International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 23s, 2025
https://theaspd.com/index.php

Greening Cities for a Cooler Future: The Role of Urban Green Spaces in Climate Change Resilience

S S Prema[1*], J. Narayana[1]
[1]Department of P.G Studies & Research in Environmental Science, Kuvempu University, Shankarghatta-577451, Shivamogga, Karnataka, India.
Corresponding Author- S S Prema
E-mail-premakp12@gmail.com,

Abstract-
Urban green spaces help to control climate change by absorbing CO_2 and storing it in biomass, while also mitigating urban heat islands, enhancing air quality, and regulating urban runoff. This is particularly important as CO_2 emissions from economically vital activities are challenging to reduce. Urban green spaces offer a valuable strategy for offsetting these emissions and improving urban sustainability. These processes enhance urban resilience by moderating temperatures, cleaning the air, and protecting infrastructure, creating more livable and sustainable cities. This paper examines the significance of urban green spaces, specifically studying the diversity and carbon sequestration potential of roadside trees in Shivamogga to understand their significance in expanding urban regions. The field survey documented 2056 individual trees, representing 74 species across 22 families. In this study Pongamia pinnata showed the highest Species Important Value Index (IVI) i.e. 52.107 suggest that this species is dominant, widely distributed, and well adopted for urban environment. Fabaceae is the dominant family with Family Important Value Index 142.26 indicating its dominance in the urban vegetation, contributing significantly to urban forest's structure and function. Total Carbon Stock is 1381.11 tCO_2e/ha. Carbon stock is more in Samanae saman(456.05tCO_2e/ha) followed by Peltophorum pterocarpum(155.50t/ha), and Pongamia pinnata(98.92tCO_2e/ha).Findings of this research study focuses solely on significance of roadside trees in changing urban environment, they demonstrate the effectiveness of urban tree planting as a strategy for offsetting CO_2 emissions.
Key Words- *Climate change, Urban green spaces, Carbon sequestration, Urban resilience*

INTRODUCTION

Climate change, fueled by increasing greenhouse gas emissions, is a compelling issue of global concern and one of the most critical environmental challenges of the 21st century. Carbon dioxide (CO_2) is the primary contributor to climate change, accounting for the majority of anthropogenic emissions resulting from fossil fuel combustion, vehicular emission, industrial activities, and land-use changes. The impacts of climate change threaten both ecosystems and human communities, requiring immediate attention and action. The increased emission of CO_2 in the atmosphere due to human induced activities is largely contributing to global warming and climate change [1]

Tree-based carbon sequestration is a highly promising and cost-effective approach to reducing atmospheric CO_2 levels [2]. Through photosynthesis, trees sequester CO_2 from the atmosphere, retaining it in both biomass and soil organic matter.

Forests are renowned carbon sinks, storing nearly two-thirds of terrestrial carbon in trees, understory vegetation, leaf litter, and forest floor debris [3]. Similarly in recent decades Urban Green Spaces (UGSs) have emerged as valuable assets in climate change mitigation efforts, despite their relatively small size. Urban trees perform a vital role by acting as significant reservoirs for carbon sequestration.

Urban trees help combat climate change by absorbing CO_2 and reducing energy use, leading to lower greenhouse gas emissions [4]. Urban trees not only enhance air quality and provide cooling but also help reduce CO_2levels, supporting global climate change mitigation effort. Carbon sequestration potential of urban trees needs urgent assessment due to rapid urbanization and natural ecosystem decline.

Recent studies in Shivamogga city emphasize the crucial role of UGSs of educational institutions in promoting sustainability through tree diversity and carbon sequestration [5, 6].

In this connection the current study addressed tree diversity documentation and estimation of carbon stock in trees on roadside which are one among many urban green spaces of Shivamogga city, to develop local greening strategies for sustainable urban planning and management.

STUDY AREA

The research work was carried out in Shivamogga City. The total area coverage of the city is 70.01 sq.km (27.03 sq.mi) Fig 1. The city is situated at a latitude of 13^0 56 ^{I}N and 75^0 34 ^{I}E with the average elevation of 569m (1867 ft) above sea level. Shivamogga experiences a tropical wet and dry climate, classified as Aw under the Koppen climate classification; with summer temperatures ranging from 20°C to 35°C (68°F to 95°F).The majority of the rainfall occurs between June and early October. The city's climate is characterized by an average annual rainfall of 731.1 mm, with a significant variation between the driest months (January and February) and the wettest month (July). April stands out as the warmest month, with an average high temperature of 35.5°C (95.9°F) (world weather online, 2025).

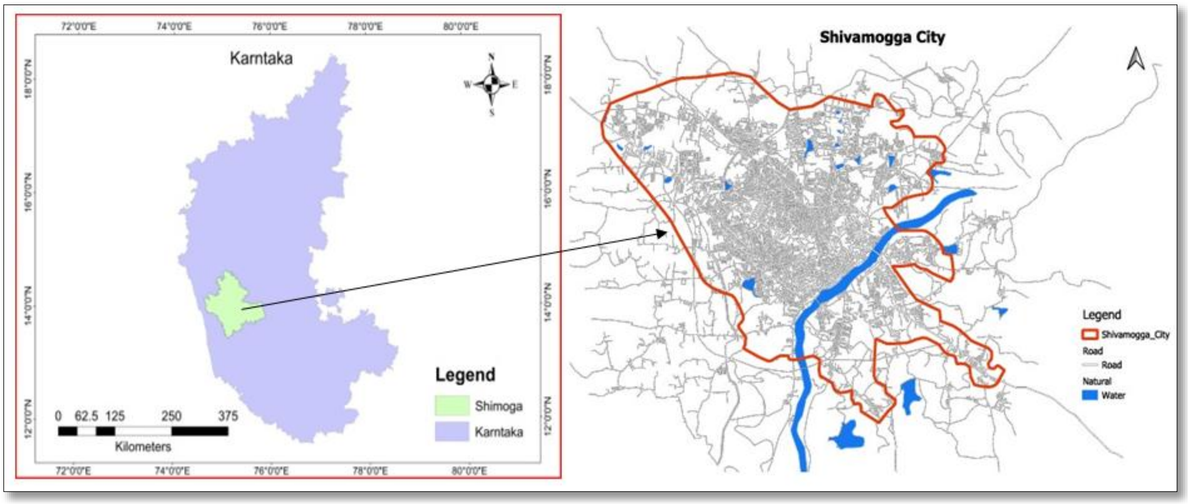

Fig1. Map showing the study area

MATERIALS AND METHODS

Floristic study

UGSs of Shivamogga city comprises of recreational, institutional, sacred, and utility greens, as well as roadside vegetation, all of these play significant role in maintaining microclimate. To understand the tree diversity in roads of the city, regular field study was conducted from June 2024 to June 2025 in the selected roads and recorded the diversity and distribution of tree species using random sampling methods. The quadrat method (10m×10m) was followed to document density, frequency, abundance and dominance of tree species. Shannon and Simpson indices are used to measure the diversity [7, 8, 9].
The documented trees were identified using various regional and district flora such as Trees of Sahyadri [10].

Assessment of Carbon Stock

A non-destructive method and procedures were used to measure DBH (Diameter at breast height) of tree, and the measured DBH was used to estimate the carbon stock of recorded tree species [11, 12, 13, 14]. Tree biomass was estimated using Diameter at Breast Height (DBH) and allometric equations, with Above Ground Biomass (AGB), Below Ground Biomass (BGB), and Total Biomass (TB) calculated for each tree species using standard equations [15].

RESULTS

Diversity

A total of 2056 trees from 74 species and 22 families were documented across 130 quadrats along selected roads in Shivamogga city. The frequently abundant tree species recorded in the study sites were Pongamia pinnata (L.)Pierrewith 1200 individuals, Peltrophorum pterocarpum(DC.)Backer ex K. Heynewith 201 individuals, and Samanea saman(Jacq.)Merrwith 191 individuals.
The Fabaceae family had the highest species richness, with 21 species and 1200 individuals, while Bignoniaceae (9 species, 131 individuals) and Combretaceae (5 species, 139 individuals) also showed significant presence. The top ten species occupied 65.9% (197.7) of species important value index-IVI (Table 1). The most important tree species based on IVI (total score 300) score were, 52.10 for Pongamia pinnata (L.) Pierre, 47.25 for Samanae saman(Jacq.)Merr, and 27.98 for Peltophorum pterocarpum(DC.) Backer ex K. Heyne.

Species Name	Family Name	Density	IVI
Pongamiapinnata	Fabaceae	611	52.11
Samanaesaman	Fabaceae	191	47.25
Peltophorumpterocarpum	Fabaceae	201	27.98
Terminaliacatappa	Combretaceae	97	12.38
Ficusreligiosa	Moraceae	30	12.32
Syzygiumcumini	Myrtaceae	82	11.14
Spathodeacampanulata	Bignoniaceae	58	10.83
Madhucalongifolia	Sapotaceae	31	9.64
Swieteniamacrophylla	Meliaceae	44	7.39
Muntingiacalabura	Muntingiaceae	54	6.66
Total		1399	197.70
Percentage for Top 10 Species		68.04	65.9

Table 1. Species importance value (IVI) for study area

The study area comprised 22 families, with Fabaceae being the most dominant (20 species), followed by Bignoniaceae (8 species) and Moraceae (6 species) (Table 2). Based on Family Importance Value (FIV) scores, Fabaceae ranked highest with 142.26, followed by Moraceae (23.56), Bignoniaceae (22.65), Combretaceae (16.70), and Myrtaceae (15.50) out of a total score of 300.Shannon and Simpson's index calculated were 2.99 and 0.12 respectively.

Family Name	Species Richness	Density	FIV
Anacardiaceae	1	10	2.31
Annonaceae	2	48	6.64
Apocynaceae	2	35	5.42
Arecaceae	2	12	3.69
Bignoniaceae	8	131	22.65
Combretaceae	5	139	16.70
Fabaceae	20	1200	142.26
Lamiaceae	3	46	7.20
Lythraceae	2	6	2.98
Magnoliaceae	1	47	3.99
Malvaceae	4	14	6.88
Meliaceae	4	68	12.49
Moraceae	6	72	23.56
Muntingiaceae	1	54	4.40
Myrtaceae	5	107	15.50
Proteaceae	1	1	1.37
Rubiaceae	1	4	1.93
Rutaceae	1	2	1.45
Santalaceae	1	8	1.74
Sapotaceae	2	39	11.45
Simaroubaceae	1	6	2.10
Ulmaceae	1	7	3.31
Total	74	2056	300

Table 2. Family diversity, density and family important value (FIV) of roads as UGSs of Shivamogga, India

Biomass and carbon sequestration potential

The CO_2 sequestration potential of trees along selected roadsides is detailed in Table 3. Total Carbon Stock estimated in this study was138.11tCO_2e/ha. The major contributor is Samanea saman(Jacq.) Merr with 191 individuals having of 456.05tCO_2e/ha. The Carbon stock of other dominant species Peltrophorum pterocarpum(DC.) Backer ex K. Heyne (201) and Pongamia pinnata(L.)Pierre (611) was 155.05tCO_2e/ha and 98.92tCO_2e/hare spectively. With less number of tree individuals Carbon stock recorded in Ficus religiosa L. (30) and Madhuca longifolia(J. Konig ex L.) J.F.Macbr (31) contributed high carbon stock compared to other tree species because of the higher girth size.

Sl. No	Name of Road	Total No. of roadside Trees documented	Area of the road (Hectare)	Total CO_2 Sequesterred (ton)
1	Bengaluru Honnavara Highway	233	0.27	108.51
2	100 FEET Road,Vinobanagar	371	0.13	267.41
3	BalrajUrs Road	66	0.04	203.64
4	60 FEET Road Vinobanagar	83	0.04	77.97
5	Veera Rani KeladiChennamma Road	61	0.05	28.37
6	Kuvempu Road	102	0.06	242.33
7	Jail Road	28	0.03	72.79
8	Durgigudi Main Road	57	0.04	40.95
9	Nehru Road	12	0.01	1.31
10	Savalanga Road Phase 1	126	0.08	158.38
11	Savalanga Road (SIR MV Road)	49	0.06	32.55
12	BYPASS Road-Solapura Mangalore Highway	194	0.18	215.82
13	GopalaGowda Main Road	196	0.09	73.07
14	100 FEET Outer Ring Road	70	0.03	28.44
15	NT Road	16	0.03	37.63
16	ShimogaChitradurga Road	77	0.05	82.61
17	Shimoga-Harihara-Hospet Road	96	0.03	53.11
18	Sominkoppa Road	219	0.08	70.57
	Total	**2056**	**1.3**	1795.45
				1381.12 tCO_2e/ha

Table 3: Total CO_2 sequestered by trees from selected Roadsides of Shivamogga City

Total Biomass (TB) and Total Carbon (TC) contribution by ten dominant species is detailed in Fig 2.

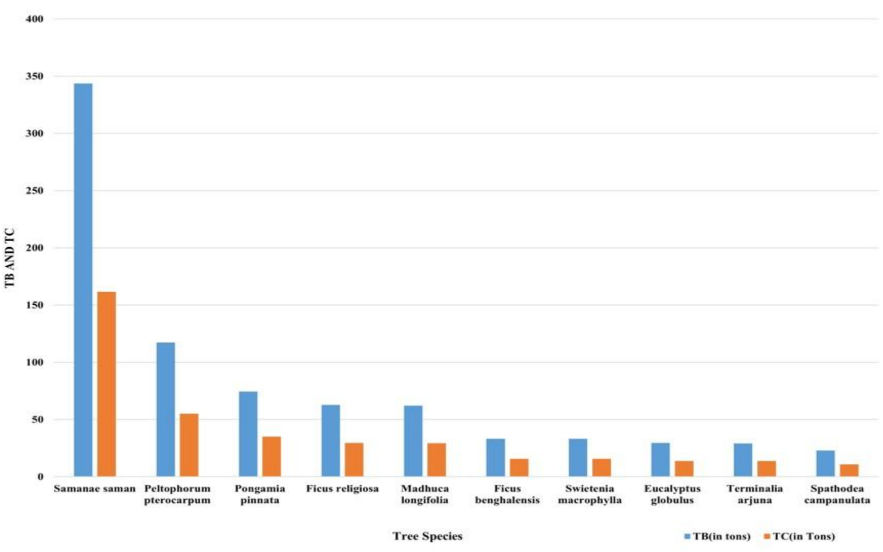

Fig.2. Total Biomass and Total Carbon Sequestration contribution by ten dominant Tree Species on roadsides in Shivamogga City

The percentage contribution of carbon sequestration by different Families is detailed in Fig.3.

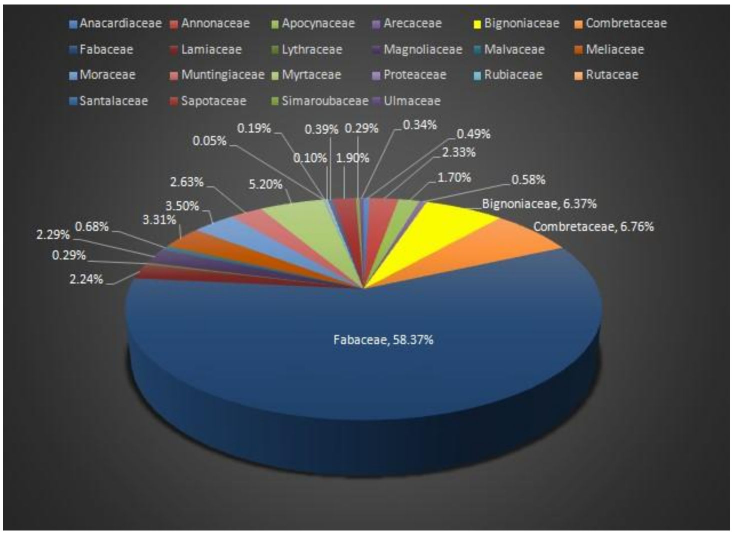

Fig.3. Percentage of TCS contribution by different families of trees on roads of Shivamogga City

Vehicle exhausts emit various pollutants, including CO_2, a major greenhouse gas, contributing to increased anthropogenic CO_2 concentrations [16]. Observations revealed a consistent increase in the number of 2-wheelers, 3-wheelers, and 4-wheelers over the last decade, resulting in rising CO_2 emissions on city roads (Fig 4).

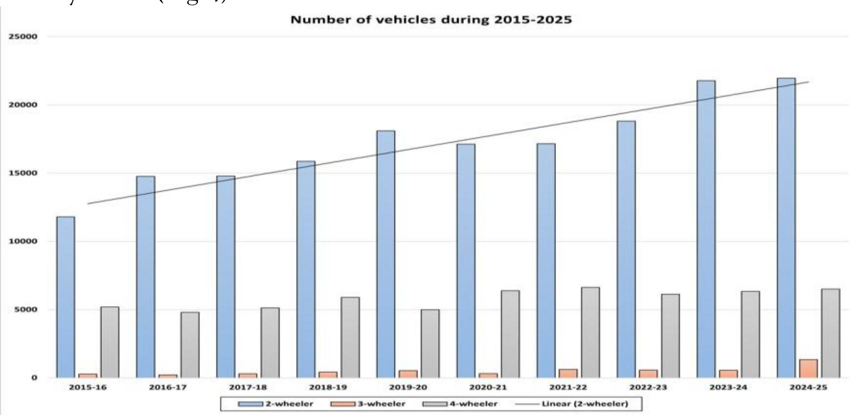

Fig 4. Number of vehicles increasing during 2015-2025 in Shivamogga city
(Source: Regional RTO office)

Annual CO_2 emissions totalled 23,070.04 tons, with 2-wheelers contributing 7,535.85 tons, 3-wheelers contributing 3,530.62 tons, and 4-wheelers contributing 12,003.57 tons. The current tree population in the study area mitigates merely 5.99% of carbon emissions from vehicles, underscoring the necessity for expanded green cover to maintain the carbon cycle balance.

DISCUSSION

The rise in atmospheric CO_2 levels has sparked global alarm, prompting immediate action to address climate change. Tree diversity and carbon sequestration have been studied in various urban and forest environments. In our study the dominant tree species document on roadsides were Pongamia pinnata(L.) Pierre (611) followed by Peltrophorum pterocarpum(DC.) Backer ex K. Heyne (201).Species recorded from roadside vegetation that represent UGSsof Shivamogga are common compared to urban vegetation of other cities of India.

According to Nagendra et al., Bangalore's street tree population is highly diverse, with the top four species Albizia saman, Peltophorum pterocarpum, Spathodea campanulata, and Pongamia pinnata making up approximately one-third of the population, and no single species exceeding 10% dominance [17].

The tree diversity study by Nagendra et al. in 127 plots of urban green spaces of Bangalore city, reported that out of 1423 trees sampled, most dominant trees were Polyalthia longifolia with 274 trees followed by Pongamia pinnata with 107 individuals [18].

Lahoti et al. found high tree diversity along Nagpur's roads, with 46 species and significant variation according to Shannon and Simpson indices, storing 334.61 t/ha of biomass [19]. Our study reveals a

Shannon's index of 2.99, suggesting high diversity. However, Simpson's index of 0.9 indicates low evenness, with the vegetation community dominated by a few species

The total carbon stock in this study was estimated at 1381.11 tCO_2e/ha for roadside trees, differing from Vadodara city's roadside trees, which sequestered 73.59 tons of CO_2 annually [20].

Pongamia pinnata (L.) Pierre, the dominant species in this study, contributed 7% to the total carbon stock, despite its dominance, due to the large number of individuals with small diameters (low DBH).Similar findings was reported by Narayana et al. [21]in their study on Carbon sequestration potential of tree in Kuvempu University, reported that the dominated Terminalia paniculatawith high number contributed just 13% of carbon stock to total of 457.0 tha-^{1} due to many individuals of species is under mature condition (low DBH).

This study reveals that existing roadside trees can offset only 5.99% of vehicular carbon emissions, highlighting the need for additional tree planting. Increasing tree cover through well-planned plantation activities in roadsides can help to achieve the goal of sustainability.

The research by Chakre [22] suggests selecting deciduous trees for planting in urban environment are trees with higher surface area, coarse-textured and presence of hairs on leaves like Largerstroemia speciosa, Mimusops elengi, Swietenia macrophylla, Cassia siamea, Peltophorum pterocarpum, effectively capture airborne particulate matter, showing high dust-capturing capacity.

CONCLUSION

Trees in urban region have the ability to sequester carbon and regulate temperature makes them essential for creating resilient and livable cities. Planting diverse, native tree species with substantial canopies in cities strengthens the ecological foundations and enhances air quality.

Our study indicates that Shivamogga city, a rapidly urbanizing Tier-II city in Karnataka, has moderate roadside tree diversity and significant carbon sequestration potential, with opportunities for enhancement through targeted planting initiatives. In conclusion, along with existing vegetation of city selecting of tree species for future planting programs such as Indian Tamarind (Tamarindus indica), Indian Mahogany (Swietenia macrophylla), Indian Mast Tree (Polyalthia longifolia), Neem (Azadirachta indica), Gulmohar (Delonix regia), Peepal (Ficus religiosa), Black Plum (Syzygium cumini), Jacaranda (Jacaranda mimosifolia), Temple Tree (Plumeria rubra and P. alba), and Indian Almond (Terminalia catappa) offers a strategic solution for enhancing urban sustainability by providing various ecological benefits. These species are not only well-adapted to the challenges of urban environments but also provide essential ecological, social, and aesthetic benefits.

ACKNOWLEDGEMENT

The authors express their gratitude to Dr. Nanda A., Biodiversity Education and Research Lab, Environmental Study Centre, Shivamogga, for his valuable time and suggestions throughout the research. Prema S.S. extends sincere thanks to research assistants Varnashree R., Ibbani H. R. Deeksha, and Sandesh S. O. for their valuable contributions to this study.

CONFLICTS OF INTEREST

There are no conflicts of interest.

REFERENCES

1. Singh, H.S., Tree wealth in the non-forest areas of Gujarat. Trees outside forest (TOF) - Third tree counting-2013, Gandhinagar, Gujarat Forest Department, 2013.
2. Sedjo, R A., Carbon sequestration in forest and soils. Annual review of resources and Economics. 2012; 4 (1):127-144.
3. Warran, A., Patwardhan, A., Carbon sequestration potential of trees in and around Pune city. Master's thesis submitted to University of Pune. 2001.
4. Devi, R., Carbonstorage by trees in urban parks: a case study of Jammu, Jammu and Kashmir, India. International Journal of Advance Research and Development. 2017; 2(4), pp. 250–253.
5. Prema, S. S., Narayana, J., Carbon Sequestration Potential of trees in urban green spaces at Sahyadri college campus of Shivamogga city, Karnataka, India. Ecology, Environment and Conservation. 2025;31, pp. 329-334.
6. Prema, S. S., Narayana, J., Role of urban green spaces of educational institutions in shaping sustainable cities: A case study of Shivamogga City, India. Ecology, Environment and Conservation.2025; 31, pp. 236-241.
7. Magurran, A. E., Ecological diversity and its measurement. Princeton university press. 1988.
8. Shannon, C.E., A mathematical theory of communication. The Bell System Technical Journal. 1948; 27(3), pp. 379-423.
9. Simpson, E.H., Measurement of diversity. Nature. 1949; 163(4148), pp.688-688
10. Shrikant Ingalhalikar., Trees of Sahyadri, Pune. Corolla publications. 2021.
11. Pearson, T.R.H., Brown, S., and Ravindranath, N.H., Integrating carbon benefits estimates into GEF Projects. 2005; pp. 1-56.

12. Sheikh, M.A., Kumar, M., Bussman, Wand T N P., Carbon balance and management. 2011; doi.: 10.1186-1750-0680-6-1
13. Suryawanshi, M. N., Patel, A. R., Kale, T. S. and Patil, P. R.,Carbon sequestration potential of tree species in the environment of North Maharashtra University Campus, Jalgaon (MS) India., Bioscience Discovery. 2014; 5(2), pp. 175-179.
14. Sangareswari, M., Manjuhashini, A. R., Carbon Sequestration Potential of a Few Selected Tree Species in Coimbatore District, Tamil Nadu. Advances in Research. 2018;14(4):1-7.
15. Chave, J., Rejou-Mechain, Burquez, A., Improved allometric models to estimate the above ground biomass of tropical tree. Global Biology. 2014; 20(10), pp. 3177-3190.
16. Kumar, Ankith, Shukla A K., Estimation of carbon dioxide emission from vehicles in Lucknow. Advances in Civil Engineering and Infrastructural Development. 2020; 87, pp. 495-500
17. Nagendra, H., and Gopal, D., Street trees in Bangalore: density, diversity, composition and distribution.Urban Forestry and Urban Greening. 2009. Doi: 10.1016/j.ufug.2009.12.005.
18. Nagendra, H. and D. Gopal., Tree diversity, distribution, history and change in urban parks: studies in Bangalore, India. Urban Ecosystems. 2010. Doi: 10.1007/s/11252-010-0148-1.
19. Lahoti, S., Lahoti, A., Joshi, R.K. and Saito, O., Vegetation Structure, Species composition: and Carbon Sink Potential of Urban Green Spaces in Nagpur City, India. Land. 2020. 9, pp.107.
20. Sandhya, K. G., Carbon sequestration by urban trees on roadsides of Vadodara city. International Journal of Engineering Science and Technology.2011; 3, pp. 3066-3069.
21. Narayan, J., Shashidhar, Savinaya, M. S., Carbon sequestration potential of trees in Kuvempu University Campus forest area, Western Ghats, Karnataka. Socio-economic and Eco-biological Dimensions in Resource use and conservation, Environmental Science and Engineering. 2020; pp. 303-312
22. Chakre, O., Choice of Eco-friendly Trees in Urban Environment to Mitigate Airborne Particulate Pollution. J. Hum. Ecol. 2006; 20(2), pp. 135-138.