Above Ground Carbon sequestration potential in Urban green spaces of Lahore, Pakistan

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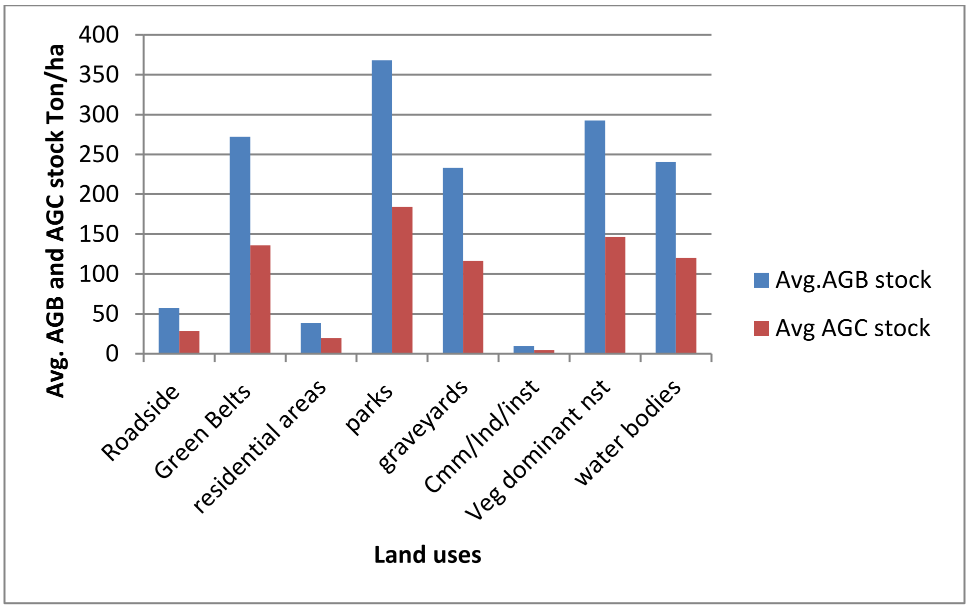
Abstract

Most people believe that cities are the world's largest source of carbon dioxide emissions. Meanwhile, UGSs offer important ecosystem services and function as carbon sinks by absorbing carbon into their biomass. This study aims to evaluate the urban tree canopy and determineWith the increasing levels of carbon dioxide emissions in cities, it is vital to evaluate the potential for above-ground carbon storage in urban green spaces (UGS) so that these areas can mitigate these emissions. Both both private and public land in Lahore city were analysed to identify nine main land cover classifications. The structure, biomass, and carbon reserves of urban green spaces were determined using stratified random sampling of the regions. In order to determine the potential carbon storage capacity of UGS, 200 plots were sampled. For tree vegetation, we employed allometric equations, and for understory vegetation, we used destructive sampling to determine the plant biomass carbon reservoir. At UGS, we discovered 42 distinct species of trees. The average stem density in urban trees was found to be 441 ha−1, the average basal area to be 31.46 m2 ha−1, and the average diameter to be 26.91 cm. When looking at stem density, base area, and relative frequency, Alstonia scholaris, Polyalthia longifolia, Acacia citriodora, Fibre religiosa, Azadirachta indica, and Cassia fistula received the highest Importance Value Index compared to other tree species. The vegetation above ground in Lahore's urban areas stores 5574.20 Gg of carbon. In general, trees retain an average of 94.46 (±0.63) MgC/ha, but shrubs and herbs store an average of 3.46 ±0.01 or 1.44±0.08 MgC/ha, respectively. Public green spaces and green belts, which are heavily forested and subject to little human interference, The study found that trees retain a higher amount of carbon than other kinds of green areas. Near homes, businesses, and industrial zones, as well as other development regions, green spaces often have lower carbon stocks. Carbon emissions have increased due to the expansion of Lahore's numerous industries. As a result of development, green spaces in urban areas management is receiving less attention. National while regional carbon budgets should incorporate UGS, and urban development should take them into consideration. Urban global warming policy can benefit from these results, which supplement global carbon budget databases.

Key words: Urban green spaces, carbon sequestration, urban tree structure, urban planning

Graphical Abstract



1. Introduction

Cities are home to half of the world's population, says the United Nations. In addition, by 2030, predictions indicate a 60% increase. According to Phdungsilp (2009). Because fossil fuels are so widely used, city dwellers may enjoy a high standard of living. Urban systems rely on fossil fuel combustion for energy, but this practice comes at a cost: massive emissions of carbon dioxide and other greenhouse gases that have far-reaching consequences for human health and ecological harmony (Dhakal, 2004). The most significant man-made greenhouse gas, carbon dioxide (CO2), has seen its concentration increase from 280 ppm during industrialisation to 400 parts per million in May 2013, which is precisely proportionate to the 0.8 °C increase in surface temperature worldwide (NOAA, 2013). Cities with good management have a chance to mitigate climate change in the long run.Fong et al. (2015) suggest that cities may do this by reducing emissions and adapting to climate change through innovative solutions that use their enormous human capital. As an example, in dry climates, people in urban areas often plant and care for shade trees, which results in a higher density of forest cover than in natural forests. However, this is not necessarily the case everywhere. Even urban woods, with careful design, may form unique patterns of carbon sequestration (Golubiewski, 2006). Ponds, lakes, and streams are all examples of small bodies of water; urban green spaces may also refer to any area of land covered with plant, regardless of its size or purpose. Neither the political nor the scientific communities pay much attention to these areas, even though they are crucial for the survival of urban life forms (Budruk and colleagues, 2009). It was found by Strohbach et al. (2012). For the purpose of valuing carbon storage in ecosystems and understanding carbon dynamics in light of climate change, precise estimations of plants mass et carbon stocks are essential (Brassard et colleagues, 2009). Urban green areas, such as parks, may have the potential to store carbon, according to new study.Using spatial analytic visualisation, Strohbach and Haas e (2012) assessed the outside carbon storage offered by urban trees in Leipzig and studied the effects of industrialisation on carbon stocks. Carbon retention was greatest at the medium degree of urbanisation, according to their findings. Nero et al. (2017) conducted research in Kumasi, Ghana, where they quantified and mapped the locations of UGS in carbon reservoirs above and below ground.It is evident that urban climate change strategies should involve UGS planning and management, as they discovered that various UGS had diverse effects on carbon stocks. Varying degrees of urbanisation, land use administration, green space age, size, or structure may cause UGS to reduce atmospheric carbon to varying degrees across countries. According to Jo (2002), several studies done at the local and regional levels can provide light on the role of UGS in reducing atmospheric C levels.The study's stated goals included determining the carbon storage capability of urban green areas and the structural and functional roles played by urban trees.

2. Methods

2.1. Study area

The 1,772 square kilometre (684 sq. mi.) flat alluvial plain that Lahore sits on along the bank of the Ravi River is where the city is located. This location may be found in the coordinates 31.554606 N latitude and 74.357158 E longitude. The Sheikhupura District forms its northern boundary, the Nankana Sahib District its western, the Kasur District its southern, and India its eastern neighbour (Mazhar and Jamal, a 2009).

The 2017 population census estimates 11,126,285 people living in Lahore.Temperatures between 40 and 48 Celsius degrees (104 and 118 degrees Fahrenheit) are typical in Lahore during the summer months of May, June, and July. The city also has uncommon dust storms and monsoons. In the province, considerable rainfall is seen during the monsoon season, which begins in late July and continues until August. The typical monthly relative humidity falls anywhere between 20% in May and 58% in August, with an average yearly relative humidity of 37.9%. According to Ashraf et al. (2013), the monsoon rains start in the final week of June and continue all the way till the end of September.Information Ganj Bakhsh town, Samarabad, Gulgerg, Shalimar, and Ravi are the five urban towns that make up Lahore. Aziz Bhatti, Nishter, Wahga, and the entire Allama Iqbal town are also considered to be part of Lahore's urban region. Circular roads encircle this city. The study concentrated on the portion of Lahore within the ring road, which included 561 km2.

2.2. Sampling design

We followed the instructions for stratified random sampling provided by Nowak et al. (2003) and divided the region into two main categories according to land use: public and private. Private lands comprise residential, commercial, and industrial buildings, whereas public lands include parks, water bodies, and vegetation along roadways and in institutional enclosures.

The number of sites in each stratum was directly proportionate to the amount of trees present in that region, and each of the 200 plots that were randomly selected had a quadrat size of 40 m x 10 m, as recommended by Yang et al. (2005).The study utilised a 5x5 m shrub quadrat and a 1x1 m herb quadrat (Salunkhea et al., 2014).

2.3. Importance Value Index (IVI) calculation

Derivative of density, basal area, or frequency of each reported species were used to compute the IVI of urban trees (Nguyen et al., 2014).

2.4. Collecting Data

A total of all woody plants measuring more than 2 cm in diameter were collected. Trees' diameters were measured at the height of the breasts using measuring tape. Each sampling plot has all of the trees identified to the species level.

2.4.1 Measurement of tree biomass

Measurement of tree biomass (sectionFor tropical and subtropical metropolitan environments, there is a lack of genus and site specific equations. The construction of these allometric models is a long process that involves damaging harvesting (Rahman et al., 2015).As a fallback, researchers from over the globe are turning to popular allometric formulas developed by tree-falling specialists in subtropical and tropical regions. Therefore, in order to estimate tree biomass, the allometric equations developed for populations of arid tropical forests by Chave was and colleagues (2005) were used. Carsan et al. (2012) cited the World Agroforestry Database as the source for tree-specific wood density statistics.The values of the biomass were multiplied by 0.8 to account for the fact that, when applied to urban areas, equations developed from forests often anticipate higher levels of above-ground biomass (Nowak and Crane, 2002).

2.4.2. Understory biomass measurement

The grasses, shrubs, and herbs were collected from the sample plots, and their fresh weight was measured in kilogrammes. The collected vegetation was then placed in a paper bag and appropriately labelled. The newly-collected samples were moved to the lab and left to dry for a couple of days at 720C.Arif et al. (201x) utilised the dry weight of the sample bags to calculate the biomass of the plant.

2.4.3. Determination of Vegetation C-Stocks

The carbon store of shrubs and trees may be calculated by multiplying biomass by an atmospheric transformation ratio of 0.5 [(USDA Forestry Items Lab (1952) Chang and Dodd (1989) Nowak et Crane (2002)].The carbon inventory for grasses and plants was calculated by multiplying their biomass with a carbon transformation value of 0.45 (Davis et al., 2011).

2.4.4.Analysing Statistics

In Microsoft Excel, we analysed the relative frequency, the density ratio, biomass, and carbon stock estimates statistically.

3. Results

3.1. The urban green space structure in Lahore:

The supervised classification method achieved a 75% overall accuracy rate when attempting to determine the land cover of a region.In Figure 1, you can see the results of the land cover evaluations conducted in the study region. The research region's land cover was analysed using the Landsat eight satellite photograph. The satellite view, however, does not reveal the layers of underbrush and plants, making it impossible to see the overlapped regions. Clearly, there is a lot of impermeable cover in the research area and very little vegetation, including trees, bushes, and herbs.It makes sense, considering that Lahore is a megacity that has undergone several stages of growth, resulting in a higher percentage of buildup areas in its urban zone.

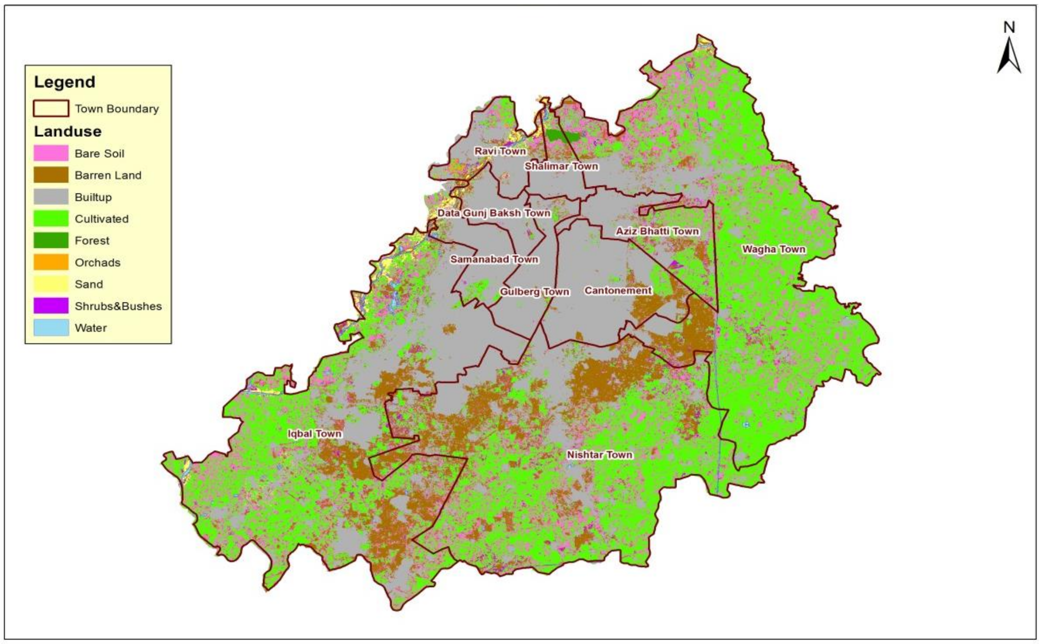


Figure 1 Land cover map of Lahore city

Due to the fact that majority of the plots are located in sensitive regions (e.g., home gardens) and therefore did not grant access or permission for sampling, only 200 out of 250 initially chosen plots were actually sampled. Parks, roadways, green belts, cemeteries, big institutional sites, and government offices are examples of publicly maintained territory with a higher tree density than smaller schools, offices, detached or semidetached dwellings, and other privately owned land. However, compared to unplanned residential areas, planned residential areas (i.e., housing societies) have a comparatively higher tree cover. While sampling did provide 42 different kinds of trees, this is insufficient to compare to Lahore's planted species due to the fact that part of the city was included in the sample.Alstonia scholaris, Polyalthia longifolia, Eucalyptus citriodora, Ficus religiosa, and Cassia fistula were the most prevalent tree species in the research region.On public spaces, you'll often see these native tree species planted to provide shade and improve the area's aesthetic appeal; on private property, though, you'll mostly see Polyalthia longifolia as well as Fucus Benjamina planted due to their relative ease of cultivation and rapid growth rate.

3.1.1. The Critical Mass of Urban Trees

The results of the 200 sample plots revealed the presence of 42 different species.When looking at stem density, basal location, and relative frequency, the most important species out of the 42 species of Alstonia scholaris were Polyalthia longifolia, Acacia citriodora, Fibre religiosa, Azadirachta indica, and Cassia fistula (Table 2). In Lahore's UGS, the most common families were Moraceae and Fabceae.

Table 1 Urban trees are valued according to their abundance, frequency, dominance, and significance in urban green spaces in Lahore, Pakistan. List according to importance value (from high to low)

Scientific name	RD	RF	Rdom	IVI
Alstonia scholaris	14.52	10.54	13.13	38.20
Polyalthia longifolia	20.54	5.43	1.18	27.15
Eucalyptus citriodora	4.54	4.15	15.76	24.45
Ficus religiosa	2.48	5.43	12.17	20.08
Azadirachta indica	5.86	7.35	6.25	19.46
Cassia fistula	5.28	5.11	5.04	15.43
Dalbergia sisso	3.05	5.75	6.05	14.85
Eugenia jambulana	4.46	5.11	4.78	14.35
Ficus bangalensis	1.57	2.88	7.37	11.81
Terminalia arjuna	2.81	4.79	4.13	11.73
Bombax malabaricum	1.40	3.19	6.94	11.54
Pongamia pinnata	2.64	2.56	3.33	8.53
Morus alba	1.90	4.15	2.05	8.10
Callistemon citrinus	2.89	2.24	0.75	5.88
Fucus benjamina	2.23	3.19	0.64	6.06
Manifera indica	2.89	1.92	0.28	5.09
Cordia gharaf	0.83	2.24	1.25	4.31
Moringa oleifera	1.98	1.28	1.14	4.40
Arecaceae	1.32	2.24	0.13	3.68
Achras spota	1.57	1.60	0.49	3.65
Heterophargama adenophyllum	1.49	0.96	1.05	3.49
Conucarpus lancifolius	1.24	0.96	1.28	3.47
Bauhinia purpurea	0.74	1.92	0.58	3.23

Nephelium litchi	2.06	0.64	0.41	3.11
Ficus lyrata	0.83	1.28	0.86	2.96
Utranjiva roxburghii	1.07	1.28	0.41	2.76
Bambusa spp.	1.24	0.64	0.72	2.59
Carica papaya	0.41	0.96	0.72	2.09
Citrus sinensis	1.07	0.64	0.20	1.92
Pterospermum acerifolium	0.41	0.96	0.32	1.69
Phylanthusemblica	0.66	0.96	0.05	1.67
Chukrasia tabularis	1.16	0.32	0.05	1.53
Sapindus makorossi	0.50	0.96	0.05	1.50
Acacia nilotica	0.33	0.96	0.08	1.37
Zizphus mauritiana	0.33	0.96	0.05	1.34
Ficus elastica	0.25	0.96	0.05	1.26
Ziziphu jojuba	0.50	0.64	0.05	1.19
Musa balbisiana,	0.17	0.96	0.01	1.13
Terminillia bellirica	0.33	0.64	0.05	1.02
Psidium guajava	0.17	0.64	0.05	0.86
Phoenix dactylifera	0.17	0.32	0.05	0.54
Plumeria rubera	0.17	0.32	0.05	0.54

3.1.2. Tree Density and Basal area of urban trees in public and private land uses

After comparing public and private lands, it was found that public lands had a higher tree density (441 tree/ha), basal area (31.46m2/ha), and diameter (26.91 cm). Similarly, private lands had a lower mean diameter as well as basal area.

Table 2 Stem density, basal area and diameter of urban trees across public and private land uses of Lahore Pakistan. Figures in parenthesis are standard errors.

Land uses	Density(ha)	Basal Area(m^2/ha)	Diameter(cm)
Public Lands	593(±4.27)	49.31(±0.31)	29.36(±0.14)

Private Lands	289(±1.29)	14.72(±0.10)	23.59581(±0.1)
Mean value	441(±1.5)	31.46(±0.5)	26.91(±0.12)

3.1.3. DBH Distribution of Tree species

Assuming that older trees, when grown according to the same conditions and with the same management plan, will have greater diameters, the diameter distribution indicated an age distribution.

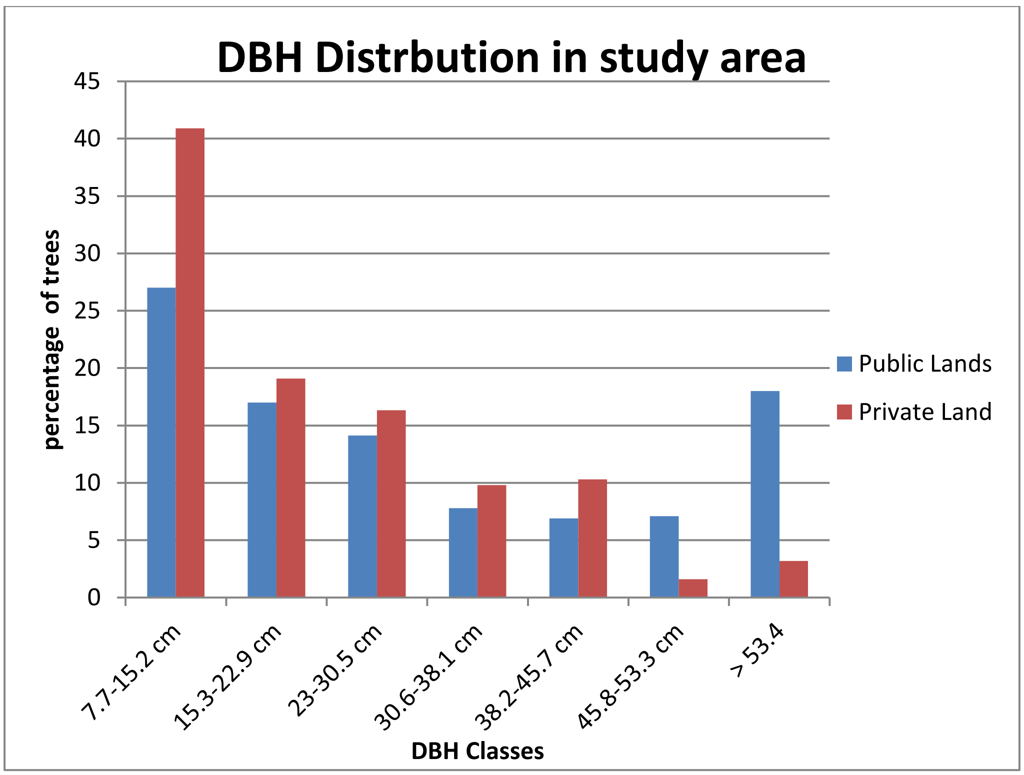


Figure 2 Distribution of trees by DBH classes for public and private land uses

The proportion of plants had a circumference at the breast (DBH) of more than 53.4 cm was greater on public lands than on private ones, and the plants themselves tend to be younger.

Biomass + carbon stocks in the upper storey (3.2)The AGB and AGC stocks of urban green spaces in Lahore were calculated using the allometric formulas for tropical dry forests given by Chave et al. (2005) using land use cover for estimate. The tree cover in these places is estimated to contain 5299.20 Gg C. The city's average carbon storage was 94.46(±0.63)MgC /ha, with values ranging from 4.36(±0.02) urban 184.13 (±1.5) MgC /ha. The regions with the highest levels of carbon storage were public parks, green belts as well, graveyards, and places next to bodies of water, whereas the areas with the lowest levels were very dense urban districts, commercial, industrial, and roadside.The table below displays the results broken down by land cover class.

Table 2 Mean Above ground carbon stored in urban trees across urban green spaces of Lahore, Pakistan.(Values in parenthesis are standard errors)

Sr No	Land cover classes	Mean AGC stock by trees (MgC/ha)
1.	Public Parks	184.13 (±1.5)
2.	Green belts	136.09 (±1.01)
3.	Roadside vegetation	28.60(±0.61)
4.	Vegetation dominated institutional compounds	146.37.29(±0.81)
5.	Graveyards	116.66(±0.56)
6.	Residential area	19.42(±0.29)
7.	Industrial and Commercial units	4.36075(±0.02)
8.	Vegetation along water bodies	120.09(±1.07)
9.	Mean AGC storage	94.46(±0.63)

3.2.1. Under Storey Biomass and Carbon Stocks

Grass biomass was 0.65 (Mg ha-1), but undergrowth and shrubs had a maximum energy of 12.19 (Mg ha-1). Grasslands have an average biomass of 3.13 ± 0.01 Mg ha-1 and an average carbon stock of 1.44±0.08 MgC ha-1, whereas shrubs and thicket have an average biomass that varies between 6.92 ± 0.02 MgC ha-1 and an average carbon stock of 3.46 ± 0.01.

4. Conversation

Any area of land within an urban area that is vegetated in some way is considered an urban green space. Any kind of vegetation, whether on public or private property, and any size or purpose of water body, including ponds, lakes, and streams, can be included in this category (WHO, 2017).Finding out how much carbon is stored above ground in plants on different levels was the driving force for this study.Within the realm of carbon cycle research, cities were thought of as C-emissions' sources, whereas UGS were either disregarded or given minimal priority (Churkina, 2016).Urban green areas may store 5574.20 Gg of carbon and operate as a carbon sink, according to our study. A tree's age directly correlates to its diameter. Older trees have bigger trunk diameters. In contrast to public and private areas, the urban forest in Lahore contains trees of different ages, according to the results. In private grounds, younger trees made up the majority of the tree age structure, whereas older trees made up 45% of the tree age structure in public areas.

The average tree density across every property's uses was 441 trees per hectare, with public and private property having stem densities of 593 and 289 ha-1, respectively. There is a noticeable difference in tree density in relatively congested urban areas compared to private property. This is mostly due to space constraints, which prevent more trees from being planted there. Additionally, trees in Lahore are only planted in regulated and planned urban areas, such housing societies. There were 279 trees per hectare in Shenyang, China; 257 trees per hectare in the Ukhiya natural woods of the Cox's Bazar Forest Division; and 369 trees per hectare in the Bamu forest preserves of Cox's Bazar. There was a higher density of trees noted.While our 42-family record has more species than roadside plantations in Nigeria's southern zone (16 species), it is lower than records from Mexico City's neotropical a gradient of urbanisation (89 species) or a farm agricultural land in Bangladesh's southwestern region (146 species) (Kabir and Webb, a 2008, and Motiur et al., 2006). Soil fertility, weather, environmental variables, and plantation management techniques might all have a role in these variations. But to make cities greener, it's important to encourage people to plant different kinds of trees, so that parks and other green spaces are more diverse (Pataki et al., 2011). The Fabceae and Moraceae families did, in fact, predominate in the tree communities. Given the Importance Value Index The urban forest of Lahore is mostly composed of Alstonia scholaris, Polyalthia longifolia, Eucalyptus citriodora, Ficus religiosa, Azadirachta Indica, and Cassia fistula.In the city, trees sequester around 5574Gg of carbon dioxide, while herbs and shrubs provide further 1.44 Mg C/ha and 3.46 Mg C/ha, respectively. This result shows that trees store 94% of carbon dioxide, shrubs 3.8%, while herb 1.6%. This is in line with earlier study by Davis and colleagues (2011) , Bianco et al. (2017).Publicly maintained urban green areas, such as parks, natural belts, institutional complexes, and cemeteries, store more carbon than privately owned or operated ones. Rising urban populations and industrialisation have contributed to this inequality. People residing in overcrowded, unplanned housing sites reduce tree density and carbon storage capacity.Its above-ground plant carbon storage is equivalent to Leipzig, Germany's, despite the fact that the latter has 11 Mg ha-1 fewer greenhouse gases storage based on grassland caver classes. Storage capabilities vary between green urban areas and cemeteries close to Lahore (Table 2, area cover classes 1 vs 5) and the "urban forest" class in Leipzig, Germany (29.8 Magnesium C ha−1 vs 27.84 Mg C ha−1). The amount of carbon retained in industrial or business buildings (8.52 Mg C ha−1) was very comparable to that in Punjab and Leipzig, Germany (Table 2, ground cover category 7). Contrarily, low density "residential" zones in Leipzig, Germany, have a lower storage space (13.7 Mg C ha−1) than residential areas in Lahore.(Table 2's Class 6 land cover).

The average carbon reserves of urban trees in Lahore are below 239 MgC/ha, as compared to the city of Ghana.Compared to Lahore's land use values, which are presented in Table 2 for Land cover classes 1, 4, and 5, the carbon storage of Kamusai Ghana's public parks, cemeteries, and institutional compounds is significantly higher at 420 tC ha-1, 291.1 tC ha-1, and 228 tCha-1, respectively. This demonstrates that various nations may adhere to different concepts while planning and administering certain domains. Nevertheless, further case studies involving comparable land cover classifications are necessary to determine the consistency and underlying causes of these parallels and variations. The median carbon storage varies among three cities in three foreign nations.

While the carbon stores found in Lahore's urban green areas' above-ground plants are significant, they won't stay forever. It is essential to replenish the vegetation that is chopped down or killed in order to prevent the release of carbon back into the atmosphere (Nowak & al., 2002).

Because urban expansion typically results in tree loss, reforestation is necessary to preserve urban areas' existing carbon sinks (Rowntree and Nowak,1991).Increased tree planting in urban areas is necessary to slow the rate of carbon emissions, but only if trees are carefully selected and planted to last for many years (MacFarlane, 2009).Urban trees may experience stunted growth rates as a result of increasing air pollutants, heat stress, reduced root spacing, and a lack of water availability caused by densely populated areas and impermeable surfaces; thus, it is important to plan for future climate change scenarios when selecting tree species to plant (Willby and Perry 2006).A total of six species of trees—five native and one invasive—made up nearly half of Lahore's tree canopy. The beauty, medical benefits, and shade provided by native species make them an important part of the ecosystem. With the exception of Eucalyptus citriodora, which is not suited for urban environments due to its ability to lower water tables.

5. Conclusion

In order to reduce emissions of carbon dioxide (CO2) from cities, we looked at how urban trees are structured and how much carbon they can store in developing nations' parks and other green areas. Studies conducted on a national or regional level cannot ignore city-level estimates of carbon storage, since Lahore's potential to store a significant quantity of carbon within its UGS is evident. In urban areas, 94% of carbon sequestration came from urban trees and 6% from understory vegetation. Consequently, research on carbon storage should equally focus on both types of plants. Compared to privately owned property, publicly maintained areas had higher stem densities, basal areas, and diameters.

Greater care and less human intervention cause tree-dominated regions, such public parks or green belts, to store more carbon, which has a significant impact on carbon storage estimates. The carbon stocks of green spaces are lower in regions that are adjacent to development, such as residential, commercial, and industrial neighbourhoods. Consequently, tree-dominated green areas must be preserved and managed in order to maximise urban biological systems' advantages from the storage of carbon and other sustainable development initiatives. Along with this, towns might increase their carbon sequestration by planting trees and plants along streets and in abandoned spaces. Therefore, compared to low-density urban regions, dense-urban areas have a lower carbon storage density.

Urban carbon storage has received less attention in Pakistani research, but this study has the potential to fill a gap in the literature, inform urban policy, and strengthen the country's database of carbon storage estimates.

Interest disclosure

I have no disputes of interest to disclose. All ideas and opinions expressed in this post are solely those of the writers.

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