Assessing and Perceiving the Carbon Storage Potential of Urban Green Spaces to Improve Environmental Sustainability: A Case Study in Parks of Zhengzhou, China

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Abstract: Urban green spaces (UGSs) are vital for reducing atmospheric carbon dioxide (CO_2) concentrations and mitigating climate warming within cities. Enhancing the carbon storage efficiency of existing green spaces under the constraints of limited urban land has become a significant challenge for sustainable urban development. This study quantified the carbon storage (CS) of urban park green spaces in Zhengzhou using multi-source data and identified plant species with high CS potential. The results revealed that Zhengzhou's urban park green spaces store 126.88 Gg C, with a carbon storage density (CSD) of 5.2 kg C/m². Notable spatial heterogeneity in CS was observed, offering planners valuable insights into targeting areas that require improvement. Moreover, the dominant plant species in Zhengzhou's parks differ significantly from species with high CS potential. To address this, a list of high CS tree and shrub species, including *Paulownia fortunei, Salix babylonica, Lonicera japonica*, and *Pyracantha fortuneana,* is proposed. The results of this study provide critical information for landscape designers, supporting efforts to promote ecological balance, human well-being, and sustainable urban development.

Introduction

As one of the most populous countries in the world, China has experienced rapid urbanization since the reform and opening-up period. By 2018, China's total population had reached 1.4 billion, with 837 million people residing in urban areas. Urban residents accounted for 59% of the national population and 20% of the global population. Projections indicate that China's urban population will increase by an additional 255 million by 2050 (*World Urbanization Prospects*, 2019). This rapid urban population growth has been accompanied by a dramatic expansion of urban areas. From 1978 to 2017, the impervious surface area in China increased 13.6-fold, reaching 798,101 km² by 2018 (Gong et al., 2020; Li et al., 2020).

The rapid urbanization process, characterized by substantial population growth and changes to urban surfaces, has led to increased energy consumption and greenhouse gas emissions. CO_2 emissions are now widely recognized as the primary driver of global climate change. UGSs, as key natural components of urban ecosystems, play an essential role in mitigating CO_2 emissions from fossil fuel combustion and regulating the global carbon cycle (Sun et al., 2019). Through photosynthesis, vegetation absorbs atmospheric CO_2 and stores it in plant biomass, water bodies, and soil, thereby reducing atmospheric CO_2 concentrations (Russo et al., 2014). With appropriate and scientifically-informed planning, UGSs can not only help reduce carbon emissions but also enhance CS capacity significantly, while influencing the microclimate of surrounding areas (Zhang et al., 2024). However, the lack of sustainable development considerations in the early stages of urban planning has resulted in insufficient ecological quality of green spaces in many Chinese cities. Thus, a critical research focus is identifying effective strategies for renovating existing green spaces in space-constrained urban environments to maximize their CS potential.

Background and Literature Review

UGSs are the only natural carbon sinks within urban areas in China, and their carbon sequestration potential has been increasingly recognized. Research has shown the significant role that UGSs play in mitigating carbon emissions. For instance, McPherson et al. reported that the annual CS of UGSs in Sacramento, USA, was 23.8×10^4 t C, which accounted for 1.8% of the city's total carbon emissions (G. E. McPherson et al., 1994). Similarly, (Vaccari et al., 2013) found that UGSs in Florence, Italy, sequestered an amount of carbon equivalent to 6.2% of the city's direct carbon emissions.

In China, with the growing concern over climate change, there has been an increasing focus on studying the carbon sequestration capacity of UGSs. Yao found that in Xi'an's central urban area, the average aboveground carbon density of UGSs was 0.28 kg C m^{-2} (Z. Yao et al., 2015). Similarly, Sun estimated that Beijing's UGSs stored a total of 956.3 Gg of carbon, with an average aboveground carbon density of 0.78 kg C /m^2 in the central urban area (Sun et al., 2019).

As research progresses, urban parks, a key component of green spaces, have gained increasing attention for their role in carbon sequestration. In 2019, Hyun-Kil Jo et al. quantified the CS and sequestration capacity of urban parks in Seoul, South Korea, and found that the trees in these parks stored 222.3 k t of carbon and sequestered 20.2 k t annually, offsetting approximately 2.3% of the city's total gasoline-related carbon emissions each year (Jo et al., 2019). Similarly, Tammeorg et al. conducted carbon sink monitoring in Hyväntoivonpuisto Park in Helsinki, Finland, and proposed design strategies to enhance the park's carbon sequestration potential (Tammeorg et al., 2021). In Beijing, (Wang et al., 2021) demonstrated the feasibility of enhancing park carbon sequestration through plant design.

However, vegetation characteristics differ across regions, even within the same country. Therefore, conducting studies based on local park data and proposing tailored strategies is critical for optimizing the carbon sequestration potential of urban parks.

Goals and Objectives

During the early stages of China's rapid urban development, sustainable development considerations were largely overlooked. As a result, Zhengzhou, currently undergoing rapid urbanization, has been increasingly affected by extreme climate phenomena such as global warming and frequent urban flooding. Addressing these challenges necessitates enhancing the CS capacity of urban park green spaces, quantifying their existing CS potential, and proposing effective strategies for improvement.

This study focuses on 123 parks in Zhengzhou, the core city of the Central Plains Urban Agglomeration in China. By integrating remote sensing data, field surveys, and the i-Tree Eco model, the study aims to quantify the CS potential of urban parks in Zhengzhou and to recommend suitable plant species for improving carbon sequestration. Specifically, the objectives of this study are to:

1. Quantify the spatial distribution of carbon storage across urban parks in Zhengzhou;
2. Examine the variations in carbon storage capacities among different plant species; 3. Analyse the Strategies to enhance the carbon storage potential of urban parks.

4. Method and Data

Study Area: Zhengzhou (112°42′–114°14′ E, 34°16′–34°58′ N), located in central China, is a prominent example of rapid urbanization and serves as the core megacity of the Central Plains urban agglomeration. As the capital of Henan Province, Zhengzhou covers a total area of 7,567 km^2, including 130.58 km^2 of parkland, and had a resident population of approximately 12.742 million in 2021 (Zhengzhou Statistics Bureau, 2022). Over the past three decades, the city has undergone remarkable urban transformation, with urban construction land expanding by 346.57%, the population increasing by 226.19%, and the urbanization rate reaching 79.1% as of 2021 (Zhengzhou Statistics Bureau, 2022; ZZP, 2022). For this study, 123 parks were randomly selected as research sites (Figure 1). These parks are distributed across the central districts of Zhengzhou, including Jinshui, Erqi, Huiji, Zhongyuan, and Guancheng.

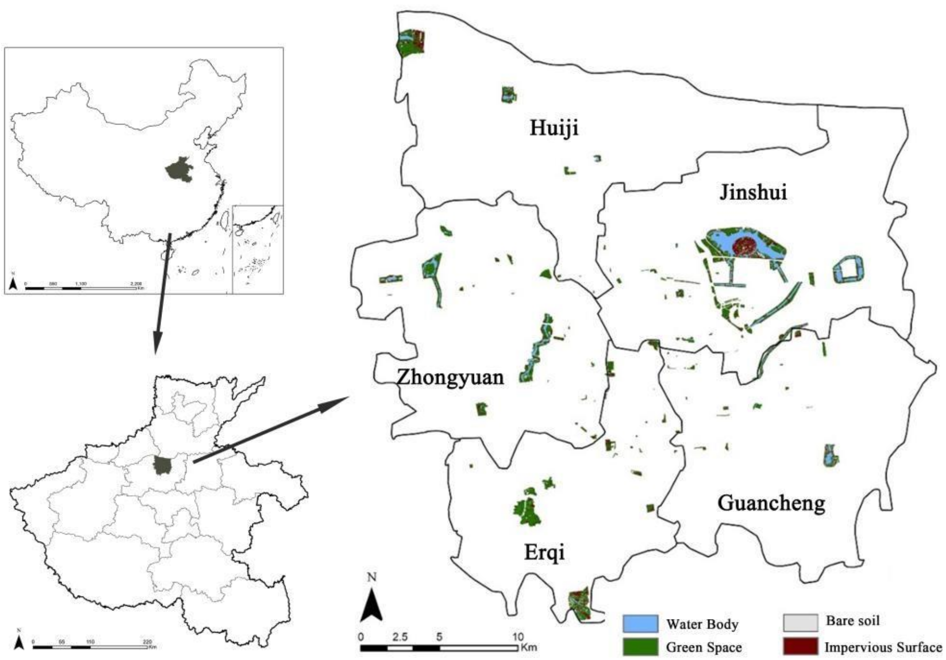

Figure 1. The study parks' location with a background map displaying land cover data in the Zhengzhou central zone.

Filed survey: This study selected 123 parks in the main urban area of Zhengzhou as research subjects based on their location, size, and level of development. The vector boundaries of these parks were manually delineated on the ArcGIS 10.2 platform using visual interpretation of 0.5meter resolution GF-2 remote sensing images, combined with Baidu Maps and field observations (Figure 1). Sampling locations within the parks were generated randomly, and the number of sampling plots per park was determined based on the park's area.

For the selected parks, random points were generated within the park boundaries using the "Create Random Points" tool in ArcGIS. Circular sampling plots with an approximate area of 400 m² were created around these points. The number of sampling plots in each park was determined by its size, with one plot set for every 2.5 hectares of park area. For parks smaller than 2.5 hectares, a single sampling plot was created, while larger parks were limited to a maximum of 25 sampling plots.

The field survey was conducted in July 2021, covering 805 sampling plots of 400 m² each. A total of 17,615 trees and 2,162 shrubs were measured. The survey content included:1) Trees: species, diameter at breast height (defined as the diameter of the trunk at 1.3 m above the ground), height , crown width ; 2) Shrubs: species, shrub height, shrub basal diameter, shrub crown width.

Remote sensing data: The remote sensing imagery used in this study was sourced from the Gaofen-2 (GF-2) satellite, which has a spatial resolution of 0.8 m × 0.8 m. Two GF-2 satellite images, acquired on May 25, 2017, and April 16, 2018, were used to extract land use information for the study area. After mosaicking and a series of preprocessing steps, the images were classified into four land use categories: vegetation, impervious surfaces, water bodies, and bare soil. Vegetation, which includes all vegetated areas, is referred to in this study as green space.To evaluate the accuracy of the classification results, a confusion matrix was used, achieving an overall accuracy of 89%, indicating reliable precision. To further refine the results, highresolution Google Earth imagery from 2022 was employed for manual visual corrections. This step was particularly important for minimizing classification errors in small parks and improving the precision of green space extraction (Figure 1).This combination of satellite imagery, classification techniques, and post-classification corrections ensures that the land use information extracted from the study area is both accurate and reliable for further analysis.

Carbon storage estimation: In this study, the carbon sequestration capacity of trees was estimated using the i-Tree Eco model, which applies species-specific allometric growth equations to calculate CS. These equations account for factors such as tree species, diameter at breast height (DBH), crown width, and crown missing rate (E. G. McPherson & Kotow, 2013; Nowak et al., 2013; Nyelele et al., 2019).When species-specific equations were unavailable, equations for species within the same genus or family were used, following a proximity principle. The CS of shrubs was calculated using biomass models developed by Chinese researchers for regions with environmental conditions similar to Zhengzhou (Li XiaoNa et al., 2010; Z. Yao et al., 2015; Z.-Y. Yao & Liu, 2014). The estimated biomass was converted into CS by applying a carbon conversion coefficient of 0.5 (Houghton, 2005; Nowak & Crane, 2002). In addition to species attributes, the i-Tree Eco model requires input data on local meteorological conditions, air quality, precipitation, and climate zones. Since Zhengzhou-specific parameters are not available in the iTree Eco model, Xianyang, a city with similar climatic conditions, was used as the reference city for parameter input The total CS of a park was calculated as the product of the per-unit green space CS of sample plots and the total park area. The per-unit green space CS was determined by dividing the total CS of all trees and shrubs within a sample plot by the green space area of that plot. The CSD of a park was then derived by dividing the park's total CS by its total area.

5. Results

5.1 Overview of Carbon Storage in Zhengzhou' s Urban Park Green Spaces

The total CS of the 123 urban park green spaces in Zhengzhou is 126.88 Gg C, with an average CSD of 5.2 kg C /m² (Table 1). However, there is considerable variability in the CS capacity among the parks, reflecting significant heterogeneity across the study area. On average, the CS per park is 1.14 Gg C, with values ranging from 0.0088 Gg C to 22.47 Gg C. Similarly, the CSD shows substantial variation, ranging from 0.36 kg C /m² to 21.59 kg C /m².

Table 1. Statistics on the carbon storage capacity of parks in Zhengzhou

	Maximum values	Minimum value	Standard deviation	Average value	Total
Carbon Storage (Gg C)	22.47	0.0088	2.50	1.14	126.88
Carbon Storage density (kg C /m²)	21.59	0.36	4.36	5.2	/

A comparison of the rankings for total CS and CSD reveals a clear disparity, suggesting substantial potential for enhancing the carbon sequestration capacity of urban parks in Zhengzhou. Notably, larger parks that rank high in total CS are often absent from the rankings for CSD, while smaller parks tend to perform better in density rankings. For instance, the New District Wetland Park ranks first in CSD at 21.59 kg C/m², despite its small area of only 4.8 ha. Conversely, the Zhengzhou Yellow River Cultural Park (Park ID: 11), which has the highest total CS at 321.55 ha, achieves a relatively low CSD of 7.0 kg C/m², ranking only 25th.These findings underscore the heterogeneity in the CS capacities of Zhengzhou's urban parks and reveal opportunities for targeted improvements.

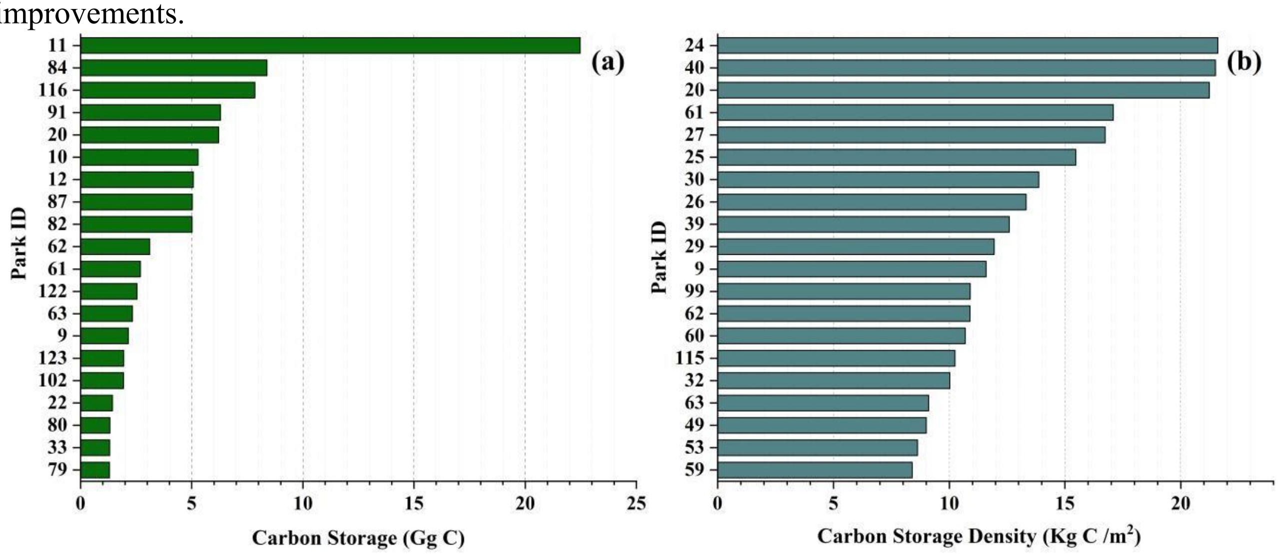

Figure 2. Ranking top 20 of carbon storage (a), carbon storage density (b) in park green spaces in Zhengzhou.

The spatial distribution of CS in urban parks and green spaces in Zhengzhou exhibits significant heterogeneity. Parks with high CS capacity are predominantly located in the central region of

Zhengzhou and are generally small in size. The southeastern and northern parts of the city have relatively few parks, and their overall CS capacity is comparatively low. In contrast, the western and eastern regions of Zhengzhou contain more parks, most of which demonstrate moderate levels of CS capacity. The southwestern region is characterized by a relatively large number of parks, most of which are larger in size and exhibit higher CS capacity.

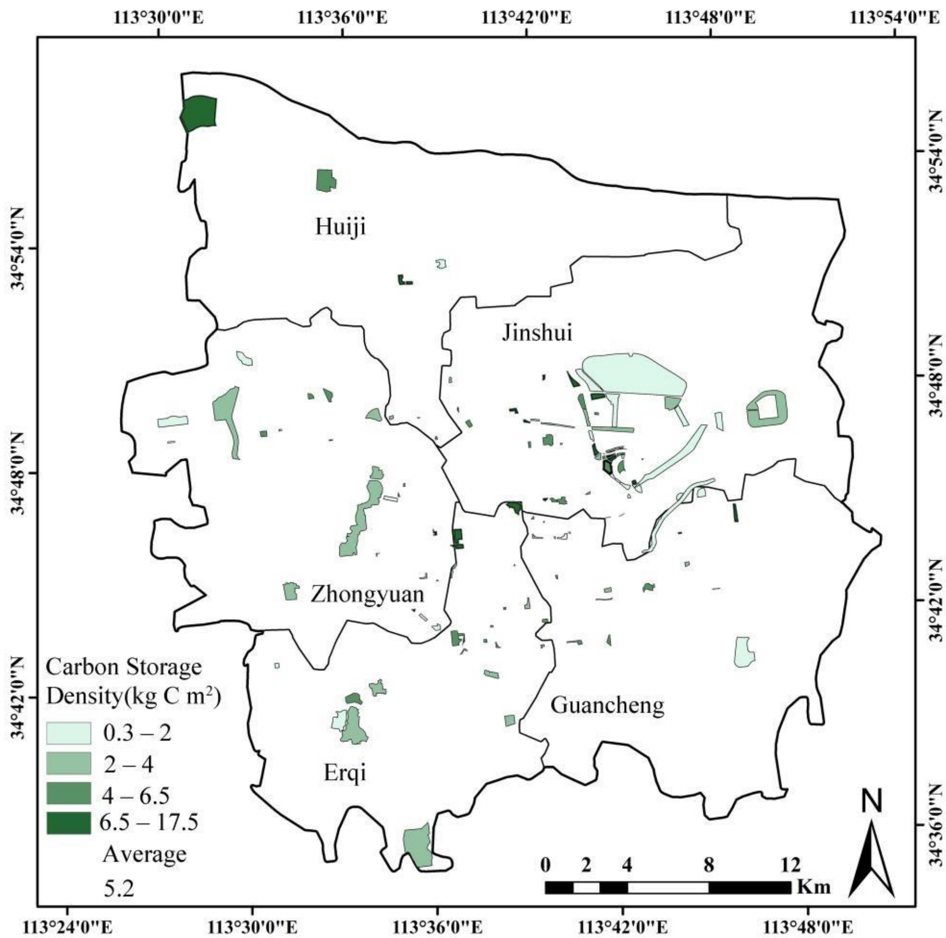

Figure 3. Spatial distribution map of carbon storage density in park green spaces in Zhengzhou

In terms of the number of parks, Jinshui District ranks first with 50 parks. The number of parks in Zhongyuan District, Erqi District, and Guancheng District is relatively comparable, with 24, 23, and 18 parks, respectively. Huiji District has the fewest parks, with only 8 (Table 2). With respect to CS, the average CS across districts varies considerably, ranging from 0.48 to 3.76 Gg C. Huiji District has the highest average CS (3.76 Gg C), while Guancheng District has the lowest (0.48 Gg C). This indicates that Guancheng District exhibits a deficit in CS in park green spaces, which should be a priority for improvement in future green space planning, particularly from a carbon sink perspective.

In terms of CS density, the average values across districts also demonstrate significant variability, ranging from 3.96 to 6.26 kg C /m² . Jinshui District has the highest average CSD (6.26 kg C /m²), followed by Guancheng District (5.53 kg C /m²)The carbon storage densities in Erqi

District, Huiji District, and Zhongyuan District are relatively similar, at 4.32 kg C /m², 4.18 kg C /m², and 3.96 kg C /m², respectively. Notably, although Guancheng District has the smallest park area (282.2 ha), its average CSD exceeds that of Erqi District, Huiji District, and Zhongyuan District, which have larger park areas (Table 2). These findings suggest that CSD is not strictly proportional to park area, highlighting the importance of targeted planning to maximize carbon storage efficiency parks.

Table 2. Statistics on the carbon storage capacity of parks in different administrative districts of Zhengzhou

		Administrative district				
		Jinshui	**Erqi**	**Huiji**	**Guancheng**	**Zhongyuan**
Basic information	Number of parks	50	23	8	18	24
	Total area of parks(ha)	1658.06	633.76	446.28	282.20	713
Carbon Storage (Gg C)	Maximum	7.84	8.38	22.47	2.69	6.29
	minimum	0.20	0.009	0.009	0.01	0.008
	mean	0.84	1.08	3.76	0.48	0.88
	standard deviation	1.52	1.98	7.79	0.74	1.60
Carbon Storage density (kg C /m²)	Maximum	21.59	10.9	11.6	17.08	10.9
	Minimum	0.85	0.36	0.75	1.14	0.79
	Mean	6.26	4.32	4.18	5.53	3.96
	Standard deviation	5.61	2.26	3.76	4.06	2.67

5.2 Characterization of vegetation for carbon storage in park green spaces in Zhengzhou

In the study area, a total of 17,615 trees belonging to 38 families, 69 genera, and 101 species were sampled and measured. Among them, *Ligustrum lucidum*、*Ginkgo biloba*、*Cedrus deodara,* and *Prunus cerasifera* were the dominant tree species in Zhengzhou parks, accounting for 8.87%, 6.99%, 5.43%, and 4.75% of the total sampled trees, respectively.

Other common species included *Fraxinus chinensis*, *Platanus orientalis*, *Salix babylonica*, *Prunus serrulata*, *Koelreuteria paniculata Laxm*, *Robinia pseudoacacia*, *Prunus persica*, *Magnolia grandiflora*, *Populus tomentosa*, *Styphnolobium japonicum,* and *Photinia serratifolia.* Collectively, the 15 most abundant tree species accounted for 58.50% of the total sampled trees (Figure 4a).

Among the 101 tree species sampled and measured, the top 20 species with the highest average CS were *Paulownia fortunei*, *Salix babylonica*, *Salix matsudana*, *Sapindus saponaria Linnaeus*, *Bischofia polycarpa* , *Chimonanthus praecox* , *Populus tomentosa*, *Cinnamomum camphora*, *Triadica sebifera* , *Liriodendron chinense* , *Prunus armeniaca* , *Acer buergerianum*, *Chaenomeles sinensis* , *Melia azedarach* , *Catalpa ovata* , *Acer pictum* , *Cedrus deodara*, *Hibiscus syriacus* , and *Firmiana simplex* (Figure 4b).

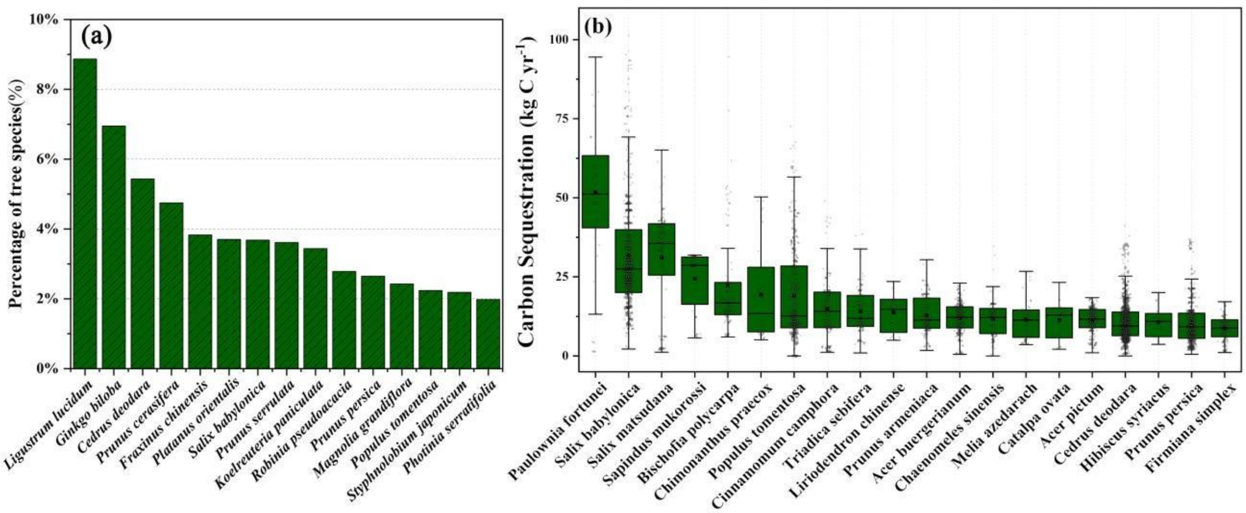

Figure 4. (a) Top 15 rankings of tree species proportions in Zhengzhou parks (survey results); (b) Top 20 rankings of tree species carbon sequestration in Zhengzhou parks (survey results).

A total of 2,162 shrubs, belonging to 44 families, 82 genera, and 140 species, were sampled and surveyed in the study area. The dominant shrub species in Zhengzhou parks were *Photinia × fraseri*, *Buxus megistophylla*, *Ligustrum quihoui,* and *Pittosporum tobira* accounting for 15.54%, 15.40%, 9.02%, and 6.89% of the total sampled shrubs, respectively, and collectively comprising 46.85% of the surveyed shrubs.

Other common shrubs included *Lagerstroemia indica* , *Cercis chinensis Bunge*, *Pyracantha fortuneana*, *Fatsia japonica*, *Hibiscus syriacus*, *Nerium oleander* , *Nandina domestica* , *Euonymus japonicus*, *Jasminum nudiflorum*, *Euonymus alatus*, and *Rosa chinensis.* Collectively, the 15 most abundant shrub species accounted for 73.77% of the total sampled shrubs (Figure 5a).

Among the 140 shrub species sampled, the top 15 species with the highest average CS were *Lonicera japonica* , *Pyracantha fortuneana* , *Buxus megistophylla*, *Lonicera maackii* , *Rosa chinensis*, *Syringa oblata*, *Juniperus chinensis* , *Rosa xanthina* , *Forsythia suspensa* ,*Wisteria sinensis* , *Pittosporum tobira*, *Prunus triloba* , *Punica granatum*, *Lagerstroemia indica* , and *Fatsia japonica* (Figure 5b).

A comparative analysis of the surveyed park vegetation in Zhengzhou revealed that the tree and shrub species with the highest CS capacity differ almost entirely from the dominant tree and shrub species in the parks (Figures 4a, b; 5a, b). This finding underscores a significant gap in the carbon sink potential of Zhengzhou parks. To address this, park management could consider gradually introducing and incorporating tree and shrub species with higher CS capacity to optimize the CS function of UGSs.

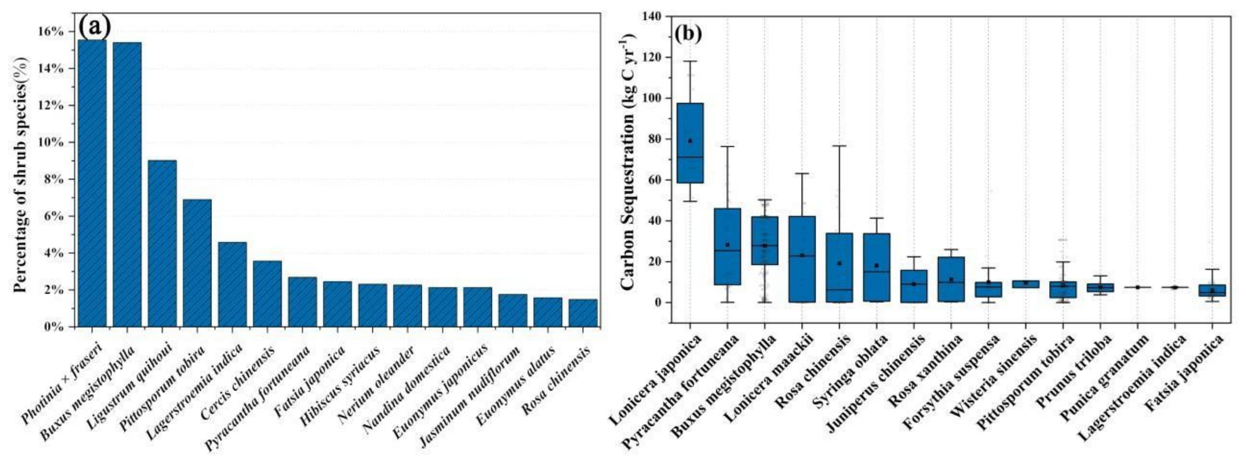

Figure 5. (a) Top 15 rankings of shrub species proportions in Zhengzhou parks (survey results); (b) Top 20 rankings of shrub species carbon storage in Zhengzhou parks (survey results).

5.3 The Strategies to enhance the carbon storage potential of urban parks.

Table 3 presents the high-carbon-sequestration tree and shrub species found in Zhengzhou's parks, offering options for urban planners or park designers to improve carbon sequestration through plant selection.

Table 3. Plant selection lists from the carbon sequestration perspective

		Latin name			Latin name
Tree	**Deciduous**	*Paulownia fortunei*	**Shrub**	**Deciduous**	*Lonicera maackii*
		Salix babylonica			*Rosa chinensis*
		Salix matsudana			*Syringa oblata*
		Sapindus saponaria Linnaeus			*Rosa xanthina*
		Bischofia polycarpa			*Forsythia suspensa*
		Chimonanthus praecox			*Wisteria sinensis*
		Populus tomentosa			*Prunus triloba*
		Triadica sebifera			*Punica granatum*
		Liriodendron chinense			*Lagerstroemia indica*
		Prunus armeniaca		**everygreen**	*Lonicera japonica*
		Acer buergerianum			*Pyracantha fortuneana*
		Chaenomeles sinensis			*Buxus megistophylla*
		Melia azedarach			*Juniperus chinensis*
		Catalpa ovata			*Fatsia japonica*
		Acer pictum			*Pittosporum tobira*
		Hibiscus syriacus			
		Firmiana simplex			
	everygreen	*Cinnamomum camphora*			
		Cedrus deodara			

Figure 6 presents a schematic comparison of the carbon sequestration capacity achieved by different tree species combinations before and after renovation. In the original design, three *Platanus* *orientalis*, one *Celtis sinensis*, and four *Photinia serratifolia* together sequestered approximately 65.62 kg of carbon per year. After replacing these species with three *Liriodendron chinense*, one *Triadica sebifera*, and four *Cinnamomum camphora*, the overall annual carbon sequestration increased to about 114.73 kg, representing a 175% enhancement relative to the original combination.These results highlight the importance of selecting tree species with robust growth rates, large biomass accumulation, or extended photosynthetic periods to maximize carbon sequestration. This finding serves as a reference for landscape design strategies aimed at mitigating urban carbon emissions.

	Before	Average Carbon Sequestration(kg/y)	Type	After	Average Carbon Sequestration(kg/y)
1	*Platanus orientalis*	9.06	Deciduous tree	*Liriodendron chinense*	13.70
2	*Platanus orientalis*	9.06	Deciduous tree	*Liriodendron chinense*	13.70
3	*Platanus orientalis*	9.06	Deciduous tree	*Liriodendron chinense*	13.70
4	*Photinia serratifolia*	9.12	Everygreen tree	*Cinnamomum camphora*	14.86
5	*Photinia serratifolia*	9.12	Everygreen tree	*Cinnamomum camphora*	14.86
6	*Photinia serratifolia*	9.12	Everygreen tree	*Cinnamomum camphora*	14.86
7	*Photinia serratifolia*	9.12	Everygreen tree	*Cinnamomum camphora*	14.86
8	*Celtis sinensis*	1.97	Deciduous tree	*Triadica sebifera*	14.19

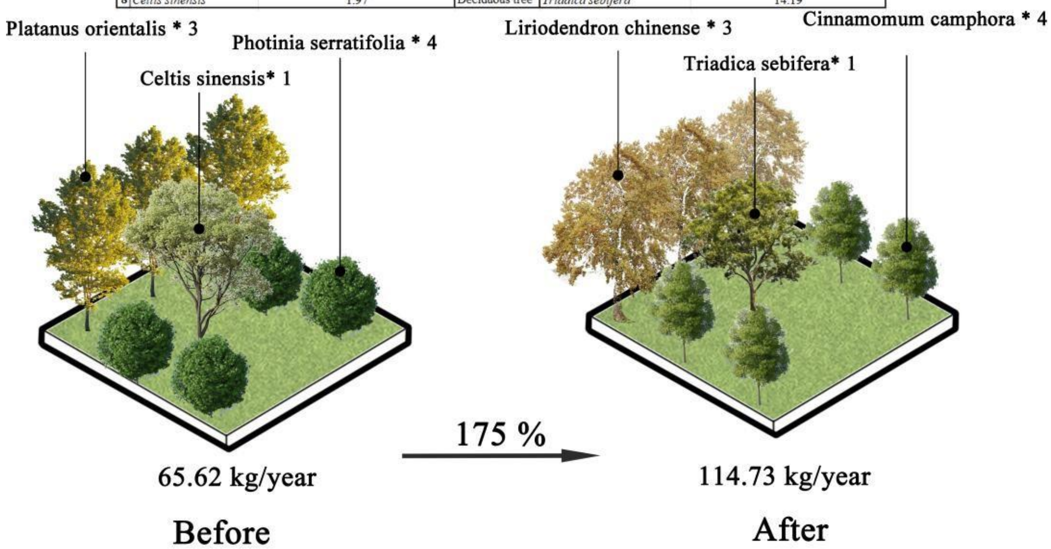

Figure 6. Schematic Diagram of Enhanced Carbon Sequestration Capacity of Tree Species Combinations Before and After Renovation

6. Discussion, Limitation and Conclusion

Discussion: The findings of this study suggest that parks with high CSD are predominantly located in the central areas of Zhengzhou and are generally smaller in size. One possible explanation for this is the higher frequency of park usage in urban centers. Due to the higher population density in these areas, parks must fulfill greater greening and recreational functions, which drives designers to prioritize the creation of dense and diverse green spaces to meet these demands (Wu et al., 2024). Additionally, vegetation in central urban areas is easier to maintain due to the greater accessibility of maintenance resources, as compared to parks located on the outskirts of the city. This convenience may also contribute to the higher CSD observed in central areas. Lastly, the study's methodology, which calculates park CSD based on tree sampling and park area, may lead to underestimation in larger parks where the sampling intensity is lower compared to smaller parks.

The results also highlight that different tree and shrub species exhibit varying CS capacities. This variation can be attributed to differences in photosynthetic efficiency, growth rates, and biomass accumulation among species. Furthermore, the structure of green spaces and the surrounding growth environment can also influence CS capacity. As such, the deliberate selection of plant species with high CS potential in future park planning represents a feasible and sustainable approach. During China's rapid urbanization, urban greening has expanded significantly as ecological awareness has grown. However, the plant selection process for UGSs has often prioritized species that are cost-effective, readily available, and resilient. Consequently, species such as *Ligustrum lucidum, Ginkgo biloba*, and *Photinia* × *fraseri* have come to dominate the green spaces in Zhengzhou's parks, despite their relatively low carbon sink efficiency. In developed urban areas, constraints imposed by various stakeholders make it challenging to increase carbon sinks by altering land use. This limitation, however, creates an opportunity for urban planners and park designers to enhance the quality of existing green spaces. By replacing low-efficiency species with those that have higher CS capacities, it is possible to improve the ecological function and carbon sequestration performance of urban parks without requiring significant land-use changes.

Limitation: This study focuses on improving green space carbon sinks primarily from the perspective of plant species selection. However, other vegetation metrics, such as diameter at breast height (DBH), height, and crown width, may also significantly influence CS and could be addressed in future research. Additionally, this study provides plant selection recommendations based solely on the goal of enhancing carbon sink capacity. In practice, the design of park vegetation must take into account a broader range of factors, including site functionality, light availability, soil conditions, and humidity. Future research could consider integrating these factors into a holistic framework to better balance ecological, functional, and environmental goals in park design.

Conclusion: This study utilized field surveys, remote sensing data, and the i-Tree Eco model to quantify the CS of park green spaces in Zhengzhou and to analyze differences in CS capacities among various vegetation species. The results revealed that the park green spaces in Zhengzhou collectively store 126.88 Gg C, with a CSD of 5.2 kg C/m^2 . Significant spatial heterogeneity was observed in the distribution of CS, with Guancheng District in the southeastern part of the city identified as a key area with low carbon sink capacity.

Additionally, the dominant plant species in Zhengzhou's parks differ markedly from those with high CS potential. This discrepancy highlights the considerable opportunity to enhance CS in park green spaces by optimizing vegetation composition. To this end, a list of high CS plant species—such as *Paulownia fortunei, Salix babylonica, Lonicera japonica,* and *Pyracantha fortuneana*—has been proposed to provide scientific support for carbon sink-oriented vegetation transformations in urban parks.

The findings of this study offer valuable theoretical guidance for improving the ecological services provided by UGSs and for promoting human well-being. By identifying sustainable design pathways for urban green space ecological enhancement, this research contributes to the broader goal of sustainable urban development.

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