Indian J. Applied & Pure Bio. Vol. 39(2), 1207-1218 (2024). **ISSN: 0970-2091**
A Web of Science Journal

Air pollution in Durgapur, West Bengal: an assessment of the trees' potential to sequester Carbon dioxide

[1]Anamika Pandey and [2]Debnath Palit

[1]Department of Conservation Biology, Durgapur Government College,
Durgapur– 713214 (India)
Email : pandeyanamika2106@gmail.com
[2]Principal, Durgapur Government College, Durgapur – 713214 (India)
Email : drdpalit@gmail.com

Abstract

In the last several decades, air pollution has become a serious global concern. Numerous air pollutants are discharged into the environment worldwide as a result of fast urbanization, industrialization, and excessive transportation usage. This has led to a decline in air quality and the development of serious environmental health risks for both humans and the environment. Since they absorb air pollutants on their leaves, mitigate CO_2 emissions through photosynthesis, and store carbon (C) as biomass, trees are widely acknowledged to have the ability to improve air quality. Utilizing a non-destructive sampling technique, the current study examines the effect of 10 chosen tree species' capacity to sequester carbon on air pollution, which is mostly prevalent in five distinct locations in Durgapur, Paschim Burdwan, West Bengal. The findings showed that, out of the five locations, Angadpur has the worst air pollution and the greatest potential for tree carbon storage. Additionally, the results demonstrated the great CO_2 sequestration potential of all tree species with a diameter at breast height (DBH) $\geq$ 30 cm. *Ficus benghalensis* L. and *Shorea robusta* Gaertn. were shown to have the highest capacity for sequestering carbon among the ten common tree species. As a result, they may be suggested for afforestation projects in the polluted area in order to reduce air pollution levels.

Key words : Air pollution, Urbanization, Carbon sequestration potential, Diameter at Breast Height.

India is a fast-growing country with a growing population, and nine of the ten most polluted cities in the world are located there. More rural regions have been transformed into urban settlements in recent decades due to the growing urbanization trend. According to Tiwari *et al.*,[25] and Horaginamani and Ravichandran[12], air pollution damages leaves, causes chlorophyll loss, causes leaves to drop, damages stomata, causes early senescence, reduces photosynthetic activity, and disturbs membrane permeability. It also inhibits the growth and yield of plant species. In urban areas, major indoor and outdoor air contaminants can be either main or secondary, according to Bernstein[1]. Dust particles, SO_2, NO_2, CO, ammonia, particulate matter ($PM_{2.5}$, PM_{10}), suspended particulate matter (SPM), respirable particulate matter (RPM), and particulate matter ($PM_{2.5}$, PM_{10}) are the main air pollutants that are directly released into the environment. Secondary pollutants include things like smog, ozone, peroxyacyl nitrates (PANs), and other air pollutants. Combustion engines, the production of power, construction, industrial and agricultural processes, home wood and coal burning, and agricultural activities are the most common man-made sources of air pollution. Trees in particular have a significant deal of potential to absorb carbon from the atmosphere and lessen the effects of air pollution in urban areas. The process by which plants naturally take CO_2 from the atmosphere through photosynthesis and store it for as long as they live, measured in terms of living biomass, is known as carbon sequestration[19]. After they pass away, the biomass enters the soil as soil carbon and joins the food chain. Carbon is released back into the atmosphere as carbon dioxide if the biomass is burned. The majority of terrestrial carbon storage sites are found in biomass, or tree trunks, branches, leaves, and roots. The potential of trees to sequester carbon is estimated using a variety of methods. The conventional technique to measure the amount of carbon biomass is destructive sampling (direct approach), which entails removing or uprooting and weighing complete components (*e.g.*, stem, branches, leaves, flowers, fruits, and roots).The entire process is laborious, costly, unworkable, often unlawful, and goes against the goals of forest preservation[8,16-18,26]. The indirect approach of non-destructive sampling employs allometric equations that incorporate biophysical parameters such as wood density, tree height, and diameter at breast height (DBH)[26]. To reduce CO_2 emissions, vegetation is currently employed as a carbon dioxide trap[7,9]. This research describes the CO_2 sequestration potential of tree species in Durgapur, W.B. and its association with air pollution during January, 2022 – December, 2022. For the study in Durgapur, the following five locations have been chosen: Angadpur, Muchipara, City Center, Mahatama Gandhi Avenue, and the Durgapur Government College Campus. It is simple to compute each species' CO_2 sequestration potential using the formula given by the IPCC in 2007, and it is also simple to determine the relationship between air pollution and CO_2 sequestration capacity of trees.

Study Site : Located at 23.55° N and 87.32° E, the Indian city of Durgapur is part of the West Bengal state. It is home to several small enterprises and large steel mills that regularly emit air pollutants into the surrounding environment. Among these contaminants are heavy metals, SO_2, NO_2, CO, and other respirable and suspended particulate matter. Among the significant goods produced in Durgapur by significant manufacturers are graphite carbon, DSP, DPL, ASP, DTPS, and DVC. Millions of tons of carbon, toxic gases, particulate matter, and fly ash are released into the sky by these big and small ferro alloy steel plants, adding to the haze that forms around dusk. The amount of internal traffic in the city and the National Highway that passes through it every day have had a substantial impact on the ecology. Unplanned urbanization, the growth of industries, and daily and hourly high traffic are the main causes of air pollution. The simplest way to characterize the climate of this research area is as dry, subtropical, with few deciduous trees and little precipitation (about 1,500 mm). 45.0 degrees is the average highest temperature, and 6.0 degrees is the average lowest temperature.

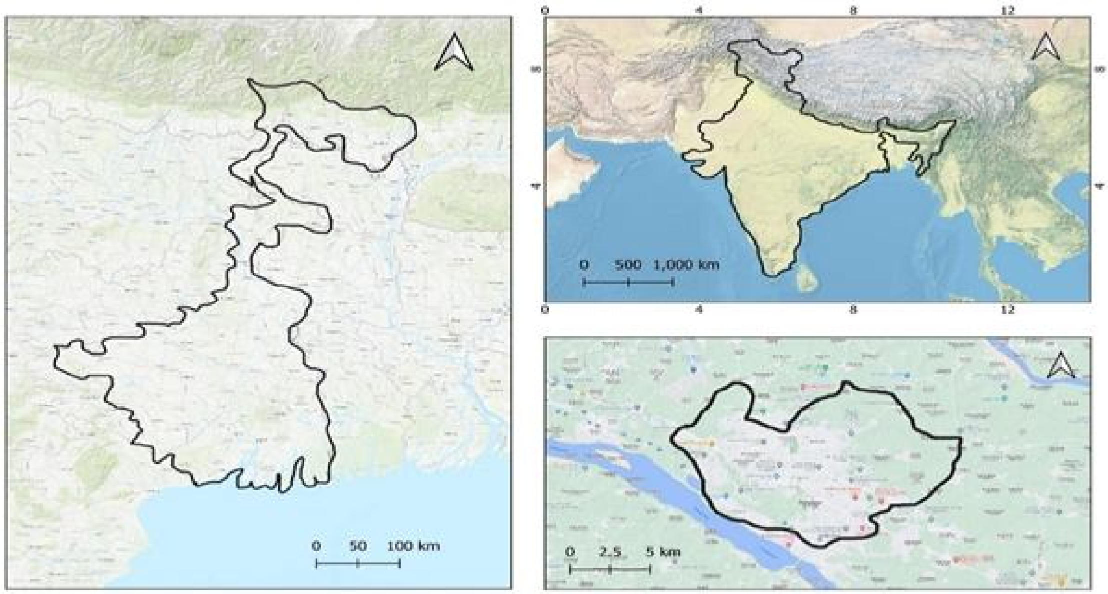

Figure 1. Showing maps of India (Top Right), West Bengal (Left), and Durgapur (Bottom Right)

The West Bengal Pollution Control Board website provided the information about the state of the air. The West Bengal Pollution Control Board's website contained information on air quality, including changes in NO_2, SO_2, and PM_{10} in 2022. The statistical method known as anova was used to evaluate the data. Ten dominant species in the research area were chosen in order to estimate the potential for CO_2 sequestration.

The standard measurement for the girth of each species of tree was taken at the breast height (GBH), or approximately 1.32 meters above the ground. To find the diameter (D) of the tree, divide π (22/7) by the species' actual marked girth[3], or GBH x 7/22. Calculating the biomass of the specified tree species only required the use of allometric equations based on biostatistics. By multiplying the bio-volume by the green wood density of various tree species, above ground biomass, or AGB, is calculated. The diameter multiplied by the height of the tree species yields the tree bio-volume (TBV) value, which is then multiplied by 0.4.

Table-1. The list of tree species are as follows

Sl. No.	Plant Name with Abbreviation	Local Name	Family	Use/s
1.	*Acacia auriculiformis* A. Cunn ex Benth. (ACAU)	Sonajhuri	Leguminosae	Timber
2.	*Aegle marmelous* (L.) Correa (AEMA)	Bel	Rutaceae	Wood, Medicine
3.	*Albizzia lebbeck* (L.) Benth. (ALLE)	Sirish	Leguminosae	Timber and fodder
4.	*Alstonia scholaris* (L.) R.Br. (ALSC)	Chattim	Apocynaceae	Timber, Medicine
5.	*Bauhinia purpurea* L. (BAPU)	Kanchan	Fabaceae	Fodder, Medicine, Timber
6.	*Ficus benghalensis* L. (FIBE)	Banyan	Moraceae	Fodder, Medicine
7.	*Shorea robusta* Gaertn. (SHRO)	Sal	Dipterocarp-aceae	Fodder, Fuel, Timber
8.	*Tamarindus indica* L. (TAIN)	Tentul	Leguminoceae	Food, Fodder, Timber, Medicine
9.	*Tectona grandis* L. (TEGR)	Segun	Verbenaceae	Timber, Medicine
10.	*Zizyphus jujuba* Mill. (ZIJU)	Kul	Rhamnaceae	Food, Fodder, Fuel

Bio-volume (TBV) = 0.4 X D x H
AGB=Wood density x TBV

Where H = Height in meters, and D is computed using GBH on the assumption that the trunk is cylindrical. A theodolite is a tool used to measure height. Zanne *et al.*,[27], used the Global Wood Density Database to determine wood density. In cases when the density value for a tree species is unavailable, the standard average density of 0.6 gm/cm is used. As the root: shoot ratio, the above ground biomass (AGB) has been multiplied by 0.26 factors to determine the belowground biomass[10].

BGB =AGB x 0.26

The total biomass is the total biomass that is found above and below ground[24].

Total Biomass (TB) = Above Ground Biomass + Below Ground Biomass.

Carbon Estimation : Carbon is

generally defined as 50% of a plant species' biomass[20]; that is, carbon storage/carbon sequestration capacity = biomass /2.

Carbon di-oxide Sequestration Potenial Estimation :

CO_2 sequestration potential was calculated using the formula given by the IPCC[13] in (*i.e.*, multiplying the carbon amount x 3.67).

Anova and correlation were used to statistically examine the to determine the relationship between air pollution and CO_2 sequestration capacity of trees.

According to the average yearly readings of NO_2, SO_2, and PM_{10} in the cities of Durgapur, Muchipara, City Center, Mahatama Gandhi Avenue, and Durgapur Government College Campus, Angadpur has the highest levels of air pollution, followed by these locations. All five locations had the highest concentration of PM_{10}, with NO_2 and SO_2 following closely behind. The areas of

Table-2. Characteristics of trees that are associated with their ability to sequester CO_2 in Angadpur :

Name of the plant	GBH (in meter)	Diameter (in meter)	Height (in meter)	T_{BV} (meter^3)	AGB (in kg)	BGB (in kg)	TB (in kg)	Carbon storage (in kg)	Carbon di-oxide sequestration potential (in kg)
Acacia auriculiformis A. Cunn ex Benth.	3.7	1.177	14.5	6.828	4.096	1.0651	5.161	2.5805	9.4706
Alstonia scholaris (L.) R.Br.	2.87	0.913	35.4	12.928	7.756	2.016	9.772	4.886	17.931
Aegle marmelous (L.) Correa	1.27	0.504	13.3	2.149	1.289	0.335	1.624	0.812	2.980
Albizzia lebbeck (L.) Willd	2.17	0.6904	23.5	6.4902	3.8941	1.0124	4.9065	2.453	9.0034
Bauhinia purpurea L.	0.59	0.1877	9	0.675	0.405	0.105	0.51	0.255	0.9358
Ficus benghalensis L.	9.3	4.959	37.3	44.149	26.489	6.887	33.376	29.9325	109.852
Shorea robusta Gaertn.	4.10	1.304	33.1	17.272	10.3633	2.694	13.057	6.5288	23.9609
Tamarindus indica L.	1.95	0.6204	19.6	4.864	2.918	0.758	3.676	1.838	6.745
Tectona grandis L.	1.02	0.324	32.8	4.258	2.554	0.664	3.218	1.609	5.905
Zizyphus jujuba Mill.	0.35	0.1113	7.7	0.3429	0.2057	0.0535	0.2592	0.1296	0.4756
Total CO_2 sequestration potential									**187.256**

Table-3. Characteristics of trees that are associated with their ability to sequester CO_2 in Muchipara

Name of the plant	GBH (in meter)	Diameter (in meter)	Height (in meter)	T_{BV} (meter^3)	AGB (in kg)	BGB (in kg)	TB (in kg)	Carbon Storage (in kg)	Carbon di-oxide sequestration potential (in kg)
Acacia auriculiformis A. Cunn ex Benth.	3.9	1.240	27.2	13.501	8.1006	2.106	10.2066	5.103	18.729
Alstonia scholaris (L.) R.Br.	3.56	1.132	25.9	11.735	7.041	1.8306	8.8716	4.4358	16.279
Aegle marmelos (L.) Correa	1.38	0.539	13.1	2.3003	1.3802	0.3588	1.738	0.869	3.189
Albizzia lebbeck (L.) Willd.	2.80	0.8909	18.1	6.4501	3.8701	1.0062	4.8763	2.438	8.948
Bauhinia purpurea L.	0.95	0.3022	6.5	0.785	0.471	0.122	0.593	0.296	1.0881
Ficus benghalensis L.	11.2	3.563	34.8	49.605	29.763	7.738	37.501	18.7505	68.814
Shorea robusta Gaertn.	4.82	1.533	38.9	23.863	14.318	3.722	18.04	9.02	33.103
Tamarindus indica L.	1.80	0.572	18.5	4.238	2.542	0.6611	3.2031	1.60155	5.877
Tectona grandis L.	2.52	0.501	30.4	9.7501	5.85006	1.521	7.371	3.685	13.525
Zizyphus jujubo Mill.	0.88	0.28	10.7	1.198	0.719	0.186	0.905	0.452	1.6606
Total CO_2 sequestration potential									**171.212**

Table-4. Characteristics of trees that are associated with their ability to sequester CO_2 in City Center

Name of the plant	GBH (in meter)	Diameter (in meter)	Height (in meter)	T_{BV} (meter^3)	AGB (in kg)	BGB (in kg)	TB (in kg)	Carbon Storage (in kg)	Carbon di-oxide sequestration potential (in kg)
Acacia auriculiformis A. Cunn ex Benth.	3.8	1.209	14.9	7.205	4.323	1.124	5.447	3.285	9.056
Alstonia scholaris (L.) R.Br.	2.55	0.811	30.2	9.801	5.880	1.528	7.408	3.704	13.593
Aegle marmelos (L.) Correa	1.45	0.461	12.9	2.380	1.428	0.371	1.799	0.899	3.301
Albizzia lebbeck (L.) Willd.	2.25	0.715	20.1	5.755	3.453	0.897	4.350	2.175	7.983

Bauhinia purpurea L.	0.89	0.283	11.5	1.302	0.781	0.203	0.984	0.882	1.153
Ficus benghalensis L.	9.1	2.895	35.7	41.347	24.808	6.4501	31.258	15.629	57.358
Shorea robusta Gaertn.	3.82	1.215	29.2	14.196	8.517	2.214	10.731	5.365	19.691
Tamarindus indica L.	2.60	0.827	23.1	7.644	4.586	1.192	5.778	2.889	10.602
Tectona grandis L.	1.40	0.445	33.1	5.897	3.538	0.92005	4.458	2.229	8.180
Zizyphus jujubo Mill.	0.99	0.315	11.9	1.499	0.899	0.233	1.132	1.0155	3.726
Total CO_2 sequestration potential									**134.643**

Table-5. Characteristics of trees that are associated with their ability to sequester CO_2 in Mahatama Gandhi Avenue

Name of the plant	GBH (in meter)	Diameter (in meter)	Height (in meter)	T_{BV} (meter^3)	AGB (in kg)	BGB (in kg)	TB (in kg)	Carbon Storage (in kg)	Carbon di-oxide sequestration potential (in kg)
Acacia auriculiformis A. Cunn ex Benth.	4.1	1.304	15.3	7.980	4.788	1.244	6.024	3.012	11.054
Alstonia scholaris (L.) R.Br.	2.79	0.887	39.1	13.884	8.330	2.1659	10.495	5.247	19.259
Aegle marmelos (L.) Correa	1.58	0.502	12	2.413	1.447	0.376	1.823	0.911	3.345
Albizzia lebbeck (L.) Willd	2.85	0.906	18.3	6.63	3.982	1.035	5.017	2.5085	9.206
Bauhinia purpurea L.	0.82	0.360	11.9	1.241	0.745	0.193	0.938	0.469	1.721
Ficus benghalensis L.	10.5	3.3409	30.9	41.293	24.776	6.441	31.217	15.608	57.283
Shorea robusta Gaertn.	4.00	1.272	30.5	15.527	6.2109	3.726	0.9689	4.694	17.2302
Tamarindus indica L.	1.85	0.588	24.9	5.862	3.517	0.914	4.431	2.2155	8.1308
Tectona grandis L.	1.55	0.4931	25.9	5.109	3.065	0.797	3.862	1.931	7.0867
Zizyphus jujuba Mill.	0.79	0.251	5.6	0.563	0.337	0.08762	0.424	0.212	0.7791
Total CO_2 sequestration potential									**135.093**

Angadpur, Muchipara, the Durgapur Government College Campus, Mahatama Gandhi Avenue, and City Center had the highest total Carbon Sequestration Potential. The greatest capacity for sequestering CO_2 is possessed by trees such as *Shorea robusta* Gaertn. and *Ficus benghalensis* L. The mean values of NO_2, SO_2, PM_{10}, and Carbon Sequestration Potential have a significant relationship ($p = 9.89E\text{-}12$; $p < 0.05$). The carbon sequestration potential of various tree species is significantly correlated with their diameter at breast height

Table-6. Characteristics of trees that are associated with their ability to sequester CO_2 in Durgapur Government College Campus

Name of the plant	GBH (in meter)	Diameter (in meter)	Height (in meter)	T_{BV} (meter^3)	AGB (in kg)	BGB (in kg)	TB (in kg)	Carbon Storage (in kg)	Carbon di-oxide sequestration potential (in kg)
Acacia auriculiformis A. Cunn ex Benth.	3.5	1.413	25.8	11.492	6.8956	1.7928	8.6884	4.3442	15.943
Alstonia scholaris (L.) R.Br.	3.82	1.215	29.3	14.245	8.5470	2.222	10.769	5.3845	19.761
Aegle marmelos (L.) Correa	1.49	0.4740	11.9	2.256	1.353	0.351	1.704	1.528	1.997
Albizzia lebbeck (L.) Willd.	1.78	0.566	27.6	6.252	3.751	0.975	4.726	2.363	8.672
Bauhinia purpurea L.	0.77	0.245	7.9	0.7742	0.464	0.120	0.584	0.292	1.0716
Ficus benghalensis L.	8.6	2.736	36.9	40.383	24.230	6.299	30.529	15.264	56.022
Shorea robusta Gaertn.	3.40	1.081	30.3	13.101	7.861	2.043	9.904	4.952	18.175
Tamarindus indica L.	2.25	0.715	20.7	5.9277	3.5566	0.9247	4.48	2.24	8.2208
Tectona grandis L.	1.02	0.324	29.7	3.855	2.313	0.6014	2.9144	1.4572	5.347
Zizyphus jujuba Mill.	0.56	0.1781	8.6	0.6129	0.3677	0.0956	0.4633	0.23165	0.8501
Total CO_2 sequestration potential									**136.058**

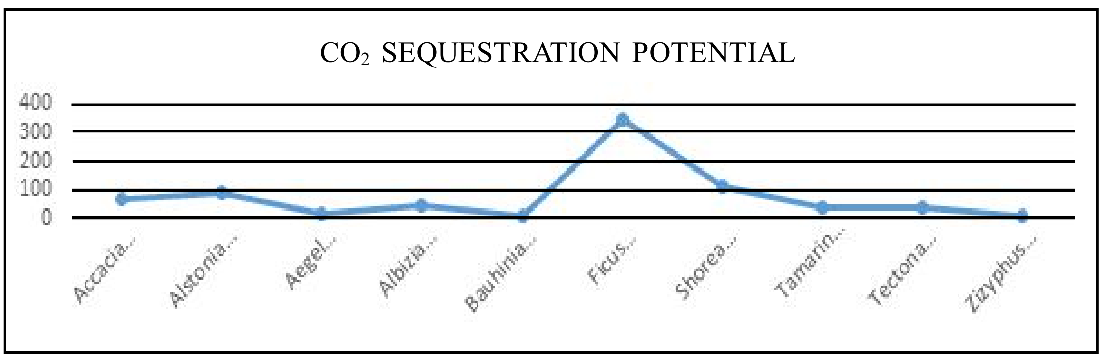

Figure 2. Showing graph of CO_2 sequestration potential of different tree species

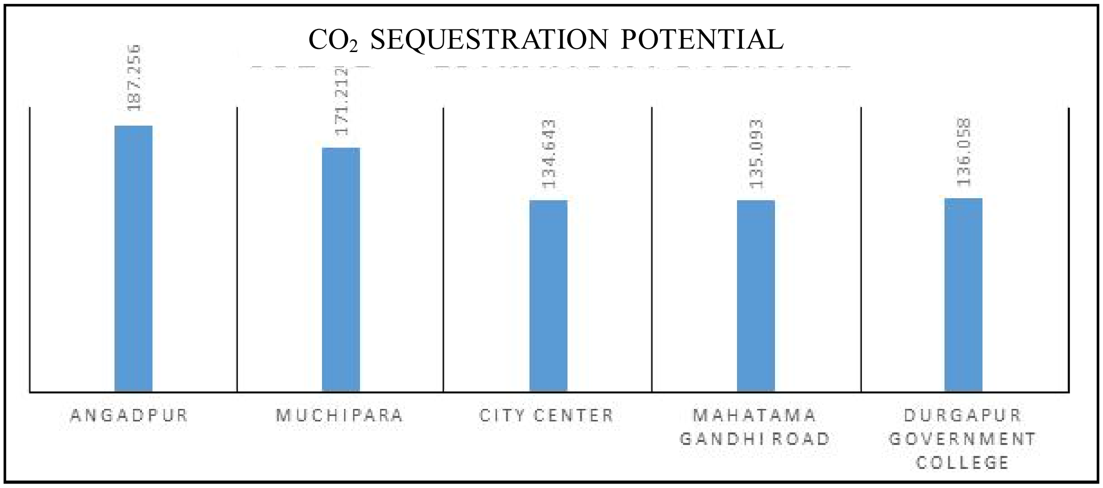

Figure 3. Showing graph of total CO_2 sequestration potential of trees at different sites

Table-7. Correlation between diameter at breast height and CO_2 sequestration potential of different tree species

Name of tree species	Correlation coefficient value
Acacia auriculiformis A. Cunn ex Benth	0.469937
Alstonia scholaris (L.) R.Br.	0.474994
Aegle marmelous (L.) Correa	0.319638
Albizia lebbeck (L.) Willd.	0.456409487
Bauhinia purpurea L.	0.863809
Ficus benghalensis L.	0.969242943
Shorea robusta Gaertn.	0.888583
Tamarindus indica L.	0.884401
Tectona grandis L	0.730959
Zizyphus jujuba Mill.	0.778985

Table-8. Mean of NO_2, SO_2 and PM_{10} at different sites in 2022

Site	Mean of NO_2	Mean of SO_2	Mean of PM_{10}
ANGADPUR	33.472	11.517	143.232
MUCHIPARA	33.218	11.303	142.25
CITY CENTER	33.055	11.285	140.035
MAHATAMA GANDHI ROAD	33.018	11.071	140.035
DURGAPUR GOVERNMENT COLLEGE	29.781	10.625	117.785

Table-9. Anova - Variation between mean of NO_2, SO_2, PM_{10} and CO_2 sequestration potential at different sites

Anova: Single Factor

Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
CO_2 Sequestration Potential	5	764.262	152.8524	612.4283
Mean of NO_2	5	162.544	32.5088	2.357308
Mean of SO_2	5	55.801	11.1602	0.114417
Mean of PM_{10}	5	683.337	136.6674	113.3715

ANOVA

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	77347.56	3	25782.52	141.6094	9.89E-12	3.238872
Within Groups	2913.086	16	182.0679			
Total	80260.65	19				

(DBH). Additionally, all tree species with a diameter at breast height (DBH) of greater than or equal to 30 cm were found to have a high potential for sequestering CO_2. *Ficus benghalensis* L. and *Shorea robusta* Gaertn. were shown to have the highest capacity for sequestering carbon among the ten common tree species.

The current study uses a non-destructive sampling technique to assess the potential for carbon sequestration of 10 chosen tree species on air pollution, with a focus on the five sites in Durgapur, Paschim Burdwan, West Bengal. According to the average yearly readings of NO_2, SO_2, and PM_{10} in the cities of Durgapur, Muchipara, City Center, Mahatama Gandhi Avenue, and Durgapur Government College Campus, Angadpur has the highest levels of air pollution, followed by these locations. All five locations had the highest concentration of PM_{10}, with NO_2 and SO_2 following closely behind. The areas of Angadpur, Muchipara, the Durgapur Government College Campus, Mahatama Gandhi Avenue, and City Center had the highest total Carbon Sequestration Potential. The greatest capacity for sequestering CO_2 is possessed by trees such as *Shorea robusta* Gaertn. and *Ficus benghalensis* L. The mean values of NO_2, SO_2, PM_{10}, and Carbon Sequestration Potential have a significant relationship ($p = 9.89E\text{-}12$; $p < 0.05$).

The carbon sequestration potential of various tree species is significantly correlated with their diameter at breast height (DBH). Additionally, all tree species with a diameter at breast height (DBH) $\geq$ 30 cm were found to have a high potential for sequestering CO_2. *Ficus benghalensis* L. and *Shorea robusta* Gaertn. were shown to have the highest capacity for sequestering carbon among the ten common tree species. As a result, they may be suggested for afforestation projects in the polluted area in order to reduce air pollution levels.

References :

1. Bernstein, J., A. Neil, C.H. Barnes, L. Bernstein, J. Bernstein, A. Neil, D. Peden, S.D. Diaz, S. Tarlo, and B. Williams (2004) *Environmental and Occupational Respiratory Disorders. 114*(5): 1116-1123.
2. Biodiversity and Environment, World Air Pollution Report 2021 - 24.03.2022, https://www.drishtiias.com
3. Bohre, P., O.P. Chaubey, and P.K. Singhal, (2012). Biomass Accumulation and Carbon Sequestration in Dalbergia sissoo Roxb. *International Journal of Bio-Science and Bio-Technology* (3): 29-44.
4. CPCB (2003) *Guidelines for Ambient Air Quality Monitoring; Central Pollution Control Board*, Ministry of Environment Forests and Climate Change, Government of India, New Delhi, India.
5. CPCB (2020) *Impact of Lockdowns 25th March to 15th April on Air Quality*.
6. Das, Moumita. and Ambarish Mukherjee, (2015) *Indian J. Sci. Res. 10*(1): 53-57, 2015 ISSN: 2250-0138
7. FAO (2019) Measuring and modelling soil carbon stocks and stock changes in livestock production systems. Guidelines for assessment (Version 1). Livestock Environmental Assessment and Performance (LEAP) Partnership. Rome, FAO. 170 pp. Licence: CC BY-NC-SA 3.0 IGO
8. Feyisa, Gudina, Legese., Henrik Meilby, Darrel Jenerette, and Stephan Pauleit, (2016) *Remote Sensing of Environment. 175:* 14-31. DOI:10.1016/j.rse. 2015. 12.026
9. Grimm, N.B., S.H. Faeth, N.E. Golubiewski, C.L. Redman, J.G. Wu, X.M. Bai, and J.M. Briggs, (2008) *Science 319*(5864): 756-60. DOI:10.1126/science.1150195
10. Guttikunda, Sarath., and K.A. Nishadh, (2022) *Environ. Sci.: Atmos. 2:* 1502-1515. DOI: 10.1039/D2EA00027J
11. Hangarge, L. M., D. K. Kulkarni, V. B. Gaikwad, D. M. Mahajan, and Nisha Chaudhari, (2012) *Annals of Biological Research. 7:* 3426-3429.
12. Horaginamani, S.M. and M. Ravichandran (2010). *Kathmandu University Journal of Science, Engineering and Technology. 6:* 13-19.
13. IPPC (2007) IPCC 4th assessment report. Intergovernmental Panel on Climate Change.
14. Karmakar, Dipti., Tirthankar Ghosh, and Padhy, Pratap Kumar (2019). *Ecological Indicators. 98 :* 377-388. https://doi.org/10.1016/j.ecolind.2018.11.014
15. Khan, Nahid., Jhariya, Manoj, Kumar., Yadav, Dhiraj, Kumar and Arnab Banerjee (2019) *Environmental Science and Pollution Research.* https://doi.org/10.1007/s11356-019-07182-8
16. López-López, Stephanie, Fabiola., Martínez-Trinidad, Tomás., Benavides-Meza, Héctor., Garcia-Nieto, Moises (2017). *Urban Forestry & Urban Greening. 24*(2): 62-70. DOI: 10.1016/j.ufug.2017.03.025
17. Mandal, Gautam., and Shambhu, Prasad Joshi (2014) *Journal of Asia-Pacific Biodiversity 7* (3): 292 -304, DOI:10.1016/j.japb.2014.07.006
18. Onyekwelu, C.J. (2004) *Biomass and Bioenergy, 26:* 39-46. https://doi.org/10.1016/S0961-9534(03)00100-4

19. Pandya, Ishan, Y., H. Salvi, O. Chahar, and N. Vaghela (2013) *Indian J. Sci. Res. 4*(1): 137-141. ISSN : 2250-0138
20. Pearson, T. R. H., S. Brown, and N. H. Ravindranath, (2005) Integrating carbon benefits estimates into GEF Projects. 1-56.
21. West Bengal Pollution Control Board, https://www.wbpcb.gov.in
22. The Times of India – After PM2.5 dip in 2020, Kolkata air now 29% more polluted than safe level - 20.01.2022, https://timesofindia.indiatimes.coms
23. Sharma, Richa., Lolita Pradhan, Maya Kumari and Prodyut Bhattacharya (2020). *Environ. Sci. Proc.* 2021, *3*(1): 52; https://doi.org/10.3390/IECF2020-08075
24. Sheikh, Mehraj, A., Munesh Kumar, Raine Bussman, and Wand, and N.P. Todaria, (2011). Carbon Balance and Management. doi.:10 .1186/1750-0680- 6-15.
25. Tiwari, S., M. Agrawal and F.M. Marshall (2006) Evaluation of ambient air pollution impact on carrot plants at a sub urban site using open chambers. Environmental Monitoring and Assessment. *119 :* 15-30.
26. Yuen, Jia, Qi., Tak Fung, Ziegler, and D. Alan (2017) Carbon stocks in bamboo ecosystems worldwide: Estimates and uncertainties. Forest Ecology and Management. Volume – 393, Pages 113-138.
27. Zanne, A. E., G. Lopez-Gonzalez, D. A. Coomes, J. llic, S. Jansen, S. L. Lewis, R.B. Miller, N.G. Swenson, M.C. Wiemann and J. Chave, (2009) *Ecology Letters, 12*(4): 351- 366.