International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

Sustainable Plantation and Carbon Sequestration by an Urban Forest: A Case Study of Estate at (Patlipada) Thane, Maharashtra, India

Tayade T Sandeep[1], Ansari K Hooma[2], Desai K Hanuman[3], Desai H Saurabh[4], Patil Balchandra[5], Dey M Seema[6]

[1, 2, 3, 4, 5, 6]Enviro Analyst and Engineers Pvt. Ltd.

Western Edge, B - 1003, Western Express Hwy, Near Food Corporation of India Warehouse, Borivali (East), Mumbai, Maharashtra 400066, India
[1]Corressponding Author Email: *sandeeptayade[at]gmail.com*

Abstract: ***Managing healthy forests within urban areas is an effort worth taking for the benefits it offers to the city dwellers. Degradation of urban forests can occur due to rapid urbanization, encroachment, depleting of natural areas, fragmentation and spread of invasive species. Decrease in tree cover due to infrastructure developmental projects is one of the major reasons for urban forest depletion. Decrease of urban tree cover due to infrastructure projects can affect terrestrial carbon sequestration potential of cities. The study was carried out at Estate (Thane) to estimate the carbon sequestration of tree species. Assessment of the carbon sequestration of urban forest was carried out through the biomass study with a quantification. It is found that total carbon sequestered by the total tree species (15, 317 count) is 10624.86 tones. The highest carbon sequestration was studied are multiple tree species and are significant components of Agro - forestry and urban plantation in the study region.***

Keywords: Carbon, Sequestration, Biomass, Agro – forestry

1. Introduction

Air pollution represents a prominent threat to society by causing cascading effects on individuals (Lim, 2018), medical systems (Yang & Zhang, 2018), the health of the ecosystem (Bell et al, 2011), and economies (Matus et al., 2012) in both developing and developed countries (Khaniabadi, et al, 2019; Fang et al., 2015; Bozkurt et al., 2018).

Continuous growth in the urban area, which is frequently disorderly, more serious the effects of climate change by increasing traffic congestion, environmental pollution, the formation of urban heat islands, and other issues that have detrimental effects on the physical and mental health of people (Hunt and Watkiss, 2011, Ng and Ren, 2018). As per World Health Organization (WHO) report, exposure to air pollutants is related with 4.2 million premature deaths per annum universal. Urban developing areas are centers of resource utilization and are a major contributor to air pollutants and greenhouse gas emissions (Karl et al., 2019; Qian et al., 2022).

The Sustainable Development Goals (SDG), adopted by the United Nations General Assembly in 2015, include sustainable cities and communities. The optimization of such objects should be a top management priority because they are interlinked with other goals, such as improving health and wellbeing, combating climate change, and reducing inequalities, and so on. Advantageous effects associated with the presence of trees in urban cities are highly valued by the population that seeks societies or areas near green spaces (Aramayo, 2012; Canales and Moreno, 2023). Based on the literature quoted, plant species can help to meet many goals as described in the UN SDGs as listed in **Table 1** (Tayade et al., 2022). Another important consideration is that not all plant species are equal. Some benefits may be more visible in specifically correlated species (Xiao and McPherson, 2016). Benefits differ within a plant species as well based on the morphological characteristics alongwith climatic conditions, can also play a prominent role. For example, a small internal road in a city, having a plant does not give the same benefits as a large plant does. Matured and old plant species can give the greatest benefits as compared to immature/growing plants (Lindenmayer and Laurance, 2017). The benefits of urban forests are related to the enhancement of pollution by reducing energy require or capturing gaseous with particulate matter. While some of the other benefits of an urban greenery are a result of the colour of the foliage, species, and other qualitative features, most of the benefits are related to plant size.

Table 1: Role of Trees Conforming UN Sustainable Development Goals

Conformity with SDGs	Benefits/Advantage of plants with references
• Goal 3: Good health and well - being, • Goal 11: Sustainable cities and communities, • Goal 16: Peace, justice, and strong institutions.	• Reduction in pollution levels (McDonald et al., 2016; Nowak et al., 2006; Nowak, et al., 2014; Nowak et al., 2018) • Enhancement in physical and mental capability (Berman et al., 2012, Li et al., 2018, Ulrich, 1984) • Support to improve community ties (Garrity, 2004; Morley et al., 2017) • Increase in physical activities (Kuo and Sullivan, 2001; Kuo, 2003; Bell et al.2008).

	• Decrease in violence and aggressiveness issues of health related (Mooney and Nicell, 1992) • Decrease in crime rate and misconduct behavior, (Donovan and Prestemon, 2012; Kuo, 1998)
• Goal 4: Quality education	• Improvement in student performance and attentiveness levels (Berman et al., 2008; Kuo et al., 2018; Browning et al., 2018) • Reduce stress levels for students (Kuo et al., 2018) • Decrease attention symptoms deficit disorder / attention deficit hyperactivity disorder in students (Rief, 2012; Faber et al., 2001) • Increase in attention and activeness with discipline manner (Kuo et al., 2018; Li and Sullivan, 2016; Matsuoka, 2010; Faber, et al., 2002)
• Goal 1: No poverty • Goal 2: Zero hunger • Goal 7: Affordable and clean energy • Goal 8: Decent work and economic growth • Goal 10: Reduced inequalities • Goal 12: Responsible consumption and production	• Return - on - investment if properly managed and applied (McPherson et al., 2010) • Support and maintain the tourist visits for attractions (Nesbitt et al., 2017) • Increase in land and home prices and rental rates also for farms lands (Nesbitt et al., 2017) • Decreases energy use and its bills (Nowak and Greenfield, 2018; Pandit and Laband, 2010) • Encourage food sustainability (to avoid damaging or wasting natural resources (Dawson et al., 2013; Clark and Nicholas, 2013) • Supply and demand for several resources (e. g. home building and firewood) (Turner, 2015; Kaoma and Shackleton, 2015; Poe et al., 2013; Sherrill, 2003; Favez et al., 2009)
• Goal 3: Good health and well - being • Goal 13: Climate action • Goal 15: Life on land	• Benefits in Urban Heat Island Effect (Patz et al., 2005; Ward et al., 2016; EPA, 2008; McDonald et al., 2016) • Assistance to store and sequester carbon and its management (Nowak and Crane 2002; Schwab, 2009) • Provide and rise in critical habitat in natural environment (Tyrvainen et al., 2005; Schwab, 2009; Fahey et al., 2015)
• Goal 3: Good health and well - being • Goal 6: Clean water and sanitation • Goal 9: Industry, innovation and infrastructure • Goal 11: Sustainable cities and communities • Goal 12: Responsible consumption and production • Goal 14: Life below water • Goal 15: Life on land	• Help to manage storm water (Berland et al., 2017; Braden and Johnston, 2004; Livesley et al., 2016) • Reduce and control the pollution levels (French et al., 2006; Schwab, 2009) • Safeguard life and protection under water and on land also (Hauer and Johnson, 2003)

Increase in the climatic crisis for the preceding years, the significant role of forest areas in carbon sequestration has been broadly documented (He et al.2018; Tzamtzis and Ganatsas 2020; Girona et al.2023a), which is derived from atmospheric carbon di oxide, absorbed by forest plant species with photosynthesis process as well as accumulation of carbon components in the various ecosystem pools. As per previous estimates, forests store approximately eighty percent of the total biosphere's biomass, and more than sixty percent of the global biomass is almost stored in wooden matters (Fazan et al.2020). It is also stated that if an appropriate management system was followed and implemented, then, the forests could absorb more carbon emissions as estimated (Nabuurs et al.2017; Girona et al.2023b). It is also concluded that forest sector in European region, absorbs approximately ten percent of the total anthropogenic carbon di oxides emissions (Janssens et al.2003).

Present study aims to assess the advantages of the urban tree area in Estate of Thane city and to describe the viability and significance of evaluating key components for the ecosystem services reduced or purified by green zone (vegetation), such as improved air quality, pollutant reduction, carbon storage, and sequestration, explicating the contribution of main tree group of species.

2. Material and Method

The study was carried out in Estate (township) located at Pathlipada village in Thane City of Maharashtra (India) as shown in **Figure 1**. The Township is well designed and planned to accommodate a luxury way of life, these residences are designed to seamlessly blend with the choices of high - class facilities. Estate township covers an area of ____ acre. The whole area surveyed, with a diversity of groups of plant species, densities, and distribution of trees. The survey was made for tree only, with respect to the height, age, and DBH. The location of the study area is shown in **Figure 1**.

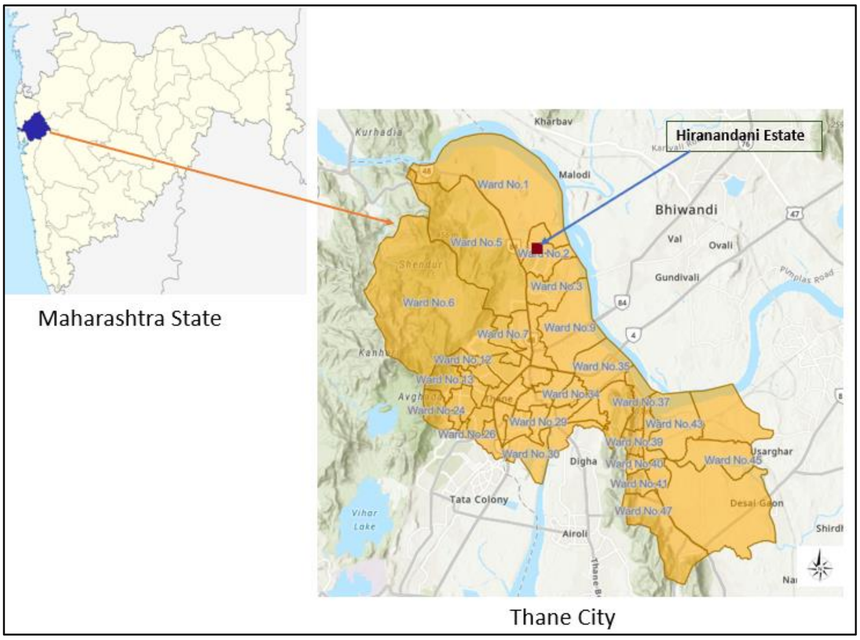

Figure 1: Map of Study Area and the Green Spaces Examined

To estimate biomass from tree species, it is not advisable to cut them. The biomass can be measured by mathematical models by measuring Height using altimeter/laser distance meter directly and the girth at GBH. In each tree, GBH (Girth at Breast Height) of each individual tree species was measured at 1.37 m from the ground level using measuring tape (Sinha et al., 2016). GBH was converted to DBH (Diameter at Breast Height) by dividing the value of GBH with 3.14 (Sinha and Sharma, 2013). Using the tree DBH and height information, the tree volumes were estimated via volumetric equations (FSI, 1996) and biomass were calculated after multiplying each tree volume (FRI, 1996). These individual biomass values were added to compute the individual biomass. Age of the tree taken as per discussion with gardeners and staffs of the respective sections.

The aboveground biomass (AGB) was calculated by multiplying volume of biomass and wood density, the volume was calculated based on diameter (Pandya et al., 2013). The wood density value for the species obtained from web (www.worldagroforestry. org) and AGB is calculated using the formula as:

AGB (g) = volume of biomass (cu cm) *wood density (g/cu cm)

The belowground biomass (BGB) was calculated by multiplying above ground biomass taking 0.26 as the root shoot ratio (Chavan and Rasal, 2011; Hangarge et al., 2012). Total Biomass (TB) is calculated using by summing the above and below ground biomass the total biomass was calculated (Sheikh et al.2011). Carbon storage is measured usually, for any plant species fifty percent of its biomass is recorded as carbon (Pearson et al., 2005). Carbon Sequestration is calculated by multiplying factor of 3.67 to get the carbon dioxide (CO_2) as one ton carbon is equal to 3.67 tons of CO_2 (C=12 and O =16; CO_2= 12+16+16=44, 44/12=3.67) (Kumar et al, 2009; Jasmin and Birundha, 2011; Jindal et al., 2007).

3. Results and Discussions

The carbon sequestration capacity of a tree species depends upon its age, height, girth size, biomass accumulation capacity, canopy diameter, and most importantly based on the wood specific density.

The data collected for all 15, 317 number of tree species only, consists of 36 families along with common names are mentioned in **Table 2**. Arecaceae family found to be highest percentage (16.35%) among 36 families within the study area as shown in **Figure 2.0**.

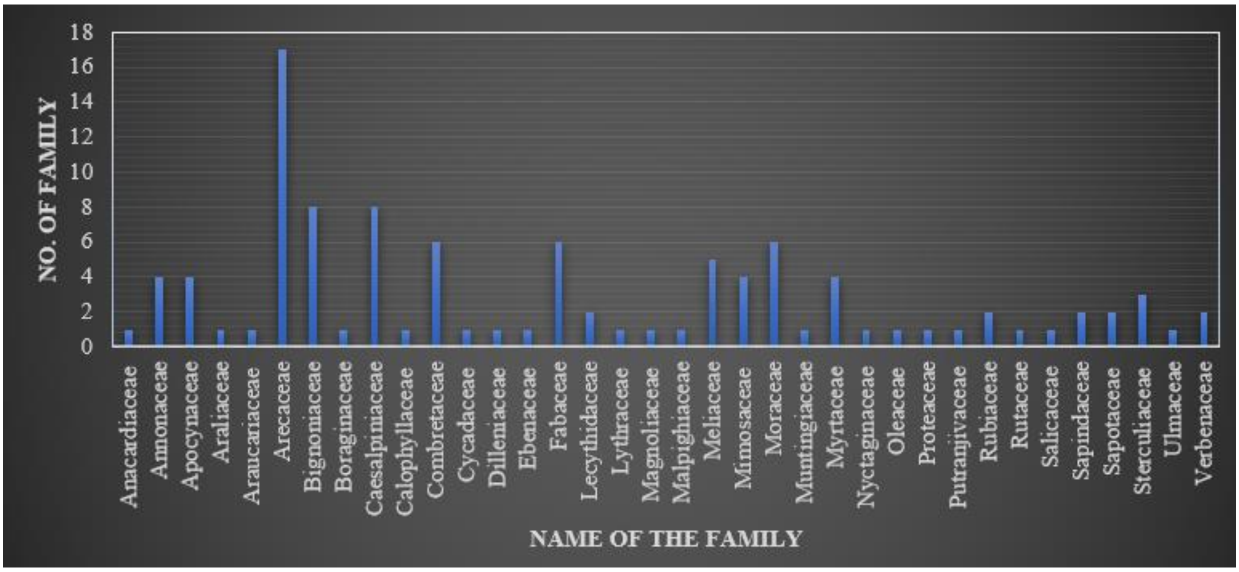

Figure 2: Distribution of Families with Highest Occurrence within the Study Area

The present study estimated the carbon sequestration for 104 tree species (15, 317 total count) belonging to 36 families (**Table 3**). *Ficus religiosa* has sequestered 4.79 tons/tree of CO_2 which is highest compared to other tree species from the study area follow by the *Madhuca indica* (4.70 tons/tree). **Figure 3** shows the highest CO2 sequestrated tree species within the study area. Tree count was found to be highest for *Swietenia macrophylla* (1035 nos.), followed by *Lagerstroemia speciose* (1000 nos.), *Bauhinia purpurea* (711 nos.), *Alstonia scholaris* (696 nos.), *Neolamarckia cadamba* (594 nos.), *Mimusops elengi* (558 nos.), *Syzygium cumini* (541 nos.), *Ficus benjamina* (532 nos.), and *Cassia fistula* (508 nos.) respectively. Tree count also affects the carbon sequestration of the plant species. Based on the tree count, the total carbon sequestration estimated highest for *Swietenia macrophylla*, followed by *Mangifera indica*, *Mimusops elengi*, *Madhuca indica*, *Neolamarckia cadamba*, *Syzygium cumini*, *Couroupita guianensis*, *Alstonia scholaris* and so on as shown in **Table 2** and **Figure 4** respectively. Maximum biomass storage is observed in the tree species of *Ficus religiosa*, *Madhuca indica*, *Ficus benghalensis*, *Samanea saman*, *Couroupita guianensis*, *Ficus racemosa*, *Mangifera indica*, *Terminalia arjuna*, *Tamarindus indica*, *Terminalia bellirica*, *Nyctanthes arbor - tristis*, and so on. Such tree species can be suggested for plantations. It is estimated that for 15, 317 trees, the total carbon sequestration is 10624.86 ton within the study area. Healthy trees more than seventy - seven cm in diameter capture approximately ninety times more carbon as compared to small trees which have diameter less than eight cm. Healthy trees also store approximately 1000 times maximum carbon than smaller trees (Nowak, 1994).

Table 2: Details of the Biomass alongwith CO_2 Sequestrated by Tree Species

Tree Species	Common Name/Local	Tree Count	Total Biomass (kg)	CO_2 Sequestrated tons/tree	Total CO_2 Sequestrated for all plant (tons/tree)
Ficus religiosa	Peepal	44	2615.21	4.79	210.58
Madhuca indica	Indian butter tree	110	2567.75	4.70	516.89
Ficus benghalensis	Banyan tree	20	2167.78	3.97	79.34
Samanea saman	Rain tree	138	1369.60	2.51	345.88
Couroupita guianensis	Cannon ball tree	162	1257.87	2.30	372.91
Ficus racemosa	Cluster fig	141	1043.71	1.91	269.31
Mangifera indica	Mango	441	873.97	1.60	705.32
Terminalia arjuna	Arjun tree	17	780.40	1.43	24.28
Tamarindus indica	Tamarind	13	722.59	1.32	17.19
Terminalia bellirica	Belliric myrobalan	130	674.42	1.23	160.44
Nyctanthes arbor - tristis	Har singar	61	668.19	1.22	74.59
Swietenia macrophylla	Big - leaf mahogany	1035	657.08	1.20	1244.54
Putranjiva roxburghii	Putranjiva	239	615.65	1.13	269.27
Terminalia elliptica	Indian laurel	48	589.93	1.08	51.82
Pithecellobium dulce	Manilla tamarind	96	557.49	1.02	97.94
Mimusops elengi	Spanish cherry	558	538.70	0.99	550.09
Terminalia catappa	Indian almond	33	520.27	0.95	31.42
Tabebuia aurea	Caribbean trumpet tree	41	519.37	0.95	38.97
Terminalia mantaly	Umbrella tree	167	512.73	0.94	156.70
Peltophorum africanum	African wattle	30	490.93	0.90	26.95
Pongamia pinnata	Indian beech tree	115	487.68	0.89	102.63
Peltophorum pterocarpum	Copper pod	34	466.12	0.85	29.00
Schleichera oleosa	Ceylon oak	146	466.04	0.85	124.52
Dalbergia sissoo	Indian rosewood	50	463.99	0.85	42.46

Tree Species	Common Name/Local	Tree Count	Total Biomass (kg)	CO_2 Sequestrated tons/tree	Total CO_2 Sequestrated for all plant (tons/tree)
Tectona grandis	Teak	45	452.59	0.83	37.27
Brownea coccinea	West indian mountain rose	28	447.47	0.82	22.93
Wodyetia bifurcata	Foxtail palm	177	437.36	0.80	141.67
Tabebuia heterophylla	Pink trumpet tree	65	412.52	0.75	49.07
Syzygium cumini	Java plum	541	405.89	0.74	401.84
Neolamarckia cadamba	Kadam	594	391.12	0.72	425.16
Acacia auriculiformis	Earleaf acacia	143	390.79	0.72	102.27
Millingtonia hortensis	Indian cork tree	417	372.38	0.68	284.17
Tabebuia rosea	Pink trumpet tree	276	370.57	0.68	187.17
Ficus benjamina	Weeping fig	532	369.17	0.68	359.41
Tabebuia pentandra	Midday yellow trumpet	13	364.47	0.67	8.67
Metroxylon sagu	Sago palm	12	350.45	0.64	7.70
Caryota mitis	Clustered fish - tail palm	23	339.00	0.62	14.27
Markhamia lutea	Markhamia, siala	55	338.03	0.62	34.02
Cocos nucifera	Coconut tree	161	321.87	0.59	94.83
Acacia mangium	Hickory wattle	21	320.27	0.59	12.31
Artocarpus heterophyllus	Jackfruit tree	266	312.03	0.57	151.89
Ficus virens	White fig	22	307.16	0.56	12.37
Albizia lebbeck	Siris tree	259	304.72	0.56	144.43
Gmelina arborea	Gamhar	96	295.40	0.54	51.90
Alstonia scholaris	Scholar tree	696	289.60	0.53	368.86
Populus nigra	Black poplar	16	285.65	0.52	8.36
Conocarpus erectus	Buttonwood mangrove	44	279.42	0.51	22.50
Melaleuca alternifolia	Tea tree	14	279.29	0.51	7.16
Adenanthera pavonina	Red bead tree	129	277.16	0.51	65.43
Holoptelea integrifolia	Indian elm	96	276.87	0.51	48.64
Grevillea robusta	Southern silky oak	10	275.54	0.50	5.04
Phoenix sylvestris	Wild date palm	19	271.81	0.50	9.45
Lophanthera lactescens	Golden chain tree	17	271.20	0.50	8.44
Araucaria columnaris	Cook - pine	25	265.75	0.49	12.16
Khaya senegalensis	African mahogany	341	260.56	0.48	162.60
Saraca indica	Malaysian ashok	21	259.53	0.47	9.97
Pterospermum acerifolium	Kanak champa	24	258.84	0.47	11.37
Spathodea campanulata	African tulip tree	113	256.37	0.47	53.01
Diospyros malabarica	Gaub, Indian persimmon	26	255.58	0.47	12.16
Melaleuca viminalis	Weeping Bottle brush	28	254.31	0.47	13.03
Aegle marmelos	Wood apple	17	253.52	0.46	7.89
Kleinhovia hospita	Guest tree	49	244.59	0.45	21.93
Melia azedarach	Chinaberry tree	73	236.27	0.43	31.56
Cycas revoluta	Sago palm	30	234.99	0.43	12.90
Azadirachta indica	Neem	216	231.13	0.42	91.36
Sapindus mukorossi	Soap nut	14	227.30	0.42	5.82
Monoon longifolium	Mini ashoka	56	226.56	0.41	23.22
Calophyllum inophyllum	Alexandrian laurel	37	223.46	0.41	15.13
Barringtonia asiatica	Sea poison tree	77	220.07	0.40	31.01
Pterygota alata	Buddha coconut	50	216.78	0.40	19.84
Pritchardia pacifica	Fiji fan palm	27	209.75	0.38	10.36
Livistona chinensis	Chinese fan palm	18	209.04	0.38	6.89
Bauhinia purpurea	Purple orchid tree	711	208.24	0.38	270.94
Roystonea regia	Royal palm	74	195.31	0.36	26.45
Lagerstroemia speciosa	Pride of India	1000	194.35	0.36	355.67
Delonix regia	Gulmohar	18	194.11	0.36	6.39
Cassia fistula	Indian laburnum	508	191.84	0.35	178.34
Ptychosperma macarthurii	Macarthur palm	29	183.53	0.34	9.74
Cordia sebestena	Scarlet cordia	117	176.96	0.32	37.89
Bismarckia nobilis	Bismarck palm	39	169.29	0.31	12.08
Plumeria rubra	Frangipani	313	167.80	0.31	96.12
Annona reticulata	Netted custard apple	19	167.05	0.31	5.81
Plumeria obtusa	White frangipani	68	162.76	0.30	20.25
Anonna squamosa	Sugar apple	14	162.52	0.30	4.16
Senna siamea	Siamese senna	166	159.14	0.29	48.34
Chukrasia tabularis	Chittagong wood	25	158.90	0.29	7.27
Dillenia indica	Elephant apple	16	156.78	0.29	4.59
Ravenea rivularis	Majestic palm	35	148.44	0.27	9.51
Dictyosperma album	Hurricane palm	10	140.41	0.26	2.57

Tree Species	Common Name/Local	Tree Count	Total Biomass (kg)	CO_2 Sequestrated tons/tree	Total CO_2 Sequestrated for all plant (tons/tree)
Michelia champaca	Golden champa	302	130.26	0.24	71.99
Cananga odorata	Ylang ylang	25	125.88	0.23	5.76
Adonidia merrillii	Manila palm	497	117.97	0.22	107.30
Millettia ovalifolia	Moulmein rosewood	31	105.31	0.19	5.97
Dypsis lutescens	Golden cane palm	24	97.51	0.18	4.28
Oroxylum indicum	Broken bones tree	22	93.61	0.17	3.77
Psidium guajava	Guava	243	90.20	0.17	40.11
Muntingia calabura	Jamaica cherry	63	80.98	0.15	9.34
Areca catechu	Betel palm	436	64.20	0.12	51.23
Hyophorbe lagenicaulis	Bottle palm	21	58.23	0.11	2.24
Ceodes umbellifera	Lettuce tree	255	52.85	0.10	24.66
Plumeria singaporensis	Petite pink	34	36.57	0.07	2.28
Gardenia latifolia	Indian boxwood	246	31.60	0.06	14.23
Heptapleurum actinophyllum	Octopus tree	45	31.46	0.06	2.59
Licuala spinosa	Mangrove fan palms	13	23.11	0.04	0.55

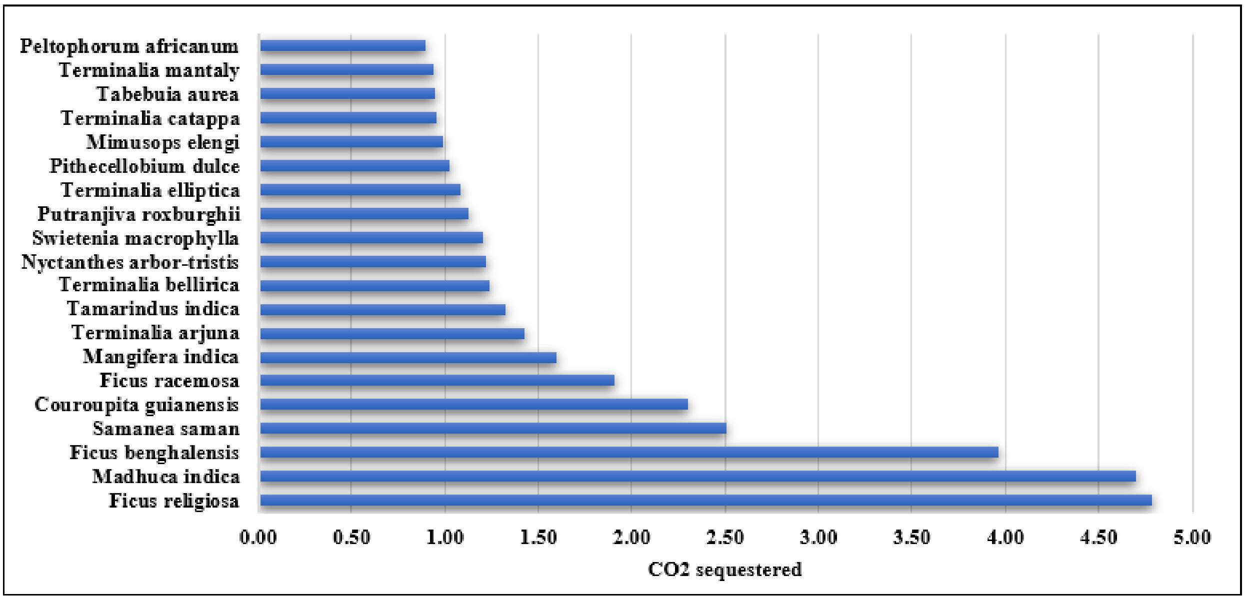

Figure 3: Highest Carbon Sequestered by the First Twenty Tree Species within the Study Area

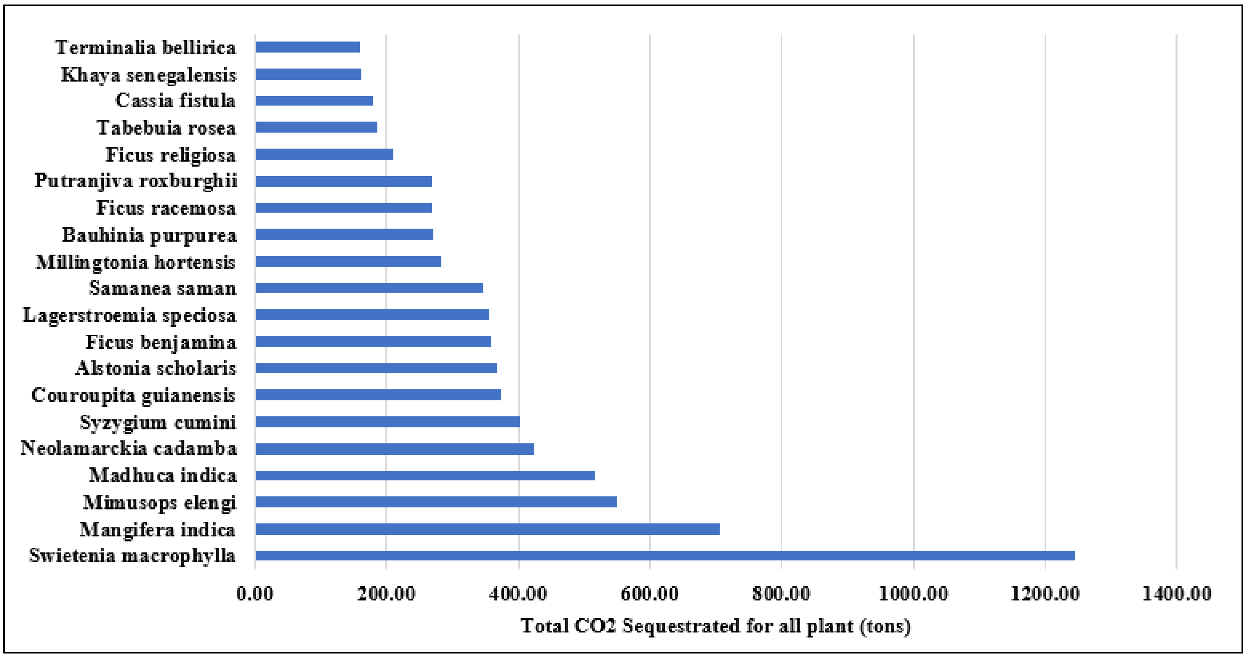

Figure 4: Highest Carbon Sequestered for First Twenty Tree Species within the Study Area

Regression Analyses

The linear regression showed that there was a significant positive relation between the tree DBH and CO_2 sequestration. The correlation coefficient (R) equals 0.8648. This means that there is a strong positive correlation between DBH (Y) and CO_2 (X) sequestrated. The coefficient of determination (R2) equals 0.7478. This means that 74.7847% of the variation in the dependent variable (x) is explained by the independent variable (Y). The slope of the regression line $b1$ equals 0.0618. This means that for every one unit increase in the independent variable (Y), the dependent variable (x) is expected to increase by 0.0618 units. Figure 5 shows the estimated regression graph DBH (cm) verses CO_2 sequestration.

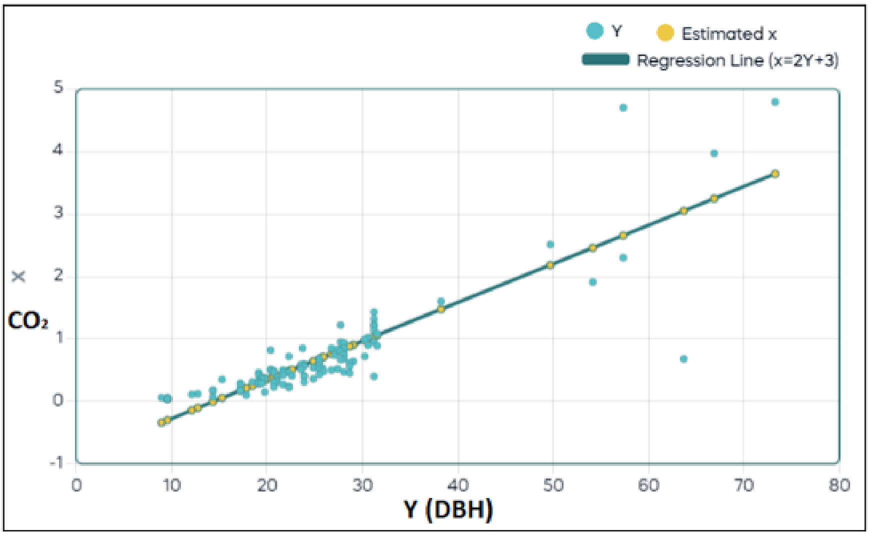

Figure 5: Estimated Regression Graph for DBH (cm) verses CO_2 sequestration

4. Conclusion

The carbon dioxide sequestration and carbon storage capability of 15, 317 tree count belonging to (104 nos.) tree species were assessed. Wood densities were referred from World Agroforestry Centre for the measurement of above ground biomass. Based on the estimation of carbon sequestration, tree species such as *Ficus religiosa, Madhuca indica*, *Ficus benghalensis*, *Samanea saman*, *Couroupita guianensis*, *Ficus racemosa*, *Mangifera indica*, *Terminalia arjuna*, *Tamarindus indica*, *Terminalia bellirica*, are recommended for urban area during the planning stage. Of course, native tree species is also highly suggested. The urban trees of the city also proved to be a highly beneficial component for reducing greenhouse effect gases, once again showing the contribution of urban forests in the fight against the effects of climate change. If such green cover areas are planned and developed by the urban local bodies or gated communities, then tremendous amount of carbon will be sequestrated by tree species. The present study strongly confirms the goal set by COP26, the 2021 United Nations Climate Change Conference in Glasgow, for recognizing the importance of restoring forest ecosystems to deliver crucial services, including acting as sinks and reservoirs of greenhouse gases.

Along with carbon capture, trees are economically benefit after certain age of growth. They add to the beauty of the area, increases avifaunal activities and green value as well. It helps to keep landscapes vegetated, soil hydrated and control the soil erosion for plants to grow.

Declaration

This manuscript has not been published anywhere and is an original research work. Authors acknowledge the institute for supporting to conduct the present work.

References

[1] Nowak, D. J., Urban biodiversity and climate change. In: Muller, N., Werner, P., Kelcey, J. G. (Eds.), Urban Biodiversity and Design. Wiley - Blackwell Publishing, Hoboken, NJ, pp.101 - 117.2010

[2] Jindal R, Kerr J, Nagar S, 2007. Voluntary carbon Trading: Potential for community forestry projects in India, Asia - Pacific development Journal, 14 (2): 107 - 226.

[3] Jasmin SKS and Birundha VD, 2011. Adaptation to climate change through forest carbon sequestration in Tamilnadu, India, International Journal of Research in Commerce & Management, 1 (8): 36 - 40.

[4] Kumar S, Rosenfield AH, Kapoor R, Mahajan K, Bajpai A and Verma N, 2009. Tables to convert energy (kWh) or CO2 (saved or used) to Familiar equivalents - cars, homes or power plants (India Average plants (India Average Data), ECO - III project, pp.1 - 4

[5] Pearson TRH Brown S and Ravindranath N H.2005. Integrating carbon benefits estimates into GEF projects.1 - 56.

[6] Sheikh MA, Kumar MB, Wand TNP (2011). Forest carbon stocks and fluxes in physiographic zones of India. Carbon Balance and Management, 6 (15): 1186 - 1750.

[7] Hangarge LM, Kulkarni DK, Gaikwad VB, Mahajan DM and Chaudhari N (2012). Carbon Sequestration potential of tree species in Somjaichi Rai (Sacred

grove) at Nandghur village, in Bhor region of Pune District, Maharashtra State, India. Annals of Biological Research, 3 (7): 3426 - 3429.

[8] Chavan BL and Rasal GB (2011). Sequestered Carbon Potential and Status of Eucalyptus Tree. International Journal of Applied Engineering and Technology, 1 (1): 41 - 47.

[9] Pandya IY, Salvi H, Chahar O, Vaghela N (2013) Quantitative Analysis on Carbon Storage of 25 Valuable Tree Species of Gujarat, Incredible India. Indian J. Sci. Res., 4 (1): 137 - 141.

[10] FRI 1996 Indian Woods; Forest Research Institute, Dehradun.

[11] FSI 1996 Volume equations for forests of India, Nepal and Bhutan; Forest Survey of India, Ministry of Environment and Forests, Govt. of India, Dehradun.

[12] Sinha S, C Jeganathan, L K Sharma, M S Nathawat, Anup K Das and Shiv Mohan, 2016, Developing synergy regression models with space - borne ALOS PALSAR and Landsat TM sensors for retrieving tropical forest biomass, J. Earth Syst. Sci., 125, No.4, June 2016, pp.725–735

[13] Sinha S and Sharma L K 2013 Investigations on potential relationship between biomass and surface temperature using thermal remote sensing over tropical deciduous forests; Research & Reviews: J. Space Sci. Technol.2 (3) 13–18.

[14] Janssens IA, Freibauer A, Ciais P, Smith P, Nabuurs G - J, Folberth G, Schlamadinger B, Hutjes RWA, Ceulemans R, Schulze E - D, Valentini R, Dolman AJ (2003) Europe's terrestrial biosphere absorbs 7 to 12% of European anthropogenic CO2 emissions. Science 300: 1538–1542

[15] Girona MM, Moussaoui L, Morin H, Thifault N, Leduc A, Raymond P et al (2023b) Innovative silviculture to achieve sustainable forest management in boreal forests: lessons from two large - scale experiments. In: Boreal Forests in the face of climate change: sustainable management. Springer International Publishing, Cham, pp 417–440

[16] Nabuurs GJ, Delacote P, Ellison D, Hanewinkel M, Hetemäki L, Lindner M (2017) By 2050 the mitigation efects of EU forests could nearly double through climate smart forestry. Forests 8: 484

[17] Fazan L, Song YG, Kozlowski G (2020) The woody planet: from past triumph to manmade decline. Plants 9: 1593.

[18] He H, Zhang C, Zhao X, Fousseni F, Wang J, Dai H et al (2018) Allometric biomass equations for 12 tree species in coniferous and broadleaved mixed forests, Northeastern China. PloS One 13 (1): e0186226. https: //doi. org/10.1371/journal. pone.0186226

[19] Tzamtzis I, Ganatsas P (2020) Land use, land - use change and their efect on greenhouse gas emissions and removals from Greek forests. Int J Glob Warm 22 (1).

[20] Girona MM, Morin H, Gauthier S, Bergeron Y (2023a) Boreal forests in the face of climate change: sustainable management. Springer Nature, p 837

[21] Tayade Sandeep, Rakesh Kumar, Chandrakant Singh, G Murali Achary, Sanjay Deshmukh, Swapnil Thanekar, SUSTAINABLE PLANTATION FOR RECLAMATION OF MUNICIPAL SOLID WASTE DISPOSAL SITE: A CASE STUDY Journal of Wastes and Biomass Management (JWBM) 4 (1) (2022) 08 - 13

[22] Hauer, R. J., Johnson, G. R., 2003. Tree risk management. In J. D. Pokorny (Ed.), Urban tree risk management: A community guide to program design and implementation (pp.5–10). St Paul, Minnesota: USDA Forest Service, Northeastern Area, State and Private Forestry.

[23] French, C. J., Dickinson, N. M., Putwain, P. D., 2006. Woody biomass phytoremediation of contaminated brownfield land. Environmental Pollution, 141 (3), Pp.387 - 395. https: //doi. org/10.1016/j. envpol.2005.08.065

[24] Livesley, S. J., McPherson, G. M., Calfapietra, C., 2016. The urban forest and ecosystem services: Impacts on urban water, heat, and pollution cycles at the tree, street, and city scale. Journal of Environmental Quality, 45 (1), Pp.119 - 124.

[25] Braden, J. B., Johnston, D. M., 2004. Downstream economic benefits from storm - water management. Journal of Water Resources Planning and Management, 130 (6), Pp.498–505.

[26] Berland, A., Shiflett, S. A., Shuster, W. D., Garmestani, A. S., Goddard, H. C., Herrmann, D. L., Hopton, M. E., 2017. The role of trees in urban stormwater management. Landscape and Urban Planning, 162, Pp.167–177. https: //doi. org/10.1016/j. landurbplan.2017.02.017

[27] Faber Taylor, A., Kuo, F. E., Sullivan, W. C., 2002. Views of nature and self - discipline: Evidence from inner city children. Journal of Environmental Psychology, 22, Pp.49 - 63.

[28] Tyrväinen, L., Pauleit, S., Seeland, K., De Vries, S., 2005. Chapter 4: Benefits and uses of urban forests and trees. In C. C. Konijnendijk, K. Nilsson, T. B. Randrup, & S. J. Heidelberg (Eds.), Urban forests and trees: A reference book (pp.81–114). New York: Springer - Verlag.

[29] Schwab, J., 2009. Planning the urban forest: Ecology, economy, and community development. Chicago, IL: American Planning Association.

[30] Nowak, D. J., Crane, D. E., 2002. Carbon storage and sequestration by urban trees in the USA. Environmental Pollution, 116 (3), Pp.381 - 389.

[31] McDonald, R., Kroeger, T., Boucher, T., Longzhu, W., Salem, R., Adams, J., Garg, S., 2016. Planting healthy air: a global analysis of the role of urban trees in addressing particulate matter pollution and extreme heat. The Nature Conservancy, 9, Pp.1 - 12.

[32] Environmental Protection Agency., 2008. Reducing urban heat islands: Compendium of strategies. Draft. U. S. Environmental Protection Agency.

[33] Ward, K., Lauf, S., Kleinschmit, B., Endlicher, W., 2016. Heat waves and urban heat islands in Europe: A review of relevant drivers. Science of the Total Environment, 569–570, Pp.527–539.

[34] Patz, J. A., Campbell - Lendrum, D., Holloway, T., Foley, J. A., 2005. Impact of regional climate change on human health. Nature, 438 (7066), Pp.310 - 317.

[35] Favez, O., Cachier, H., Sciare, J., Sarda - Estève, R., Martinon, L., 2009. Evidence for a significant contribution of wood burning aerosols to PM2.5 during

the winter season in Paris, France. Atmospheric Environment, 43 (22–23), Pp.3640 - 3644.
[36] Sherrill, S., 2003. Harvesting urban timber: A guide to making better use of urban trees. Fresno, CA: Linden Publishing.
[37] Poe, M. R., McLain, R. J., Emery, M., Hurley, P. T., 2013. Urban forest justice and the rights to wild foods, medicines, and materials in the city. Human Ecology, 41 (3), Pp.409 - 422.
[38] Kaoma, H., Shackleton, C. M., 2015. The direct - use value of urban tree non - timber forest products to household income in poorer suburbs in South African towns. Forest Policy and Economics, 61, Pp.104 - 112.
[39] Turner, J. B., 2015. The root of sustainability: Investigating the relationship between medicinal plant conservation and surface mining in Appalachia. PhD diss., West Virginia University, Morgantown, WV.
[40] Clark, K. H., Nicholas, K. A., 2013. Introducing urban food forestry: A multifunctional approach to increase food security and provide ecosystem services. Landscape Ecology, 28 (9), Pp.1649 - 1669.
[41] Dawson, I. K., Place, F., Torquebiau, E., Malézieux, E., Iiyama, M., Sileshi, G. W., Jamnadass, R., 2013. Agroforestry, food, and nutritional security. In: United Nations Food and Agriculture Organization.
[42] Pandit, R., Laband, D. N., 2010. Energy savings from tree shade. Ecological Economics, 69 (6), Pp.1324 - 1329.
[43] Nowak, D. J., and Greenfield, E. J., 2018. US urban forest statistics, values, and projections. Journal of Forestry, 116 (2), Pp.164 - 177.
[44] Nesbitt, L., Hotte, N., Barron, S., Cowan, J., Sheppard, S. R. J., 2017. The social and economic value of cultural ecosystem services provided by urban forests in North America: A review and suggestions for future research. Urban Forestry and Urban Greening, 25, Pp.103 - 111.
[45] McPherson, E. G., van Doorn, N., de Goede, J., 2016. Structure, function, and value of street trees in California, USA. Urban Forestry and Urban Greening, 17 (1), Pp.104 - 115.
[46] Faber Taylor, A., Kuo, F. E., Sullivan, W. C., 2002. Views of nature and self - discipline: Evidence from inner city children. Journal of Environmental Psychology, 22, Pp.49 - 63.
[47] Matsuoka, R. H., 2010. Student performance and high school landscapes: Examining the links. Landscape and Urban Planning, 97 (4), Pp.273 - 282.
[48] Li, D., Sullivan, W. C., 2016. Impact of views to school landscapes on recovery from stress and mental fatigue. Landscape and Urban Planning, 148, Pp.149–158.
[49] Faber Taylor, A., Kuo, F. E., Sullivan, W. C., 2002. Views of nature and self - discipline: Evidence from inner city children. Journal of Environmental Psychology, 22, Pp.49 - 63.
[50] Rief, S. F., 2012. How to reach and teach children with ADD / ADHD: Practical techniques, strategies, and interventions. San Francisco, CA: John Wiley & Sons.
[51] Browning, M. H. E. M., Kuo, M., Sachdeva, S., Lee, K., Westphal, L., 2018. Might school performance grow on trees? Examining the link between ‘greenness’ and academic achievement in urban, high - poverty schools. Frontiers in Psychology, 25, Pp.1669.
[52] Kuo, M., Browning, M. H. E. M., Penner, M. L., 2018. Do lessons in nature boost subsequent classroom engagement? Refuelling students in flight. Frontiers in Psychology, 8, Pp.2253.
[53] Berman, M. G., Jonides, J., Kaplan, S., 2008. The cognitive benefits of interacting with nature. Psychological Science, 19 (12), Pp.1207 - 1212.
[54] Donovan, G. H., Prestemon, J. P., 2012. The effect of trees on crime in Portland, Oregon. Environment and Behavior, 44 (1), Pp.3 - 30.
[55] Mooney, P., Nicell, P. L., 1992. The importance of exterior environment for Alzheimer residents: Effective care and risk management. Healthcare Management Forum, 5 (2), Pp.23 - 29.
[56] Bell, J. F., Wilson, J. S., Liu, G. C., 2008. Neighborhood greenness and 2 - year changes in body mass index of children and youth. American Journal of Preventive Medicine, 35 (6), Pp.547 - 553.
[57] Kuo, F. E., 2003. Social aspects of urban forestry: The role of arboriculture in a healthy social ecology. Journal of Arboriculture, 29 (3), Pp.148 - 155.
[58] Kuo, F. E., Bacaicoa, M., Sullivan, W. C., 1998. Transforming inner - city landscapes: Trees, sense of safety, and preference. Environment and Behavior, 30 (1), Pp.28 - 59.
[59] Morley, A., Farrier, A., Dooris, M., 2017. Propagating success? The Incredible Edible Model Final Report. Manchester Metropolitan University and the University of Central Lancashire. Retrieved Kuo from https: //www.incredibleedible. org. uk/wp - content/uploads/2018/06/Propagating - success - the - incredibleedible - model - Final - report. pdf
[60] Garrity, D. P., 2004. Agroforestry and the achievement of the Millennium Development Goals. Agroforestry Systems, 61 (1 - 3), Pp.5 - 17.
[61] Ulrich, R. S., 1984. View through a window may influence recovery from surgery. Science, 224, Pp.420 - 421.
[62] Li, D., Deal, B., Zhou, X., Slavenas, M., Sullivan, W. C., 2018. Moving beyond the neighborhood: Daily exposure to nature and adolescents' mood. Landscape and Urban Planning, 173, Pp.33 - 43.
[63] Berman, M. G., Kross, E., Krpan, K. M., Askren, M. K., Burson, A., Deldin, P. J., Jonides, J., 2012. Interacting with nature improves cognition and affect for individuals with depression. Journal of Affective Disorders, 140 (3), PP.300 - 305.
[64] Nowak, D. J., Hirabayashi, S., Bodine, A., Greenfield, E., 2014. Tree and forest effects on air quality and human health in the United States. Environmental Pollution, 193, Pp.119 - 129.
[65] Nowak, D. J., and Greenfield, E. J., 2018. US urban forest statistics, values, and projections. Journal of Forestry, 116 (2), Pp.164 - 177.
[66] Nowak, D. J., Crane, D. E., Stevens, J. C., 2006. Air pollution removal by urban trees and shrubs in the United States. Urban Forestry and Urban Greening, 4, Pp.115 - 123.
[67] McDonald, R., Kroeger, T., Boucher, T., Longzhu, W., Salem, R., Adams, J., Garg, S., 2016. Planting healthy air: a global analysis of the role of urban trees in

Paper ID: ES24613120806 DOI: https://dx.doi.org/10.21275/ES24613120806

addressing particulate matter pollution and extreme heat. The Nature Conservancy, 9, Pp.1 - 12.
[68] Lindenmayer, D. B., Laurance, W. F., 2017. The ecology, distribution, conservation, and management of large old trees. Biological Reviews of the Cambridge Philosophical Society, 92 (3), PP.1434 - 1458.
[69] Aramayo, A., 2012. Percepcion ´ de la contaminacion ´ atmosf´erica en Lima: contraste entre la avenida Abancay y El Olivar de San Isidro. Rev. del Inst. Investig. la Fac. Ing. Geologica, ´ Minera. Metal. y Geografica ´ 15, 131–140.
[70] Canales, J., Moreno, R., 2023. Indicadores de sostenibilidad urbana y procesos migratorios internacionales en ciudades intermedias: la vivienda y el espacio público en dos zonas urbanas de Temuco. Chile. Urbe. Rev. Bras. Gest˜ao Urbana 15, 1–16.
[71] Qian, Y., Chakraborty, T. C., Li, J., Li, D., He, C., Sarangi, C., Chen, F., Yang, X., and Leung, L. R.: Urbanization Impact on Regional Climate and Extreme Weather: Current Understanding, Uncertainties, and Future Research Directions, Adv. Atmos. Sci., 819–860, https: //doi. org/10.1007/s00376 - 021 - 1371 - 9, 2022.
[72] Karl, T., Gohm, A., Rotach, M. W., Ward, H. C., Graus, M., Cede, A., Wohlfahrt, G., Hammerle, A., Haid, M., Tiefengraber, M., Lamprecht, C., Vergeiner, J., Kreuter, A., Wagner, J., and Staudinger, M.: Studying Urban Climate and Air Quality in the Alps: The Innsbruck Atmospheric Observatory, B. Am. Meteorol. Soc., 101, E488–E507, https: //doi. org/10.1175/bams - d - 19 - 0270.1, 2019
[73] A. Hunt, P. Watkiss, Climate change impacts and adaptation in cities: A review of the literature, Clim. Change, 104 (2011), pp.13 - 49,
[74] E. Ng, and C. Ren, China's adaptation to climate & urban climatic changes: A critical review, Urban Clim., 23 (2018), pp.352 - 372,
[75] Matus, K. et al. Health damages from air pollution in China. Glob. Environ. Change 22 (1), 55–66 (2012).
[76] Bell, J. N. B., Power, S. A., Jarraud, N., Agrawal, M. & Davies, C. The effects of air pollution on urban ecosystems and agriculture. Int. J. Sust. Dev. World 18 (3), 226–235 (2011).
[77] Yang, J. & Zhang, B. Air pollution and healthcare expenditure: implication for the benefit of air pollution control in China. Environ. Int.120, 443–455 (2018).
[78] Khaniabadi, Y. O. et al. Mortality and morbidity due to ambient air pollution in Iran. Clin. Epidemiol. Glob. Health 7 (2), 222–227 (2019).
[79] Fang, C., Liu, H., Li, G., Sun, D. & Miao, Z. Estimating the impact of urbanization on air quality in China using spatial regression models. Sustainability 7 (11), 15570–15592 (2015).
[80] Bozkurt, Z., Üzmez, Ö. Ö., Döğeroğlu, T., Artun, G. & Gaga, E. O. Atmospheric concentrations of SO2, NO2, ozone and VOCs in Düzce, Turkey using passive air samplers: sources, spatial and seasonal variations and health risk estimation. Atmos. Pollut. Res.9 (6), 1146–1156 (2018).
[81] Lim, C. C. et al. Association between long - term exposure to ambient air pollution and diabetes mortality in the US. Environ. Res.165, 330–336 (2018).