadirachta indica, Polyalthia longifolia*	0.500	83
13.	Gandhi Udyan, Opp. South Katni Railway station, Katni	N-23.811 E-80.397	*Hyophorbe lagenicaulis, Phyllanthus emblica*	0.350	56
14.	Krishna colony Park-1, Katayeghat, Katni	N-23.823 E-80.374	*Hyophorbe lagenicaulis, Azadirachta indica*	0.120	28
15.	Krishna colony Park -2, Katayeghat, Katni	N-23.823 E-80.373	*Azadirachta indica, Hyophorbe lagenicaulis*	0.130	17
16.	Mansarovar colony Park, MPHS, Katni	N-23.791 E-80.385	*Dalbergia sissoo, Millettia pinnata*	0.130	18
17.	Mittal Enclave colony, Garden-1, NaiBasti, Katni	N-23.841 E-80.393	*Wodyetia bifurcata, Polyalthia longifolia*	0.120	9
18.	Mittal Enclave colony, Garden-2, NaiBasti, Katni	N-23.840 E-80.398	*Wodyetia bifurcata, Callistemon spp., Tecoma stans*	0.129	12
19.	Mittal Enclave colony, Garden-3, NaiBasti, Katni	N-23.841 E-80.398	*Tecoma stans, Hyophorbe lagenicaulis*	0.130	10
20.	Mittal Enclave colony, Garden-3, Jhinjhari, Katni	N-23.803 E-80.371	*Hyophorbe lagenicaulis*	0.225	13
21.	Mittal Enclave colony, Garden-4, Jhinjhari, Katni	N-23.803 E-80.371	*Cascabela thevetia, Terminalia arjuna*	0.070	15
22.	Mittal Enclave colony, Garden-5, Jhinjhari, Katni	N-23.803 E-80.370	*Tabernaemontana divaricata, Cascabela thevetia*	0.333	17
23.	AnandVihar colony park, Bargawan, Katni	N-23.830 E-80.385	*Polyalthia longifolia, Hyophorbe lagenicaulis*	0.255	29
24.	Dun colony park 02, Bargawan, Katni	N-23.822 E-80.384	*Neolamarckia cadamba, Delonix regia*	0.315	25
25.	Suramya Garden, Katayeghat	N-23.824 E-80.371	*Polyalthia longifolia, Mangifera indica, Albizia lebbeck,*	5	600



Map-1. Locations of sampled Parks and Gardens in Katni City

The methodology for assessing carbon sequestration in Katni district's parks and gardens involved several key steps: collecting comprehensive secondary data on all parks and gardens, selecting these spaces based on size criteria, counting all trees within the parks and their outer boundaries, stratifying trees by species and age, and adopting a non-destructive sampling approach for large parks (5 hectares and above) as mentioned in table 2. This approach included using nested two-stage sampling to estimate above-ground tree biomass, employing super plots of 250m x 250m size with four 31.62m x 31.62m sample plots within each super plot to gather detailed data on tree distribution and density.

- A detail of sampling design at plot level study is presented in image 1.

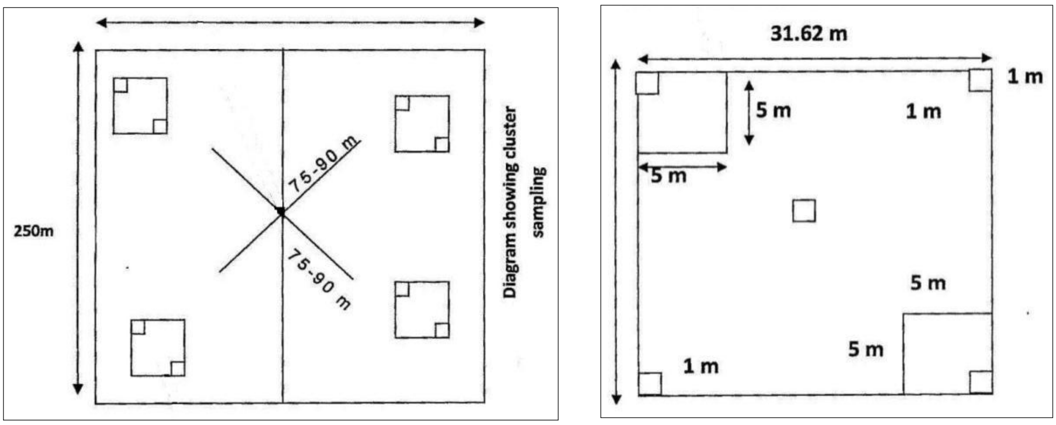


Image-1: Sample plot design for tree sampling in gardens

3.5 Tree species for Park and Gardens

Criteria for prioritization and relative weights given to each criterion to prioritize species for roadside plantation was selected after conducting PRA exercise with different stakeholders and after consulting experts. The following types of criteria were considered -

i. *Aesthetic*- Good foliage, colorful and scented flowers, evergreen, etc.
ii. *Environmental* - Higher rate of carbon sequestration, capacity to absorb air pollutants, especially those emanating from vehicular emissions, less demanding on ground water etc.
iii. *Utilitarian* – Providing shade to pedestrians, edible fruits to birds, etc.
iv. *Hardiness* – Capacity to withstand long dry spells and high temperatures, strong winds, non-browsable, etc.

4. RESULTS AND DISCUSSION

Table 3 presents data on area, tree count, and carbon sequestration in Katni sampled parks and gardens. Among the 62 parks, one is large-sized, two are medium-sized, and the rest are small-sized, with 39 of the small ones containing trees. The study included the single large park, the two medium ones-Suramya Garden, Jagruti Park, and Filter Park—and a sample of 23 small parks/gardens. Suramya Garden, being large-sized, sequestered the highest carbon at 221.705 tons from 600 trees spanning 25 species. Jagruti Park and Filter Park, both medium-sized, stored 6.514 and 4.501 tons of carbon from 101 and 60 trees, respectively. The 23 sampled small parks/gardens collectively sequestered 107.37 tons of carbon from 777 trees. Collectorate Garden among the small parks sequestered the most carbon at 15.018 tons, followed by Gandhi Udhyan at 11.550 tons. The total carbon sequestration across all 26 sampled parks in Katni reached 339.957 tons from 1538 trees.

Total-3: Carbon content in Parks and Garden of Katni

S. No.	Name of Parks	Area	Total No. of trees	Total carbon
A. Large sized garden				
1.	Suramya Park	5.070	600	221.705
	Total carbon (A)		**600**	**221.705**
B. Medium sized garden				
2.	Jaguriti Park, Bargawan, Katni	3.000	101	6.514
3.	Filter Park, Community Park-1, Kateyeghat, Katni	2.830	60	4.501
	Total carbon (B)		**161**	**11.015**
C. Small sized garden				
4.	Sant Nirankari Garden, Madhav Nagar, Katni	0.805	65	10.370
5.	Collectorate Garden, Katni	0.610	107	15.018
6.	Everest Industry, Kymore, Katni	0.500	83	9.013
7.	Mittal Enclave Colony Garden-4, Jhinjhari, Katni	0.400	13	0.494
8.	Sant Nirankari Park	0.400	29	10.370
9.	Mittal Enclave Colony Garden-5, Jhinjhari, Katni	0.382	15	2.513
10.	Gandhi Udyan, Opp. South Katni Railway Station, Katni	0.320	56	11.550
11.	Baba Narayan Shah Colony Garden, Jhinjhari, Katni	0.305	74	9.864
12.	Caldryz Club Garden, Ofk, Katni	0.300	48	8.559
13.	Mittal Enclave Colony Garden-6, Jhinjhari, Katni	0.279	17	0.060
14.	Dun Colony Park, Bargawan, Katni	0.200	25	0.327
15.	DaddaDham Colony Park, Jhinjhari, Katni	0.167	44	2.415
16.	Krishna Colony Park -2, Katayeghat, Katni	0.130	17	3.020
17.	Mansarovar Colony Park, MPHS, Katni	0.130	18	2.789
18.	Krishna Colony Park-1, Katayeghat, Katni	0.120	28	6.001
19.	BalViharUdyan, NKJ, Katni	0.105	17	0.641
20.	Dwarka City Colony Park-1, Madhavnagar, Katni	0.100	30	3.652
21.	Dwarka City Colony Park-2, Madhavnagar, Katni	0.100	22	3.624
22.	Dwarka City Colony Park-3, Madhavnagar, Katni	0.100	16	0.543
23.	Mittal Enclave Colony Garden-1, NaiBasti, Katni	0.052	9	0.098
24.	Nagar Nigam Office Garden, Katni	0.038	22	5.416
25.	Mittal Enclave Colony Garden-3, NaiBasti, Katni	0.030	10	0.204
26.	Mittal Enclave Colony Garden-2, NaiBasti, Katni	0.024	12	0.696
	Total carbon (C)		**777**	**107.237**
	Total Carbon (A+B+C)		**1538**	**339.957**

Out of 62 parks and gardens in Katni, 26 parks and gardens of large, medium and small size were sampled. In sampled parks and gardens a total of 339.957 tons of carbon is sequestered by 1538 different trees.

In the large size and medium sized parks, several different species ranging between 33 in large size gardens and to 25 species in medium sized gardens were observed. The species were a mix of native and exotic species.

4.1 Total carbon sequestration by all parks and gardens of Katni

On the basis of 26 sampled parks/gardens of Katni which constitute about 42% of the total parks/gardens it was estimated that the average carbon content per park/garden is 4.662 tons in Katni. Therefore the total carbon content in Katni is 414.557 tons given in table 4.

Table 4: carbon sequestration by all parks and gardens of Katni

S. No	Park size		Total No. of park in Katni	Sampled park	Total carbon of sampled parks (in tons)	Total carbon of all parks in Katni (in tons)
1.	Large-sized park/garden		1	1	221.705	221.705
2.	Medium-sized park/garden		2	2	11.015	11.015
3.	Small-size park/garden	Stocked parks	39	23	107.237	181.837
		Blank parks	20	12	-	-
	Total		**62**	**38**	**339.957**	**414.557**

4.2Identification of suitable trees in parks and gardens

Trees in parks and gardens not only make them beautiful but also play an important role in purifying the air. The recommendations for suitable trees were derived from existing plantation and corroborated with prior studies. The study identified 70 tree species within sampled areas. Table 5 shows the preferred trees for parks and gardens on the basis of five different criteria that is i- aesthetic, ii- utilitarian, iii- environmental, iv- Hardiness, and v- Air pollution abatement.

34 tree species were having aesthetic and utility criteria serving purposes such as beauty, edibility, medicinal properties, religious significance, shade and forage.

Additionally 43 species demonstrated environmental values, including carbon sequestration, pollution abatement and hardiness as given in Table 5. Fifteen species had high carbon sequestration rates, 14 species had pollution abatement potential and 17 had displayed hardiness. Notably six species, viz., *Albizia lebbeck, Albizia procera, Azadiracta indica, Ficus benhalensis, Ficus religiosa* and *Peltophorum pterocarpum* excelled across all the three criterias. The recommended best tree species to be considered for planting in parks and gardens which suit all the above five criteria are *Ailanthus excelsa, Azadirachta indica, Cassia siamea, Dalbergia sissoo. Delonix regia, Ficus benghalensis, Ficus racemosa, Ficus religiosa, Millettia pinnata* and *Peltophorum pterocarpum* (Table 6).

The study by Shinde and Mahajan, (2015) reported that in ChittaranjanVatika (park) of Pune was dominated by *Cassia siamia, Delonix regia, Milintona hotensis, Putranjiva roxburghii, Peltoforummermi, Saraca indica* and *Spathodea campanulata.* Trees in terms of higher carbon sequestration, *Ficus benghalensis* showed the highest carbon sequestration followed by *Albizia lebbeck*, *Delonix regia,* and *Pithecelobium dulce*.

Trees that have good potential for sequestering carbon sequestration and can absorb air pollutants. The recommendations made for on the basis of study results and also on earlier studies by Bhat *et al.,* 2016; Ragula and Chandra (2020); Ramchandra *et al.,* 2014 and Kiran and Kinnary (2011).

Based on the higher sequestration potential of carbon stocks in trees, a study was conducted by Ragula and Chandra (2020) in Bilaspur district of Chhattisgarh state. Climate and forest types in Chhattisgarh and Madhya Pradesh are closely similar. The study revealed that *Delonix regia* had the largest amounts of species-specific biomass and CO_2 stocks, followed by *Tamarindus indica*, *Ficus religiosa, Albizia lebbeck, Ficus benghalensis*. *Azadirachta indica, Peltophorum pterocarpum, Samanea saman* and *Cassia siamea.* In order of highest to the lowest rate of carbon sequestration, the species were sequenced as *Delonix regia, Samanea saman, Tamarindus indica, Azadirachta indica, Ficus religiosa, Peltophorum pterocarpum, Albizia lebbeck, Terminalia catappa, Ficus benghalensis,* and *Terminalia arjuna*. In conclusion of their study, they have suggested that these tree species are, therefore, recommended to sequester large amounts of CO_2 from the city and contribute to offsetting warming and mitigating the impact of climate change.

In the current study, *Peltophorum pterocarpum, Delonix regia, Ficus religiosa, Ficus benghalensis, Azadirachta indica, Albizia lebbeck* and *Terminalia arjuna* have revealed the higher potential of carbon sequestration.

Another study by Ramchandra *et al.,* 2014 suggested that in the selection of species for planting, exotic species generally flower profusely, but fail to stand during harsh wind and after a certain age, the strength of the root fails to hold the tree to the soil, and hence fall during monsoon season. In the past and also traditionally, native tree species were selected for avenues and also at the fringes, which are quite strong and provide fruits and shade to pedestrians. These native tree species are a source of nectar and food for several species of birds and insects. In this regard, it is suggested that preference may be given to the planting of native tree species.

Different plant species respond differently to pollution. While some plants can tolerate fairly high levels of pollution (suspended particulate matter, dust, and gases), others are quite sensitive. The response of plants to air pollution depends upon the type of pollutant present, its concentration, and the length of exposure to it.

Researchers in India are zeroing in on air pollution-gobbling plant species, that could be used in green belt development along roadsides, and thermal power plants and for creating urban forests, to sponge off foul air (Ghosh, 2018). Table 4 shows the lists of a few species that can help prevent air pollution.

Further, the screening pin-pointed plant species such as fig and Himalayan cherry (*Prunus cornuta*) had higher dust accumulation potential. Green belts with prioritized plant species are very effective in such scenarios. Here, plants form a surface capable of absorbing particulate matter, black carbon, and dust thereby acting as a sink for pollution. Rough leaves in the canopy trap pollutants directly on their surface thus effectively reducing their concentrations in the ambient environment (Uniyal, 2018).

Deciduous trees such as Indian redwood (*Caesalpinia sappan*), shisham (*Dalbergia sissoo*), and Kala siris (*Albizia lebbeck*) were found to be most tolerant during the present study; followed by semi-deciduous trees such as neem (*Azadirachta indica*), gulmohar (*Delonix regia*) and guava (*Psidium guajava*); whereas, evergreen trees such as Cassia (*Cassia siamea*), banyan (*Ficus benghalensis*), and eucalyptus (*Eucalyptus citriodora*) were found to be the least tolerant.

Indigenous species that support biodiversity should be given preference over exotic tree species like *Eucalyptus, Acacia auriculiformis*. Results obtained by working with *Anogeissus latifolia* indicates it's potential and can serve as the promising candidates (Waran and Patwardhan, 2005).

Advocating for native tree species due to their resilience and biodiversity support, our findings align with prior studies emphasizing the importance of indigenous species over exotic ones. Additionally, research into air pollution-gobbling plant species, such as silk oak, walnut plant, and Holly oak, underscores their efficiency in mitigating air pollution, especially in heavily contaminated environments.

Photo-1: Dwarka City Colony Park-3, Madhav Nagar, Katni

Photo-2: Gandhi Udyan, Opp. South Katni Railway Station, Katni

Table-5: Recommendations of trees of aesthetic value (evergreen trees), utility 'environmental value' (Carbon sequestration), Pollution abatement and Hardiness

S. No.	Scientific name	Flowering season	Color of flower	Uses	Aesthetic	Utility	Tolerant	Growth (slow/fast)	Carbon sequestration rate (high/low)	Pollution abatement	Hardiness
1	*Acacia auriculiformis*						drought, dust, smoke	Fast	-	-	Hardiness
2	*Acacia nilotica*						drought	Medium	-	-	Hardiness
3	*Ailanthus excelsa*						-	Fast	Low	-	-
4	*Albizia lebbeck*	Apr.- Sep.	White	Forage, medicine and wood	Aesthetic	Utility	dust and smoke	Fast	High	Pollution abatement	Hardiness
5	*Albizia procera*						dust and smoke	Fast	High	Pollution abatement	Hardiness
6	*Alstonia scholaris*	Oct.- Nov.	Green	Ornamental	Aesthetic	Utility	dust, smoke	Fast	Low	-	Hardiness
7	*Azadirachta indica*	Mar.- Jul.	White	Medicinal/shade	Aesthetic	Utility	-	Fast	Low	Pollution abatement	Hardiness
8	*Barringtonia acutangula*	Apr.- Jun.	Red	Medicine and wood	Aesthetic	Utility					
9	*Bauhinia purpurea*	Nov. - Feb.	Pink	Ornamental	Aesthetic	-					
10	*Bauhinia variegata*	Nov. - Feb.	Pink	Edible fruit	Aesthetic	Utility	-	Fast	Low	-	-
11	*Bombax ceiba*	Feb.- Apr.	Red/orange red	Edible fruit	Aesthetic	Utility	dust and smoke	Fast	High	-	Hardiness
12	*Butea monosperma*	Jan.- Mar.	Orange	Medicinal/shade	Aesthetic	Utility	dust, smoke	Slow	-	-	Hardiness
13	*Caesalpinia sappan*						-	Fast	-	Pollution abatement	-
14	*Callistemon viminalis*	Oct. - Dec.	Crimson red	Ornamental	Aesthetic	-					

S. No.	Scientific name	Flowering season	Color of flower	Uses	Aesthetic	Utility	Tolerant	Growth (slow/fast)	Carbon sequestration rate (high/low)	Pollution abatement	Hardiness
15	*Cassia fistula*	Feb.- Apr.	Yellow	Edible fruit	Aesthetic	Utility	-	Fast	Low	-	-
16	*Cassia siamea*	Feb.- Apr.	Yellow	Shade	Aesthetic	Utility	-	Fast	High	Pollution abatement	-
17	*Casuarina equisetifolia*	Feb.- Apr.	Pink	Wind barrier	Aesthetic	Utility	-	Fast	Low	-	-
18	*Ceiba pentandra*						-	Fast	Low	-	-
19	*Chukrasiata bularis*						-	Medium	High	-	-
20	*Dalbergia sissoo*						-	Medium	-	Pollution abatement	Hardiness
21	*Delonix regia*	Apr.- Jun.	Orange red	Shade	Aesthetic	Utility	-	Fast	Low	Pollution abatement	-
22	*Eucalyptus tereticornis*						-	Fast	-	Pollution abatement	Hardiness
23	*Ficus benghalensis*						drought, dust, smoke	Fast	Low	Pollution abatement	Hardiness
24	*Ficus benjamina*						drought, dust, smoke	Fast	Low	-	Hardiness
25	*Ficus hispida*	Jun. – Jul.	Yellow	Ornamental	Aesthetic	-					
26	*Ficus racemosa*	Nov. – Jan.	Greenish-white	Medicinal	Aesthetic	Utility					
27	*Ficus religiosa*	Nov. – Jan.	Greenish-white	Religiosa	Aesthetic	Utility	drought, dust, smoke	Fast	Low	Pollution abatement	Hardiness
28	*Grevillea robusta*						-	Fast	Low	Pollution abatement	-
29	*Hyophorbe laginicaulis*						-	Fast	Low	-	-
30	*Jacaranda mimosifolia*	Oct.- Nov.	Blue	Ornamental	Aesthetic	-					
31	*Kigelia pinnata*	Aug.- Nov.	Red	Ornamental	Aesthetic	-					
32	*Koelreuteria paniculata*	Oct.- Nov.	Bright yellow	Ornamental	Aesthetic	-					

S. No.	Scientific name	Flowering season	Color of flower	Uses	Aesthetic	Utility	Tolerant	Growth (slow/fast)	Carbon sequestration rate (high/low)	Pollution abatement	Hardiness
33	*Lagerstroemia speciosa*	Apr.- Jul.	Blue	Ornamental	Aesthetic	-	-	Fast	High	-	-
34	*Madhuca longifolia*						dust and smoke	Medium	Low	-	Hardiness
35	*Magnolia champaca*	Jun. – Sep.	Yellow-orange	Ornamental	Aesthetic	-					
36	*Mangifera indica*	Mar.- Apr.	Dull greenish	Edible	Aesthetic	Utility	-	Fast	Low	-	-
37	*Melia azadirach*	Mar.- Aug.	White	Medicinal	Aesthetic	Utility	-	Fast	High	-	-
38	*Millettia pinnata*	Apr.- Jun	Creamy white	Avenue	Aesthetic	Utility	-	Fast	Low	-	-
39	*Mimusopse lengi*	Apr.- Jun.	Creamy white	Shade	Aesthetic	Utility					
40	*Morus alba*						-	Fast	Low	-	-
41	*Neolamarckia cadamba*	Jun.- Aug.	Red/orange	Shade	Aesthetic	Utility	frost	Fast	High	-	Hardiness
42	*Peltophorum pterocarpum*	Apr.- Jun.	Yellow	Shade	Aesthetic	Utility	wind	Fast	High	Pollution abatement	Hardiness
43	*Pithecolobium dulce*						-	Fast	High	-	-
44	*Polyalthia longifolia*						-	Fast	Low	-	-
45	*Prosopis juliflora*						-	Slow	Low	-	-
46	*Psidium guajava*						-	Slow	-	Pollution abatement	-
47	*Putranjiva roxburghii*	Mar.- May.	Yellow	Shade	Aesthetic	Utility	-	Fast	High	-	-
48	*Samanea saman*	Mar.- May.	Pink	Ornamental	Aesthetic	-	-	Fast	High	-	-
49	*Semecarpus anacardium*	Dec.- Jan.	Greenish yellow	Medicinal	Aesthetic	Utility	-	Fast	High	-	-
50	*Syzygium cumini*	Mar.- Apr.	Bloom white	Edible/ medicinal	Aesthetic	Utility	-	Fast	High	-	-
51	*Tamarindus indica*	May.-	Red	Medicinal	Aesthetic	Utility	-	Slow	High	-	Hardiness

S. No.	Scientific name	Flowering season	Color of flower	Uses	Aesthetic	Utility	Tolerant	Growth (slow/fast)	Carbon sequestration rate (high/low)	Pollution abatement	Hardiness
		Aug.	yellow								
52	*Terminalia marjuna*	May.- Jun.	Pale yellow	Medicinal/shade	Aesthetic	Utility					
53	*Toona ciliata*						-	Fast	Low	Pollution abatement	-

Table-6: Recommended tree species suited for all five criterias

S.N.	Scientific name	Family
1.	*Ficus benghalensis*	Moraceae
2.	*Delonix regia*	Caesalpiniaceae
3.	*Millettia pinnata*	Fabaceae
4.	*Cassia siamea*	Caesalpiniaceae
5.	*Ailanthus excelsa*	Simaroubaceae
6.	*Azadirachta indica*	Meliaceae
7.	*Ficus racemosa*	Moraceae
8.	*Ficus religiosa*	Moraceae
9.	*Peltophorum pterocarpum*	Fabaceae
10.	*Dalbergia sissoo*	Fabaceae

5. CONCLUSION

The study conducted in Katni sheds light on the amount of carbon sequestration within its parks and gardens, emphasizing the important role of varied factors in this ecological process. The diversity in park sizes, ranging from large to medium and small, reveals different carbon sequestration capacities. Suramya Garden, as the large-sized park, stands out as a significant contributor, sequestering a substantial 221.705 tons of carbon through its 600 trees, showing the potential of larger green spaces. Medium-sized parks like Jagruti Park and Filter Park also play a role, although smaller in scale, demonstrating the impact of park size on carbon sequestration.

Moreover, the species diversity within these parks, encompasses a mix of native and exotic species. The challenges to climate change in urban centres needs to be addressed by adopting measures to green all available blank spaces with planting of species based on the multiple criteria discussed in the paper. Policy makers and urban planners may stress on adding mix of indigenous species which augment local biodiversity of these areas. These suggestion need to be given priority and integrated with all urban plans of the cities of India.

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