DIPLOMA THESIS

AUTHOR: DU CHENYU

YEAR: 2023

HUNGARIAN UNIVERSITY OF AGRICULTURE AND LIFE SCIENCES
INSTITUTE OF LANDSCAPE ARCHITECTURE, URBAN PLANNING AND GARDEN ART
BUDAPEST

MASTER OF ARTS IN LANDSCAPE ARCHITECTURE AND GARDEN ART

Developing an Optimal Landscape Configuration of Urban Parks to Enhance Carbon Sink

AUTHOR: **DU CHENYU**

ADVISOR: **Dr. István Valánszki**

BUDAPEST, *2023*

TABLE OF CONTENTS

Abstract

China is urbanizing at an unprecedented rate. With this comes a significant increase in greenhouse gas emissions and increasingly extreme climate problems, such as global warming. Among these greenhouse gases, carbon dioxide (CO_2) has the greatest impact on climate warming. Achieving carbon neutrality has been widely agreed upon by the international community and national governments, which have all set their own carbon neutrality targets. Urban parks, as the main natural component of urban ecosystems, play a crucial role in mitigating the increase of atmospheric CO_2 concentration. Therefore, quantifying the carbon sink capacity of urban parks and exploring their influence mechanisms are invaluable for enhancing carbon sinks in parks, promoting the achievement of carbon neutrality targets and protecting the ecological environment of cities.

However, previous studies on carbon sinks in city green spaces have mostly focused on the assessment of carbon storages in urban green spaces, with little attention to urban parks. Most of the few studies on city parks have not addressed the impact mechanisms and enhancement measures of carbon sinks in parks. Therefore, this study takes 123 parks in Zhengzhou as the research object. Based on the satellite remote sensing data and the measured data, we quantified the carbon sink capacity of the parks in Zhengzhou and explored the carbon sink differences among different types of parks. It also explores the factors influencing the carbon sink capacity of parks from the perspective of spatial configuration, and finally proposes spatial design carbon sink enhancement strategies and applies them to the design proposals.

The results showed that the total carbon storage capacity of 123 parks in Zhengzhou was 108.5 Gg C, and the carbon storage density was 5.36 kg C m^{-2}. Moreover, there were significant differences in carbon sink capacity among different types of parks in Zhengzhou. In addition, the carbon sink capacity of Zhengzhou city

parks was significantly correlated with the landscape pattern index with a certain pattern. Among them, PLNAD_imper, PLAND_bare and LPI generally showed significant negative correlations, while NP, LSI, AI, PLAND_green and PLAND_water generally showed significant positive correlations. Finally, based on the study results, a spatial design carbon sink enhancement strategy was proposed for each type of park in Zhengzhou. Detailed design proposals are also proposed for street parks, community parks, belt parks, urban parks and theme parks.
Keywords: Carbon Sink; Carbon Storage; Landscape Design; Zhengzhou Parks

1. Introduction and Literature Review

1.1. Background

1.1.1 Rapid global urbanization

Since the Industrial Revolution, global urbanization is growing at an unprecedented rate. As of 2018, global urban imperviousness has reached 797,076 km^2, 1.5 times more than in 1990 (Gong et al., 2020) . Global urban land area is expected to reach 1.2 x 106 km^2 by 2030, a threefold increase compared to 2000 (Seto et al., 2012). The global urban population reached 55.3 % of the total global population in 2018 and is expected to reach 68 % in 2015(*World Urbanization Prospects*, 2019). As the world's most populous country, China has experienced rapid urbanization since its reform and opening up. According to statistics, China's population has increased to 1.4 billion in 2018, of which the urban population totals 837 million, accounting for 59 % of China's total population and 20 % of the world's total population；China's urban population is expected to increase by another 255 million by 2050 (*World Urbanization Prospects*, 2019). With the rapid increase in urban population, China's urban area is also rising dramatically. From 1978 to 2017, China's urban impervious area has increased 13.6 times, and in 2018 it grew to 798,101 km^2(Gong et al., 2020; X. Li et al., 2020). Rapid urbanization implies dramatic population growth and urban subsurface changes, as well as greater energy consumption and greenhouse gas emissions. The effects of urbanization have dramatically altered the ecological cycles of the Earth within global regions (Grimm et al., 2008).

1.1.2 Severe global climate extremes

Rapid urbanization is directly responsible for the significant increase in greenhouse gas emissions, resulting in global warming, glacial melting, and other extreme climate phenomena. According to the 2021 IPCC report, global warming has been significant over the past century and will be more pronounced in the 21st century. A study shows that the global surface temperature has increased by 0.99 °C in 2001-2020 compared to 1850-1900, and 1.09 °C in 2011-2020 compared to 1850-1990(Masson-Delmotte et al., 2021). In addition, a report released by the World Meteorological Organization in late 2021 shows that the last seven years (2015-2021) are likely to be the hottest on record. China, as the world's most populous country, has started a rapid urbanization process since the reform and opening up in the late 1970s, and has accordingly suffered from various adverse effects of global climate change. Data show that since 1900, China has experienced a temperature increase trend of 1.3-1.7 °C (100a)(Yan Zhongwei;Ding Yihui, 2020). In addition, the 2021 IPCC Sixth Report states that global warming of the atmosphere, oceans and land is mainly caused by the large amount of greenhouse gases emitted by human activities, and that the annual average value of global carbon dioxide (CO_2) in 2019 is as high as 410 ppm (Masson-Delmotte et al., 2021). According to data measured by Variguan Jim in China, the annual average concentration of CO_2 in the atmosphere in China was 404.4 ppm in 2016 and 407 ppm in 2017. From 1980 to 2006, China's CO_2 emissions from fossil fuel combustion increased nearly fourfold, and by 2006 China's CO_2 emissions surpassed those of the United States for the first time, making it the world's top CO_2 emitter. (Gregg et al., 2008). The increasing emission of carbon dioxide and other greenhouse gases has led to many climate problems and has had a serious impact on human society and the natural environment, and the reduction of urban carbon emissions has become a priority issue for countries around the world.

1.1.3 Significant carbon sink effect of urban green space

Currently, reducing CO_2 emissions and enhancing intra-city carbon sinks are considered important responses to adapt to climate change and mitigate its subsequent impacts on urban areas (Dhakal, 2010). Although cities cover only 3% of the global land area, they are home to more than 1/2 of the world's population and generate more than 70% of carbon emissions, making them the most carbon-emitting regions(Luo Xinyue;Chen Mingxing;, 2019). As the main natural component of urban ecosystems, urban green spaces play an important role in offsetting CO_2 emissions from fossil fuel combustion and regulating the global carbon cycle (Ren et al., 2019; Sun et al., 2019). The carbon sink function of urban green spaces is a valuable ecosystem service for cities (Dorendorf et al., 2015). Green plants can absorb atmospheric CO_2 through photosynthesis and fix it in vegetation, water bodies and soil, thereby reducing atmospheric CO_2 concentration (Russo et al., 2014; Yu & Wang, 2021). In addition, urban green space is an important part of urban green infrastructure, which has ecological effects such as absorbing pollutants, connoting water and regulating microclimate, thus reducing the carbon emissions generated by building grey infrastructure. There is a consensus that urban green spaces should be managed to maintain their sustainable and high level of carbon sink function to address future climate change and ensure a better quality of life (Ariluoma et al., 2021). Therefore, how to organically combine climate change and urban green space carbon sink, implement urban ecological restoration and protection, and enhance the consolidation of urban green space carbon sink capacity has become an important issue for China and the world to plan for carbon peaking and carbon neutral work.

1.1.4 Carbon Sink Policies in the World and China

Today, organizations and countries around the world are increasingly concerned about climate change and reducing emissions and increasing sinks, and corresponding actions have been implemented since the end of the last century. In response to the adverse effects of global climate change, the United Nations Intergovernmental Panel on Climate Change (IPCC) was established at the end of the last century, and the world's first climate change-related convention, the United Nations Framework Convention on Climate Change (UNFCCC), was concluded at the same time. In 2010, the Cancun Climate Conference proposed "incentives and policy measures for forest degradation and conservation, reducing deforestation in developing countries, sustainable management, and enhancement of forest carbon storages", and in 2015, the Paris Association also proposed a number of measures to address global climate change. many measures. Various countries and organizations around the world have also proposed specific timelines for achieving carbon neutrality goals. In 2019, EU leaders announce EU carbon neutrality by 2050 (*EU's Goal*, n.d.)，U.S. also announces goal of zero greenhouse gas emissions by 2050 (Anonymous, 2021). In 2019, the United Kingdom announced that it will achieve its goal of zero greenhouse gas emissions by 2050(Fig. 1-1)

As the world's largest developing country, resource conservation and environmental protection has always been a fundamental national policy of China, and in September 2020, President Xi Jinping solemnly announced at the 75th session of the United Nations General Assembly that China aims to peak its CO_2 emissions by 2030 and achieve carbon neutrality by 2060(Fig. 1-1). The Central Economic Work Conference held in December 2020 and the Ninth Meeting of the Central Finance and Economics Commission held in March 2021 have pointed out that carrying out large-scale greening actions and improving the carbon sink capacity of the ecosystem is one of the important elements of the work to achieve carbon peaking and carbon neutrality. The Guidance of the General Office of the State Council on Scientific Greening was proposed on June 2, 2021, to scientifically carry out large-scale national greening actions, enhance ecosystem functions and the supply capacity of ecological products, and improve the incremental carbon sink of the ecosystem. On October 24, 2021, the Central Committee of the Communist Party of China (CPC) and the State Council issued the "Opinions on Complete and Accurate Implementation of the New Development Concept to Do a Good Job in Carbon Dumping and Carbon Neutral

Work". The document proposes to "build urban ecological and ventilation corridors, improve urban landscaping; consolidate the carbon sink capacity of ecosystems, strictly adhere to the ecological protection red line, strictly control the occupation of ecological space, stabilize the carbon sequestration of existing forests, grasslands, wetlands, oceans, soils, permafrost and karst; enhance the carbon sink increment of ecosystems, carry out integrated protection and restoration of mountains, water, forests, lakes, lakes, grasses and sands, and Deeply promote large-scale national greening action". On October 28, 2021, the State Council issued the "Action Plan to Achieve Carbon Peaks by 2030", which listed the action of consolidating and improving carbon sink capacity as "one of the ten actions to achieve carbon peaks".

Therefore, by calculating the carbon sink potential of park green space in Zhengzhou City, it is important to analyze and explore the potential and measures to increase the sink of urban park green space to advance the goal of carbon neutrality by 2060.

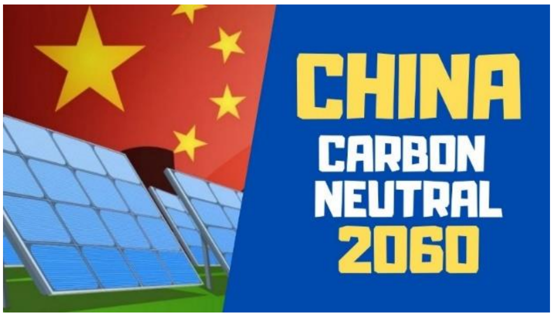


Fig. 1-1 Carbon Neutrality Goals for China and the EU. Source: Interent(*EU's Goal*, n.d.; *United Kingdom*, n.d.)

1.2 Related Concepts and Progress

1.2.1 Related Concepts

1.2.1.1 Carbon Sink Related Concepts

1. Carbon Sink

In the United Nations Framework Convention on Climate Change (UNFCCC), Carbon Sink is defined as "a process, activity or mechanism for removing CO_2 from the atmosphere" and Carbon Source is defined as "a process, activity or mechanism for releasing CO_2 into the atmosphere ". In the 6th IPCC report, a carbon sink is defined as "any process, activity or mechanism that removes greenhouse gases, aerosols or pre-greenhouse gases from the atmosphere".(Masson-Delmotte et al., 2021). In addition, carbon sources and carbon sinks are not invariable, but can be interchanged between them. In other words, when the amount of CO_2 fixed by something is greater than the amount of CO_2 emitted into the air, it can be called a carbon sink, and the opposite is a carbon source.

2. Plant carbon sequestration

The realization of plant solidification depends mainly on plant photosynthesis, or photosynthesis. Specifically, it is the process of converting CO_2 and water into organic matter and releasing O2 in green plants containing chloroplasts under visible light, through light and carbon reactions, using photosynthetic pigments. In addition, plants undergo respiration at night, which, in contrast to photosynthesis, absorbs O2 and releases CO_2 outward. in most cases, the carbon fixed by photosynthesis in plants is much greater than the carbon released in respiration. It can be said that plants are natural carbon sinks, which have an important impact on the Earth's carbon and oxygen balance, cooling and emission reduction.

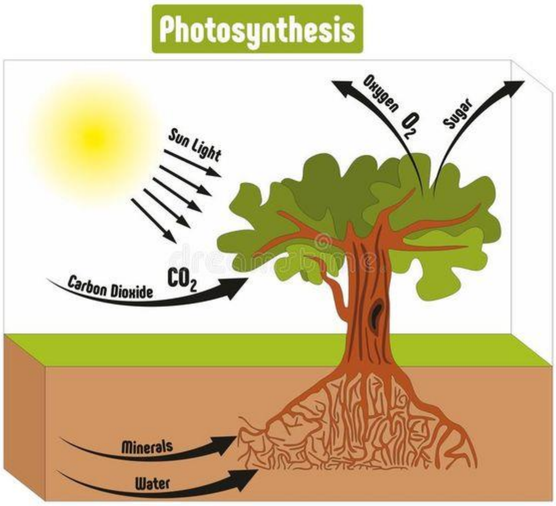


Fig. 1-2 Plant carbon sequestration diagram. Source: Interent(*Photosynthesis Process*, n.d.)

3. Biomass

Ecological term for the dry weight of organic matter contained in a tree per unit area at a given moment, including the biomass contained in the above-ground part (trunk, branches, leaves) and the below-ground part (roots).

4. Carbon neutrality

Carbon neutrality is a state of net zero carbon dioxide emissions. Also means having a balance between emitting carbon and absorbing carbon from the atmosphere in carbon sinks.

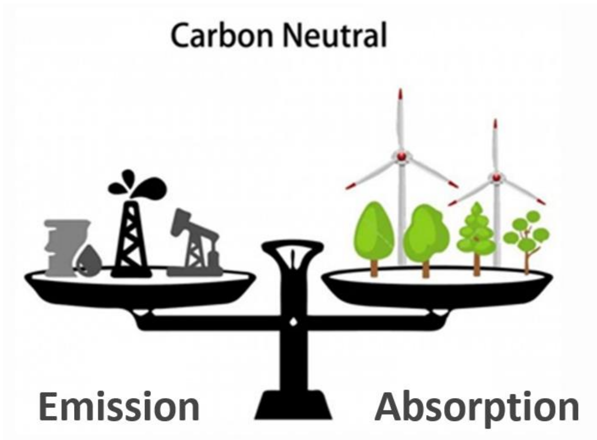


Fig. 1-3 Carbon neutral diagram. Source: Interent(*Carbon Neutral*, n.d.)

5. Carbon Storage

The reserves of elemental carbon, biomass can be converted into carbon storages by the share of carbon in the dry weight organic matter of the plant.

1.2.1.2 Park Green Space Related Concepts

1. Definition of Park Green Space

Currently, there are some differences in the definition of park green between different research institutions and scholars in China and abroad.

In his book "Nature and Urban Planning in the 19th Century", Laurie defines urban parkland as the natural home of the city, while Olmsted defines the concept of parkland with more emphasis on the public nature, greenness and functionality of parkland, i.e., the functionality of the city in addition to the gray areas (mainly hard dominated spaces such as buildings, squares, roads and facilities). public green space. The Encyclopedia of China defines a park as "an urban public green space constructed and operated by the government or a social group for public enjoyment, sightseeing and recreation". Swedish landscape architect Blum believes that parkland is a combination of nature and culture based on the existing natural ecological foundation. Taiwanese scholar Lin Lejian in his book "Gardening" defines park green space as a green space that provides public enjoyment, recreation, leisure and entertainment, can maintain the physical and mental health of citizens, improve their cultural cultivation, and can freely enjoy its internal supporting facilities, and has the function of refuge and disaster mitigation. Meng Gang, Li Lan et al. define a park in Urban Park Design as: urban park is a kind of naturalized recreational living area with certain functions for residents, and is the green infrastructure of the city; as the main public open space of the city, the park is not only the main place of leisure and recreational activities for users, but also the place of dissemination of citizen culture. In the book "Garden Planning and Design", Hu Changlong understands the park as a beautiful place for people to visit, rest, watch, carry out cultural entertainment and social behavior, sports activities, and also an important window to reflect the level of urban landscaping, which often takes the primary position in the urban public green space.

China has produced the following standards for the definition of park green space in recent years by improving the construction of park green space and drawing on the relevant definitions developed by different countries:

1) *Standard on Basic Urban Planning Terms (GB/T 50280-98):* Green space, refers to green space land in cities, dedicated to improving the environment, protecting the environment, and providing residents with places to relax and decorate the landscape. This standard divide green space into five categories: park green space, production green space, protective green space, subsidiary green space, and other green space. Park green space refers to the public green space in the city with a certain land area, good greenery, and certain recreational services.
2) In *the Standard for Urban Land Use Classification and Planning and Construction Land (GB50137-2011)*. Park green space is defined as: green space open to the public with the main functions of recreation and environment, environmental beautification, disaster prevention, etc.
3) *The national industry standard "Urban Park Design Code" (JJ48-92)* defines a park as a public green space used for visiting, sightseeing, recreation, carrying out scientific and cultural activities, physical exercise, etc., and other facilities in a relatively complete and well-conditioned environment.
4) *The Urban Green Space Classification Standard (CJJ/T85-2002T)* defines park green space as; "Green space open to the public, with recreation as the main function and both ecological, beautification and disaster prevention roles."

In general, the interpretation of urban park green space should include the use function, service population, facilities, and operating groups. In this paper, the definition of park green space in *the Classification Standard of Urban Green Space (CJJ/T85-2002T)* is used as the basis of the study.

2. Park green space classification

Since different countries and organizations have different national conditions, management and statistical mechanisms, and theories of green space construction, the classification standards for park green space vary around the world. in September 2002, in order to keep pace with environmental construction and better urban construction development, the Ministry of Housing and Construction issued the "*Urban Green Space Classification Standards" (CJJ/T85-2002T)*, which divided park green space into five main categories, namely Urban Park, Community Park, Theme Park, Belt Park and Street Park.

In the standard, each of the major categories of park green space are explained separately.

1) The Urban Park is a green space with a scale greater than 10 ha, should be rich in content, suitable for all kinds of outdoor activities, with perfect recreation and supporting management and service facilities.
2) Community Park are independent, with basic recreation and service facilities, the scale should be greater than 1 ha, mainly for a certain range of residents to carry out daily leisure activities in the vicinity of the green space.
3) Theme Park do not have a certain scale requirement, mainly Focus on specific content or form, such as zoos, botanical gardens, heritage parks, amusement parks, etc., in addition to the corresponding recreation and service facilities;
4) Belt Park are narrow green areas along urban roads, city walls, waterfront, etc., with certain recreation facilities.
5) Street Park refers to the green space located outside the urban road land, relatively independent of the piece of green space, including the street, square green space. Small green land along the street, etc. (greening ratio should be greater than or equal to 65%).

1.2.1.3 Landscape Pattern Index

Landscape pattern is the configuration of landscape elements of different shapes and sizes in different ways in space, which is the result of the long-term joint action of landscape formation factors and landscape ecological processes. To a certain extent, it reflects the evolution of the ecosystem. Landscape pattern index, also known as landscape index, is highly concentrated landscape pattern information, which is an important quantitative indicator to respond to the landscape result composition, spatial configuration and landscape heterogeneity characteristics, and is one of the basic methods to quantify landscape pattern research (Uuemaa et al., 2009). The landscape pattern index has the advantages of effective characterization and easy quantification, and has been widely used and developed in research (Chen et al., 2014; Du et al., 2022; Jia & Zhao, 2020; K. Zhang et al., 2023; Zhou et al., 2014). The landscape pattern index can be divided into three levels: landscape, landscape type and patch, including six indicator modules of shape, connectivity, diversity, agglomeration, area-edge and core area, and the indicators at different levels have different ecological significance.

1.2.2 Progress in China and the World

1.2.2.1 Methodology for estimating carbon sinks in urban green spaces

The estimation of greenland carbon sink was first started from the study of forest biomass estimation, and the forest carbon storage was estimated by measuring the forest biomass and then converting a certain proportion of it. in the middle and late 20th century, the study of forest biomass got attention, and the study of carbon storage estimation started in the world. For example, in the 1950s, Woodewll et al. obtained basic data through the sample plot survey method and analyzed the carbon source and sink layout, and pointed out that human activities and rainforest clearing had led to the reduction of carbon sinks in global forest ecosystems (Bolin, 1977; Woodwell et al., 1978). Up to now, the field of forest carbon sinks has been greatly developed, and there are many methods and research results for forest carbon sink estimation. The estimation method of carbon sinks in urban green areas is derived from the estimation of forest carbon sinks, but compared with forests, urban green areas have their special characteristics, such as more complex spatial distribution patterns, high species richness and high degree of human interference, so the estimation method of forest carbon sinks cannot be completely replicated. In this chapter, we present the carbon sink estimation methods of urban green areas based on the existing literature.

1. Sample site inventory method

The sample site inventory method refers to the method of obtaining carbon storages by setting up typical sample sites and obtaining relevant data through field research in the study area, combined with continuous observation. The method generally estimates carbon storages based on carbon content conversion factors after the biomass is derived, and mainly includes biomass conversion factor method, equilibrium biomass method and model measurement method.

1) The biomass conversion factor method is a method to obtain biomass based on the ratio between storagepile and biomass, combined with the resource inventory data, and the total storagepile of the forest stands in the statistical data. This method is widely used for vegetation biomass and carbon storage assessment at regional and national scales. Compared with other methods, this method is relatively mature, but it needs to consider the variability of parameters such as conversion factors between different regions and species. Adjusting the conversion factor parameters according to local and tree species conditions is the key to improve the accuracy of the method.
2) The average biomass method is a method to find the green space biomass after calculating the average biomass of the field research sample sites and combining it with the area of that type of green space. This method can be used to measure tree biomass directly by standard wood analysis method, and the results are more accurate. However, for a large study area with a large variety of species, the workload and human and material resources consumption will be larger. In conducting the study, the regression equation between diameter at breast height (tree height) and biomass (e.g., anisotropic growth equation) can be established based on the high-precision results of the standard wood analysis method to carry out tree biomass estimation.
3) The model measurement method is based on the actual measured tree data in the sample site, building a tree model or simulating tree growth, identifying the vegetation in the study area by inputting the vegetation information or by remote sensing images, and finally estimating the carbon sink of the study area The commonly used models are i-Tree, Citygreen, ThePathfinder, InVEST and National

tree benefit calculator. Among them, i-Tree model is more applicable to the estimation of urban green space at large scale such as urban forest and urban park; Citygreen model is mostly used for the estimation of carbon sink of single street tree and urban forest; ThePathfinder model is more comprehensive, including carbon source, carbon sink and carbon cost; InVEST model is more applicable to urban area scale, focusing more on the relationship between land use The National tree benefit calculator model can only estimate the carbon sink of a single plant.. In general, this method can save a lot of material and human resources and make the estimation more rapid, efficient and comprehensive than the traditional estimation methods such as biomass method, which requires instrumentation or field surveys. However, most of these models are developed by foreign countries, for example, Citygreen and National tree benefit calculator are developed by the U.S. Forest Service, and the basic database data to support the calculation are all from U.S. research data. Therefore, when using these models, domestic scholars will choose the U.S. cities with the same climate conditions as the study area as background parameters to reduce calculation errors.

2. **Remote sensing estimation method**

Remote sensing technology has the advantages of real-time, large-scale acquisition and fast, etc. Using remote sensing images as data source combined with field research data and driving models is an effective way to carry out carbon sink estimation. At present, the carbon sink estimation based on remote sensing technology can be mainly divided into two types: inverse estimation and model simulation.

4) The inverse estimation method obtains carbon storage data through field research, then extracts remote sensing parameters such as NDVI and EVI from remote sensing image data, establishes the fitting equation between them, and finally estimates the carbon storage of the whole region through the fitting model. This method is more suitable for large scale carbon sink research, and can realize the spatial distribution of carbon storage, and also can realize the long-term, dynamic and continuous regional urban vegetation carbon storage estimation, so it gradually becomes an

advantageous tool for urban carbon storage research(Z.-Y. Yao & Liu, 2014). However, this method will increase the uncertainty of the measurement results due to the insufficient spatial resolution of remote sensing images in the study area (Pasher et al., 2014). The uncertainty can be reduced by high-precision remote sensing images, such as LiDAR, high-resolution hyperspectral satellite data, etc. (Schreyer et al., 2014). In addition, due to the high spatial heterogeneity and species richness of urban green spaces, the fitted models based on the inverse estimation method may also suffer from poor prediction accuracy, linear correlation of estimation result residuals and poor model generalization ability. The prediction accuracy of the model can be improved by using machine learning models or selecting appropriate regression algorithms, such as random forest algorithm, KNN algorithm and linear mixed-effects model, etc.

5) Model simulations are mainly parametric models and process models. Parametric models are also called semi-empirical models, which use empirical equations to solve the carbon flux magnitude by collecting various relevant parameters, such as CASA, a light energy utilization model. process models. Process models are based on the physiological and ecological processes of forest ecosystems, and mechanistically simulate photosynthesis, transpiration and respiration of vegetation, as well as the material and energy exchange processes between them and the environment, so as to realize the simulation of ecosystem carbon cycle and its response to climate and environmental changes and anthropogenic disturbances, mainly including TEM model, CENTURY model, BIOME-BGC model, BEPS model, etc, BEPS model, etc. This method can achieve rapid and real-time realization of large-scale carbon cycle, but the limitations of the research model itself, such as uncertainty, complexity, standardization of remote sensing data and diversity of driving data, lead to less research on urban greenland carbon sink based on process simulation.

3. Assimilative and micrometeorological methods

6) The assimilation method refers to calculating the net carbon sequestration and net

assimilation of vegetation by measuring photosynthetic physiological indicators of plant leaves, and then combining them with structural parameters such as green volume and leaf area to calculate the carbon sequestration of plants, and the commonly used photosynthetic physiological indicators of leaves include stomatal conductance, net photosynthetic rate, intercellular CO_2 concentration and transpiration rate. At present, scholars have used the assimilation volume method to conduct research on the carbon sequestration capacity of urban green space species, which provides a better choice of high carbon sequestration tree species in different regions. Based on the determination of leaf area index and photosynthetic index of major plants in 28 of Fuzhou Botanical Garden, Wang Zhongjun et al. Combined with the forestry class II inventory data, the carbon sequestration and green volume values of various vegetation types in the botanical garden were estimated, and the carbon sequestration and oxygen release effects of vegetation in the botanical garden were quantified. This method is only applicable to the plant scale, and is influenced by the environment and photosynthetic rate, and there are uncertainties in carbon sink estimation.

7) The micrometeorological method obtains the flux value of the gas by measuring the near-ground turbulence conditions and the concentration of the gas being measured (Liu et al., 2018). This method allows direct continuous and dynamic detection of CO_2 fluxes between green areas and the atmosphere, and a more representative method is the eddy covariance method. For example, Saleh Shadman et al. used the vorticity covariance technique to examine CO_2 fluxes in Hyväntoivonpuisto Park in Helsinki, and based on the results, they designed a carbon sink for the Jätkäsaari demonstration area in the park. (Tammeorg et al., 2021). The eddy covariance technique can directly, accurately, and continuously detect greenfield carbon sinks, but the method requires a high level of subsurface, and some studies have shown that carbon sink values measured in atmospheric instability sites and complex terrain differ by 80%-100% from those measured using other methods. In addition, the

method can only perform point observations, and it is difficult to use the method for medium and large-scale observations.

1.2.2.2 Progress of research on carbon sinks in urban green areas

Studies of carbon sinks in urban green spaces are more limited than in other ecosystems. The earliest study of carbon sinks in urban green spaces dates back to 1993, when Nowak et al. estimated the carbon storage of urban forests across the United States based on data related to tree growth in Oakland, showing that the carbon density of urban trees in Oakland was approximately 1.1 kg C m^{-2}, which was 10% of the total storage of the entire urban forest in Oakland(Nowak, 1993). In 2002, Nowak and Crane estimated the carbon storage and sequestration of urban vegetation across the United States based on vegetation cover data from ten U.S. cities, which showed that the carbon storage of urban trees in residential areas in the United States was 700 million tons of carbon and the total carbon sequestration rate was 22.8 million tons/year (Nowak & Crane, 2002). In 2013, Nowak conducted a more precise regional estimation of vegetation carbon storage and carbon sequestration in all U.S. cities, and concluded that the carbon density and carbon sequestration of urban forests across the U.S. were 7.69 kg C m^{-2} and 0.28 kg C $m^{-2}yr^{-1}$, respectively, and the total carbon storage of U.S. urban forests was 643 million tons, which further improved the study of carbon storage in urban green spaces across the U.S. (Nowak et al., 2013).

A growing number of studies have shown the significant role of the carbon sink capacity of urban green spaces. Mc Pherson's study found that the average annual carbon storage in Sacramento, USA, was 23.8 × 104 t C, accounting for about 1.8% of the city's total carbon emissions(McPherson et al., 1994). Churkina's study shows that urban green spaces account for about 12-40% of carbon sequestration in global terrestrial ecosystems(Churkina, 2016). Stoffbery and Rooyen et al. quantified the plant carbon sequestration benefits and growth of native tree species in urban streets and green spaces in the city of Tshwane, South Africa, and showed that urban green spaces have significant carbon sequestration value (Stoffberg et al., 2010). Getter et al.

quantified the carbon sequestration potential of 12 green roofs in Maryland and Michigan, USA, and showed that the carbon sequestration capacity of green roofs is significant in cities (Getter et al., 2009). Zirkle's study of the carbon sequestration capacity of trees, shrubs and grasses in green spaces of 80 x 106 family homes in the United States found that gardens have a higher carbon sequestration capacity than natural sites (Zirkle et al., 2012). Vaccari Study Finds that Florence, Italy's Urban Green Space Carbon Sink is 6.2% of the City's Direct Carbon Emissions(Vaccari et al., 2013).

In 1998, Guan Dongsheng estimated the carbon storage of green areas in the built-up area of Guangzhou based on field research data. In 2003, Han Hongxia discussed the role of GIS and RS technology in the study of urban green space and used the technology to make an assessment of the ecological benefits of urban vegetation. In 2006, Zheng Zhonglin conducted a study on the forest carbon storages in the outer green belt of Shanghai and explored its ecological benefits. In the same year, Zhang Kan et al. used CITYgreen software to estimate and comparatively analyze the ecological service values of planted woodland, artificial greenland and natural woodland in Hangzhou. In 2010, Zhao conducted a study on the carbon reduction role of urban forests in Hangzhou and pointed out that urban forests play an important role in carbon reduction (Zhao et al., 2010). In 2015, Yao's study showing the carbon storage of above-ground vegetation showed that the average above-ground carbon density of urban green space in the main urban area of Xi'an was 0.28 kg C m^{-2}(Z. Yao et al., 2015). Lv studied the forest carbon sink in Harbin in 2016, and the results showed that the distribution of urban forest carbon density in the main urban area of Harbin ranged from 7.7 kg C m^{-2}(Lv et al., 2016). In 2019, Sun's study on carbon storage in Beijing's urban vegetation showed that the carbon storage in urban green spaces was 956.3 Gg, and the average above-ground carbon density of urban green spaces in the main urban area was 0.78 kg C m^{-2}(Sun et al., 2019).

1.2.2.3 Progress of Carbon Sink Research in Park Green Space

As an important part of the urban green space system, park green space carbon sink has gradually received wide attention from scholars at home and abroad in recent years, and the monitoring of park green space carbon sink has been carried out all over the world.

In 2019, Hyun-Kil Jo et al. quantified carbon storage and sequestration in urban parks in Seoul, South Korea, and showed that trees in all urban parks in Seoul can store 222.3 kt of carbon and sequester 20.2 k t of carbon per year. The trees in these parks can offset approximately 2.3% of the annual carbon emissions from gasoline consumption of the city's total population. The annual economic value of carbon sequestration is $7.1 million/year (Jo et al., 2019).

In 2020, Richa Sharma et al. studied the carbon sequestration potential of vegetation around the Friendship University, Noida, India. The results showed that 45 different tree species on the campus have sequestered 139.86 tons of CO_2 e (Sharma et al., 2020).

In 2021, Hye-Mi Park conducted a field survey and quantified carbon revenues and expenditures in 30 urban parks in Korea based on the whole life cycle assessment method. Ecological design and construction strategies were proposed, including expanding tree planting space by minimizing grass and impervious areas, minimizing changes to existing topography, and using local materials. When these strategies were applied to the study park, net carbon sequestration increased by a factor of approximately 9.2 (Park & Jo, 2021).

In 2021, Tammeorg P et al. conducted carbon sink monitoring in Hyväntoivonpuisto Park in Helsinki, Finland, and proposed a series of design strategies to improve the park's carbon sink capacity (Tammeorg et al., 2021).

In 2022, Saleh Shadman et al. quantified the carbon equivalent of greenhouse gas sequestration in the city park (Shaheed Zayan Chowdhury Playground) in Dhaka, Bangladesh. The results showed that the total CO_2 equivalent sequestered throughout the life cycle of the city park was 660.8 tCO_2e The annual sequestration rate was 33.24 tCO_2e. Moringa Oleifera, Mangifera Indica and Delonix Regia had the highest carbon storage potential and sequestration capacity, while Cassia Fistula had the lowest (Shadman et al., 2022).

In 2022, Zbigniew Szkop conducted an ecosystem services assessment of Warsaw Park and Garden Square in Poland, which showed that the total value of air pollution clear ecosystem services provided by the study area was €3.93-5.6 million/year, and the value of carbon storage services provided ranged from €23.3-30.2 million (Szkop, 2022).

In 2022, Nuanchan Singkran conducted a carbon sequestration capacity study of 25 parks in Bangkok, Thailand, and the results showed that the above-ground carbon sequestration and CO_2 sequestration values of these parks were 11112.2 t C and 41219.4 t CO_2, respectively.(Singkran, 2022).

1.3 Main Content and Objectives

1.3.1 Main content

1. **Quantitative research on the carbon sink capacity and landscape pattern index of park green spaces in Zhengzhou City based on actual measurements, remote sensing interpreted data and data integration.**

In this part, 123 parks in Zhengzhou City were selected as the research objects, and a total of 805 sample plots in 123 parks were surveyed in the field by means of random placement, and the carbon storage and carbon storage density of each surveyed sample plot were quantified by i-Tree eco model, so as to estimate the carbon sink capacity of 123 parks. Then based on the data integration, the landscape pattern index of Zhengzhou city parks was quantified. Finally, the parks were classified according to different criteria, and a comparative analysis of carbon sink capacity and influencing factors between park types was conducted.

2. **Analysis of the drivers of heterogeneity in the carbon sink capacity of park green**

spaces in Zhengzhou based on mathematical statistical methods.

In this part, through data collection and mathematical statistical analysis, the quantitative results of park carbon sink capacity and landscape pattern index are combined with Pearson correlation analysis to explore the correlation between park carbon sink and landscape pattern index and analyze the main influencing factors of park carbon sink capacity.

3. Exploring ways to optimize carbon sequestration in park green spaces in Zhengzhou.

Based on the results of the Pearson correlation analysis analysis in Part II, this part combines the knowledge related to landscape garden planning and design to propose carbon sink optimization measures for park green spaces in Zhengzhou from the perspective of landscape pattern optimization and gives a design optimization diagram.

1.3.2 Objectives

Through the development of the above research elements, the following research objectives were achieved:

1. Quantifying the carbon sink capacity of park green spaces in Zhengzhou and revealing the heterogeneity of carbon sink capacity among different parks types
2. Quantifying the degree of contribution of landscape pattern indices to the carbon sink capacity of parks and revealing the influence mechanism of different parks' carbon sink capacity.
3. Explore the design ways to optimize and enhance the carbon sink capacity of urban park green space and provide ideas for future park carbon enhancement.

1.4 Questions to be addressed

The key scientific questions to be addressed in this study are as follows:

1. How large is the carbon sink in Zhengzhou's parks? What is the heterogeneity of carbon sinks among different types of parks?

2. What landscape pattern indices significantly affect the carbon sink capacity of the park?
3. From the perspective of landscape garden planning and design, what are the measures to enhance the carbon sink capacity of park green space?

1.5 Workflow

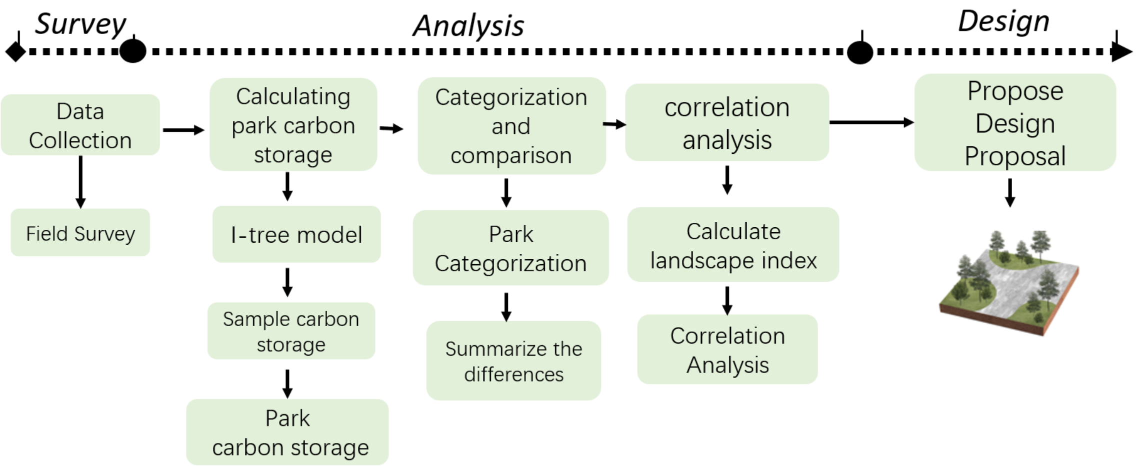


Fig. 1-4 The workflow steps of this study. Source: by author

1.6 Summary

In summary, the main points of this chapter can be summarized as follows:

1. With the intensification of global urbanization, urban warming is becoming more and more serious, and CO_2 sink emission reduction has been agreed worldwide. As the main natural component of the urban ecosystem, urban green space plays an important role in offsetting CO_2 emissions, and it is widely accepted in China and the world that CO_2 concentration can be reduced through carbon sinks in urban green space.
2. The concepts of carbon sink and park green space are defined, and the carbon sink estimation methods of urban green space are systematically sorted out, and the advantages and disadvantages of different methods and the scope of application are briefly introduced. At present, the main methods for estimating carbon sinks in urban

green areas are the sample site inventory method, remote sensing estimation method, assimilation method and micrometeorological method, and the first two methods are more commonly used. The sample inventory method can be divided into biomass conversion factor method, average biomass method and model estimation method; remote sensing estimation method can be divided into inverse estimation method and model simulation method.

3. We systematically reviewed the research progress of urban green space and park green space in China and abroad. The research on carbon sinks in urban green areas started in the 1990s, and the main research scope is to assess the carbon sink potential of urban green areas and estimate the carbon sink value of urban green areas. For park green areas, the research results are relatively few, and most of the existing studies are estimates of the carbon sink values of park green areas, but little research is done on the driving factors and optimization measures behind them. Therefore, it is fully necessary to quantify the carbon sink of park green spaces in Zhengzhou, explore the driving factors affecting the carbon sink capacity, and propose an optimization pathway for the carbon enhancement of park green spaces, which has a non-negligible role in China's response to urban climate change and achieving the carbon neutrality goal.

2. Analysis

2.1 Study Area Overview

2.1.1 Study City Overview

Zhengzhou is the capital city of Henan Province, China, located in the hinterland of the Central Plains, adjacent to the Yellow River to the north and the Song Mountains to the west. As the political, economic and cultural center of Henan Province, Zhengzhou is an important transportation hub and a center of commerce and trade in

China. Zhengzhou is known as the "Green City" and the "Mall" and is positioned as a national comprehensive transportation hub and circulation node city. In 2016, Zhengzhou was officially recognized as the eighth national central city. In addition, Zhengzhou is also one of the eight ancient capitals of China, with a long history and splendid culture as one of the earliest settlements of the Chinese nation and the birthplace of civilization.

The study parks in this paper are mainly located in the main urban area of Zhengzhou City (Figure 2-1), i.e., Jinshui District, Erqi District, Huizi District, Zhongyuan District, and Guanjihuicheng District. According to the statistics of Zhengzhou Bureau of Statistics (https://tjj.zhengzhou.gov.cn/), as of 2021, the total resident population in the central of Zhengzhou is 5,208,500, with a total area of 10.5.3 km^2 and a population density of 4857 persons/km^2.

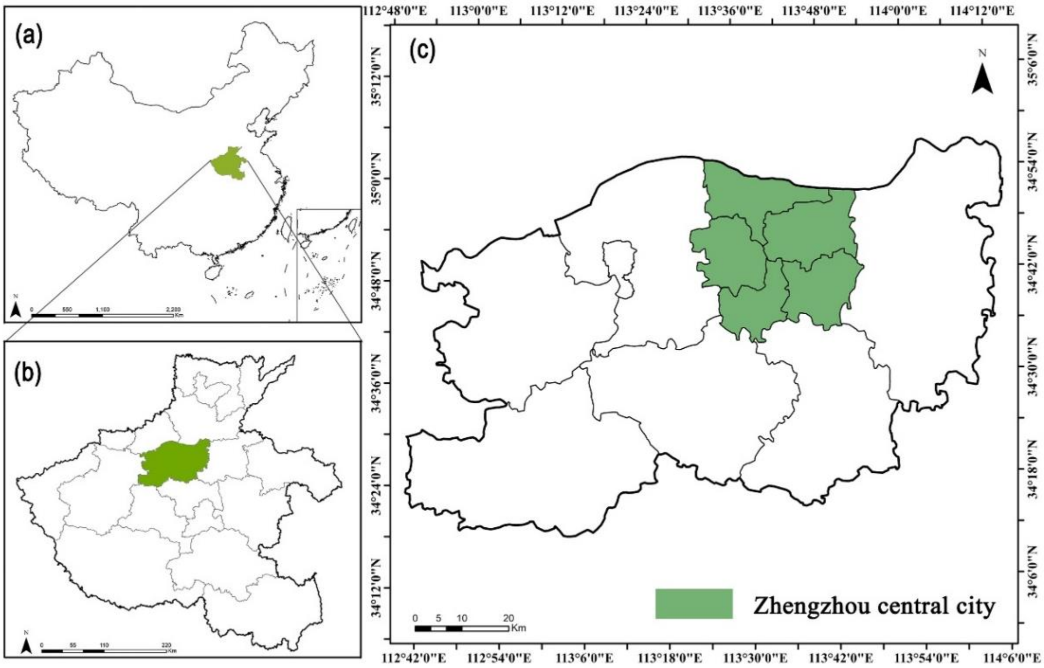


Fig. 2-1 Study area map (a: China; b: Henan Province; c: Zhengzhou Central City) Source: by author

2.1.2 Overview of the physical and geographical environment

2.1.2.1 Terrain topography

The geomorphological characteristics of Zhengzhou City are characterized by high in the southwest and low in the northeast, with the altitude of mountainous areas ranging from 400-1000m, accounting for 31.9% of the total area; the altitude of hilly areas ranging from 200-300m, accounting for 30.3% of the total area; and the plain areas accounting for 37.8% of the total area. The highest point in the city is Yuzhai Mountain, the main peak of Shaomu Mountain, with an altitude of 1512.4m, and the lowest point is around Shaogang in Zhongmou County, with an altitude of 75m. There are various types of landforms with significant differences. The soil of Zhengzhou belongs to the warm temperate brown loam and brown soil zone, and gradually transitions from brown loam to tidal soil from west to east. Brown soil and tidal soil are the main soil types in Zhengzhou, accounting for 54.2% and 30.17% of the total soil area, respectively.

2.1.2.2 Climatic conditions

Zhengzhou has a north temperate continental monsoon climate with four distinct seasons, rain and heat at the same time, hot and rainy in summer and little rain in spring and winter, with obvious seasonal changes in vegetation. The average annual sunshine time can reach 2400 hours, the average annual temperature is 14.3℃, the average humidity is 14.4℃, and the average annual rainfall is about 640mm. Summer rainfall is about 320-380 mm, accounting for 52-55% of the annual precipitation(X. Zhang, 2019).

2.1.2.3 Vegetation Overview

Zhengzhou City is rich in plant resources, mainly distributed within the warm temperate deciduous broad-leaved forest vegetation type. According to the geographical division across, it can be divided into two regions: the cultivated crop vegetation zone in the plain of east Henan and the deciduous broad-leaved forest vegetation zone in the mountains, hills and terraces of west Henan. According to the

Flora of Zhengzhou, there are about 181 families, 941 genera and 2302 species of plants. The common plain greenery species include bubinga, acacia, daikuan poplar, woolly poplar, dry willow, neem, stinky toon, acacia, date palm, persimmon, side cypress, wattle, round cypress, and purple spike acacia, etc.; herbaceous plants include matang, oxalis, dogwood, etc. Artificial vegetation is dominated by wheat and miscellaneous grains, followed by wheat and miscellaneous grains in the second half of the year, and less vegetation in the first half of the year. The main crops include wheat, corn, soybeans, sweet potatoes, grain, sorghum, sesame, cotton, melons, peanuts and tobacco.

·2.1.2.4 Land and River Resources

Zhengzhou is located at the confluence of two major water systems, the Yellow River and the Huai River, and has 124 rivers of all sizes within its borders. The seasonal rivers in the main urban area include the Jalu River, Jinshui River, Xiong'er River and Dongfeng Canal, all of which belong to the Huai River system. Except for the Jalu River, Qili River and Chao River, which have a small amount of baseflow, most of the rivers are drainage channels and lack natural baseflow. The Jalu River is a secondary tributary of the Huai River, originating in the mountains north of Xinmi City and running east-west through the city, and is an important river in the main city. The main tributary, the Jinshui River, flows from southwest to northeast through Guojiazui Reservoir and Dihu Reservoir into Zhengzhou City, while the Xiong'er River originates in Tiesanguanmiao in the southwest of Zhengzhou City, with dense residential areas along its shores, and eventually converges into the Dongfeng Canal. In addition, Zhengzhou City is also dotted with small and medium-sized reservoirs, the middle line of the South-North Water Transfer, artificial canals and waters such as Long Lake, Longzi Lake and Xiliu Lake, which together constitute the water system network of Zhengzhou City(Cai et al., 2022).

2.1.3 Socio-economic overview

As the capital city of Henan Province, Zhengzhou concentrates elements of politics, economy, education, scientific research and culture, and is an important central city in the central region and an important national transportation hub. 2021, the city's gross domestic product was 126.91 billion yuan, up 4.7% year-on-year. Among them, the added value of the primary industry was 18.17 billion yuan, up 2.5%; the added value of the secondary industry was 503.93 billion yuan, up 3.4%; and the added value of the tertiary industry was 747 billion yuan, up 5.6%. The annual per capita disposable income of residents was 39,511 yuan, an increase of 6.0% year-on-year. The per capita disposable income of urban residents was RMB 45,246, an increase of 5.5%; the per capita disposable income of rural residents was RMB 26,790, an increase of 8.1%.

As of the end of 2021, the resident population of Zhengzhou was 12.742 million, and the urbanization rate of the resident population was 79.1%, an increase of 0.7 percentage points from the end of the previous year. The annual birth rate was 8.58 per thousand, the population mortality rate was 4.81 per thousand, and the natural growth rate was 3.77 per thousand(Wang & Tomaney, 2019).

2.1.4 Overview of the park green space

Zhengzhou City had only one zoo, one Greentown Square and three municipal parks before 1992, but over the past 30 years, the Zhengzhou government has developed urban green space planning programs such as the Zhengzhou City Green Space System Plan (2003-2010), the Zhengzhou City Urban Forest Park System Plan (2011-2015) and the Zhengzhou City Green Space System Plan (2013-2030) . Zhengzhou city park green space has entered a period of systematic and large-scale high-speed development.

By 2020, there will be 253 park green areas in the main urban area of Zhengzhou, with a total area of 53.98 km^2. A park green space system has been formed within the main urban area, with comprehensive parks such as People's Park and Bishagang Park as the core, supplemented by special parks, and supported by community parks and pleasure gardens. In general, a large-scale urban park green space network structure has been formed within the main urban area, with rich green space types and structures, which is conducive to the stability and development of the urban park system(H. Li et al., 2020).

2.2 Field Survey Sampling

Based on a comprehensive survey of parks in the main urban area of Zhengzhou, this paper selects 123 park green spaces within the main urban area as the research object, covering all park green space types in Zhengzhou. The specific location map is shown in Figure 2-2.

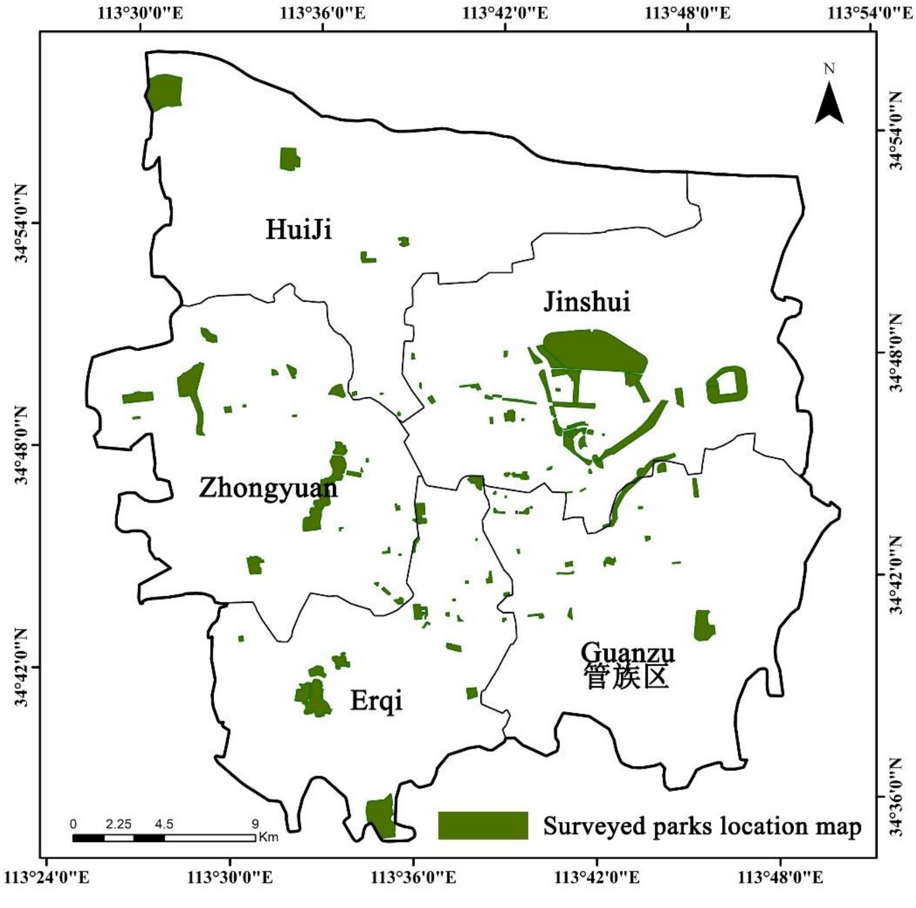


Fig. 2-2 Distribution map of the surveyed parks. Source: by author

In these 123 parks, points were randomly created within the park using the Creat Random Points tool in Arcgis, and an area of approximately 400 m^2 was created as a sample square using these points as the center of a circle. The number of park samples depended on the size of the park, usually one sample for every 2.5 ha in the park, with one sample created for parks smaller than 2.5 ha and up to 25 samples for larger parks. A total of 805 sample squares were eventually surveyed in 123 parks. Field surveys were conducted and completed in July 2021, and the spatial location of each sample square was recorded and generated in ArcGIS. All sample plots were surveyed using the per-wood method, recording data on species, height, branch height, diameter at breast height, east-west crown spread, crown loss rate and dieback rate of all trees in each sample plot; data on species, number, height, basal diameter, crown spread and canopy area of all shrubs were also recorded. The distribution map of the survey sample in some parks is shown in Figure 2-3.

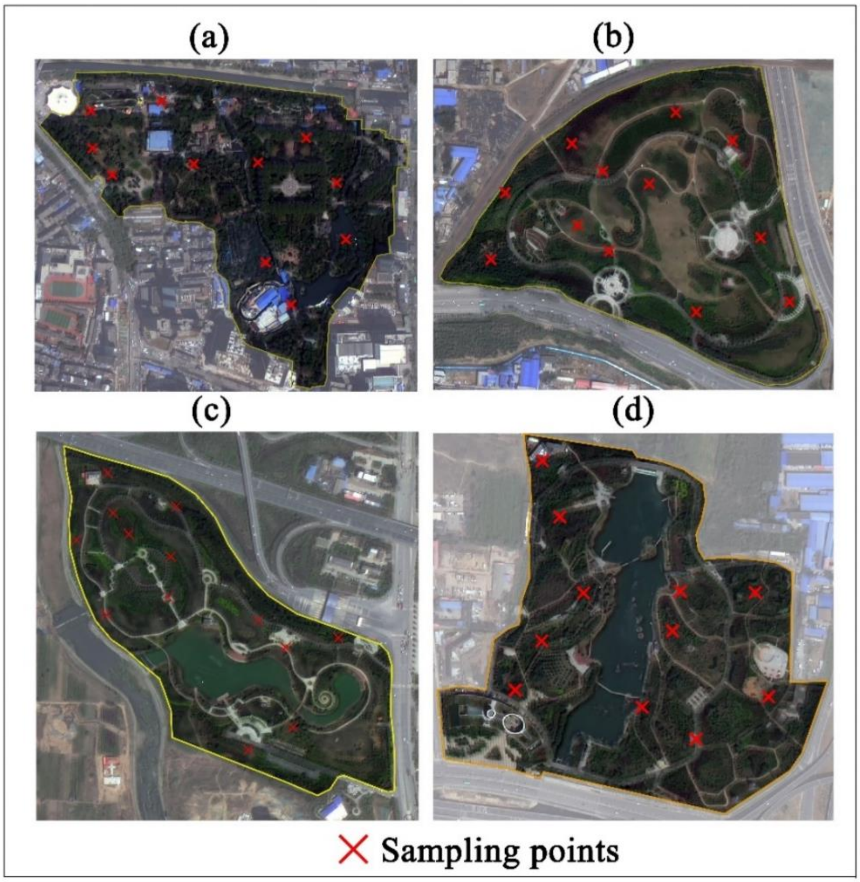


Fig. 2-3 Distribution map of sampling points of some research parks (a: People's Park; b: Green Valley Park; c: Jinhe Park d: Sculpture Park). Source: by author

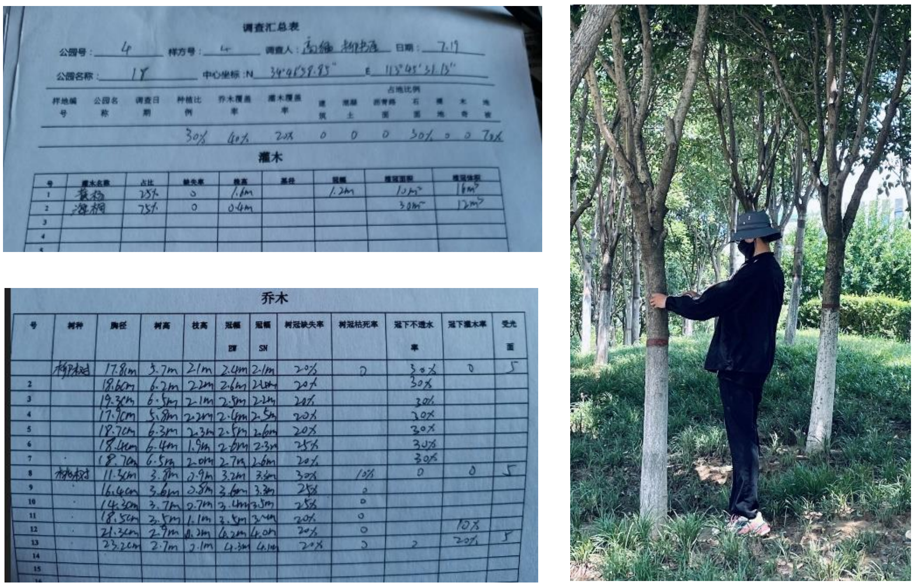


Fig. 2-4 Park field survey record sheet (left); park field survey (right). Source: by author

2.3 Remote Sensing Data

2.3.1 Remote Sensing Image Acquisition

The remote sensing image used in this paper is the remote sensing image of the Gaofen 2 satellite acquired in April 2018 with an accuracy of 0.8m×0.8m.

2.3.2 Remote sensing image pre-processing

In order to improve the overall image quality, enhance the image information expression, improve the visual effect and interpretability of remote sensing images, and improve the data accuracy, the remote sensing images must be pre-processed before classification and NDVI extraction. In this study, the pre-processing is carried out by ENVI 5.3, and the multispectral impact and panchromatic images are processed successively. The steps mainly include atmospheric radiation correction, geometric correction, projection transformation and image fusion.

Atmospheric radiation correction. Atmospheric radiation correction is to eliminate or reduce the electromagnetic radiation in the transmission process by atmospheric molecules, water vapor, aerosols and cloud particles and other atmospheric components such as absorption and scattering of radiation value changes, which can be divided into absolute radiation and relative radiation correction.

Geometric Correction. Geometric correction is to correct the image distortion caused by various factors such as the stability of satellite orbit and imaging attitude, the instantaneous field of view and size of the detector, uneven terrain, scanning deviation, atmospheric refraction, and the rotation of the Earth, etc. The process mainly includes image coordinate transformation and image resampling.

Projection Transformation. A projection transformation is the process of converting the coordinates of one map projection point to the coordinates of another map projection point and can be done by projection transformation and reprojection as needed.

Image fusion. By fusing multispectral low-resolution images with high-resolution panchromatic bands to obtain a more informative remote sensing image.

2.3.3 Land use information extraction

To interpret and classify the images, this study used a combination of supervised classification and manual interpretation. To generate the primary classification raster file in ENVI 5.3 Classification Workflow tool, training data were selected for each class using the Maximum Likelihood Algorithm. This study's land covers were divided into four categories (i.e., vegetation, impervious surface, water body, and bare soil). The images explicitly demonstrate the distribution of Surface information in Zhengzhou and can thus be used to map urban classification effectively. Vegetation included all vegetated areas, also known as green space. Impervious surfaces included transportation, industrial, commercial, and residential space. Lakes and rivers were the most common types of water bodies. Bare soil referred to construction sites and non-vegetative areas. The accuracy of the land cover classification was evaluated. The accuracy of the land cover classification was evaluated. The overall accuracy was 97.7552% and the kappa coefficient was 0.9519(Figure 2-5).

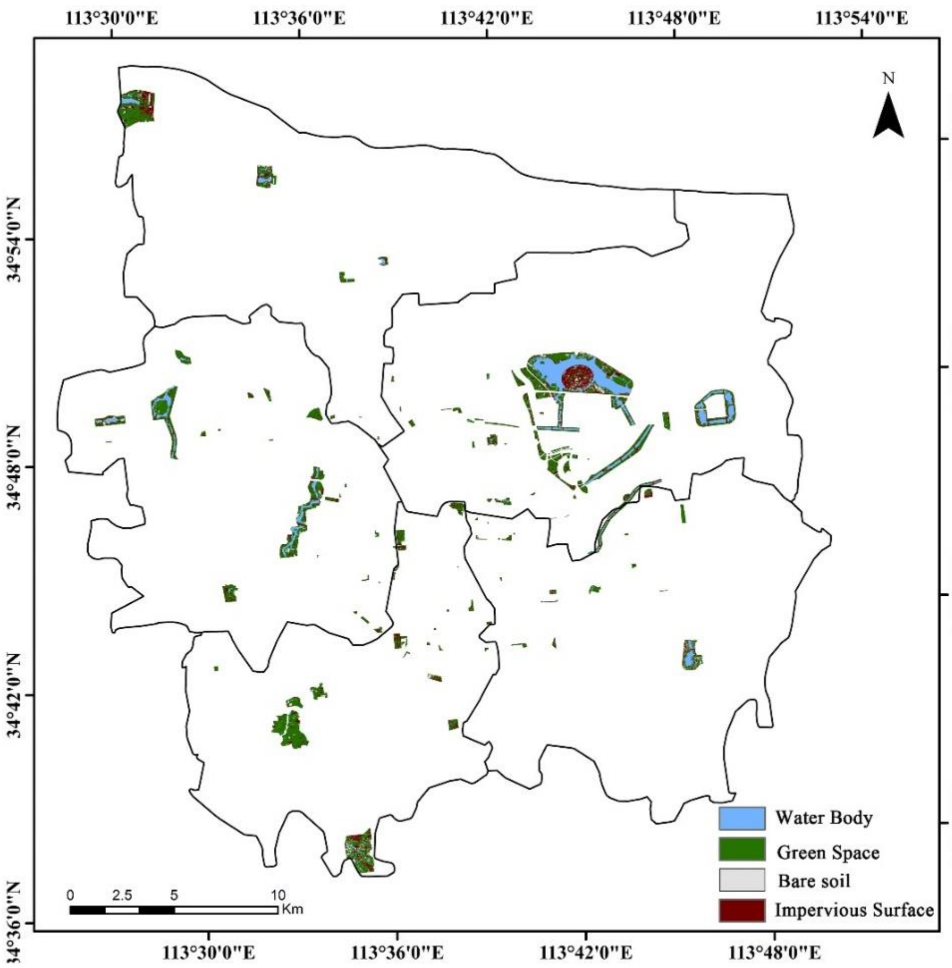


Fig 2-5 Park land use classification map. Source: by author

2.3.4 Park classification

Based on the results of park area, location, and site classification, 123 parks in Zhengzhou were classified into four categories in order to further analyze the heterogeneity of carbon storage in different types of parks and their influencing factors. These include classifying parks into less than 2 ha, 2-5 ha, 5-10 ha, and over 50 ha based on area. The parks were classified into the first, second, third, fourth and fifth rings based on their location in the Zhengzhou ring road. The parks are classified as water parks and non-water parks based on whether they contain water inside the park. The parks are divided into urban parks, Theme parks, belt parks, community parks and street park based on park characteristics (Table 1).

Table 1. Park classification criteria, results and description.

Classification standards	Park Type	Description
Park character	Urban Park	Over 10 ha; large green space with full facilities.
	Community Park	Local green space for daily leisure activities for residents; The area should be greater than 1 ha.
	Theme Park	including children's parks, zoos, botanical gardens, etc. with specific themes. Area range 1ha to 250 ha
	Belt Park	Narrow green spaces along city roads, city walls, waterfronts, etc. Width should be greater than 12 m.
	Street Park	Close to city streets, independent green spaces, including street and square green spaces. Area from 0.3 ha to 50 ha.
Park Location	1^{st} Ring Park	Parks located within the first ring road of the city
	2^{nd} Ring Park	Parks located on the 1st ring road and 2nd ring road of the city
	3^{rd} Ring Park	Parks located on the 2nd ring road and 3rd ring road of the city
	4^{th} Ring Park	Parks located on the 3rd ring road and 4th ring road of the city
	5^{th} Ring Park	Parks located outside the city's 5th ring road
Park Size	< 2 ha park	Parks less than 2 hectares in size
	2-5 ha park	Parks of 2-5 hectares in size
	5-10 ha park	Parks of 5-10 hectares in size

	10-50 ha park	Parks of 10-50 hectares in size
	>50 ha park	Parks larger than 50 hectares in size
Park with or without water	Park with water	The park has water resources such as lakes, streams and rivers.
	Park without water	No water resources such as lakes, creeks and rivers inside the park

2.4 Carbon storage and carbon storage density estimation methods for parks

The carbon storage and carbon storage density of the park and sample sites in this study were mainly calculated by the i-Tree Eco model.

The i-Tree model is a software developed by the US Forest Service in 2006. The current version of i-Tree v6.0.23 includes the following modules: i-Tree Landscape, i-Tree Canopy, i-Tree Design, and i-Tree Eco. i-Tree Landscape provides information on the location, canopy, land cover, and basic population of the area to understand how trees produce i-Tree Canopy uses random sampling to estimate tree cover and tree benefits for a given area. i-Tree Design is used to understand the value of a single tree or a small number of trees to a community. i-Tree Eco uses field data and local hourly air pollution and meteorological data to quantify the urban forest structure and its resulting ecological impacts, including 1) structural and compositional analyses: tree species status and distribution, leaf area and biomass, and species importance values; and 2) functional analyses: removal of air pollutants, carbon sequestration and storage, oxygen production benefits, and hydrological effects (including sequestration, transpiration, etc.).

After entering the tree information obtained from the field survey into the I-Tree Eco model, the model selects different allometric growth equations according to tree species categories and calculates the carbon storage of each plant in the sample square based on the information of diameter at breast height and tree height. The model selects the allometric growth equation based on the proximity principle, and the allometric growth equation of species in the same genus or family is adopted for the species without allometric growth equation.

In this study, the carbon storage in the sample square is the sum of carbon storage of all single woods in the 20m*20m sample square, which is calculated as follows:

$$CSi = \sum_{i=1}^{n} Si \tag{1}$$

Where CSi is the carbon storage of sample i ,Si is the carbon storage of the i tree in the sample square， n is the number of trees in the sample square.

The sample carbon storage density was then calculated as the sample carbon storage divided by the total area of green space in the sample, which was calculated as follows:

$$SDi = \frac{CSi}{ASi} \tag{2}$$

Where SDi is the carbon storage density of sample i, CSi is the carbon storage of sample i, and ASi is the green area of sample i.

The park carbon storage is the product of the carbon storage per unit green space area of the sample square in the park and the total green space area of the park, which is calculated as follows:

$$PCi = \frac{STi}{CGi} \times PGi \tag{3}$$

Where PCi is the carbon storage of park i, STi is the sum of carbon storage of all sample areas in park i, CGi is the sum of green areas of all sample areas in park i, and PGi is the total green area of park i.

The park carbon storage density is calculated as the park carbon storage divided by the total area of park green space, which is calculated as follows:

$$PDi = \frac{PCi}{GAi} \tag{4}$$

Where, PDi is the carbon storage density of park i, PCi is the carbon storage of park i, and GAi is the total area of green space of park i.

2.5 Landscape pattern index selection

The landscape index is a quantification of landscape pattern information, which integrates information on the number, type, proportion and spatial pattern of landscapes in the landscape pattern. Based on the selection of previous landscape pattern indices in Zhengzhou, this study selected 7 landscape pattern indices to quantify the landscape pattern of park green space (Du et al., 2022; K. Zhang et al., 2023). They are SPLIT, which characterizes the degree of landscape fragmentation, LSI, which characterizes the complexity of landscape shape, AI, which characterizes the degree of landscape aggregation, SHEI, which characterizes the homogeneity of the landscape, PLAND, which characterizes the proportion of the landscape area occupied by patches, and NP, which characterizes the number of patches. The maximum patch index (LPI) and the number of patches index NP. ecological connotations of specific landscape indices can be seen in Table 2 and Figure 2-6.

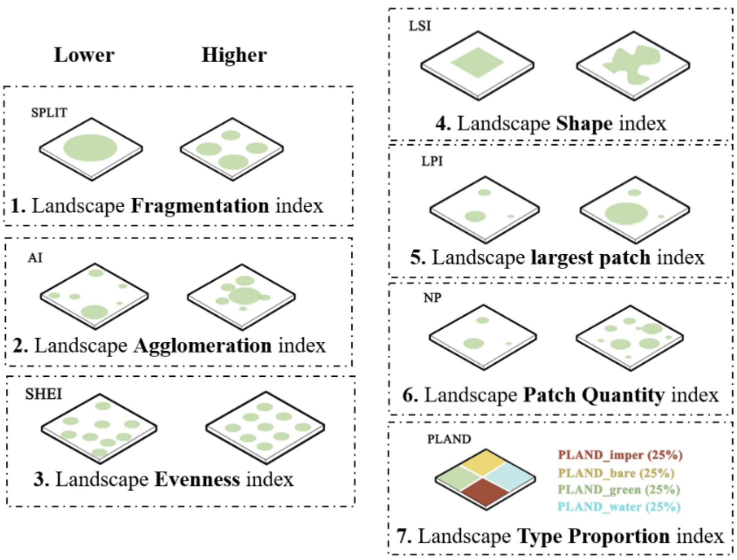


Fig 2-6 Illustration of the meaning of landscape pattern index. Source: by author

Then, this study uses Fragstats 4.2, based on the 8-unit neighborhood method, to calculate the landscape indices for each parks separately.

Table 2 Landscape Index and Description

Metric Name	**Abbreviations**	**Description**
Number of patches	NP	Reflecting the spatial pattern of the landscape, the magnitude of the value is positively correlated with the fragmentation of the landscape, the larger the value, the higher the degree of fragmentation.
Aggregation index	AI	It reflects the aggregation degree of different plaque types in the landscape, and the larger the value, the more concentrated the plaques.
Shannon's evenness index	SHEI	Reflecting the uniformity of the distribution of landscape types, a value close to 1 indicates low landscape dominance, high diversity, and a more uniform distribution of patch types.
Percentage of Landscape	PLAND	It is used to calculate the relative proportion of a patch type to the overall landscape area and is one of the bases for determining the dominant landscape element in the landscape.
Largest Patch Index	LPI	The degree to which a landscape type is occupied by large patches reflects the dominance of the landscape type, and its value changes to reflect the direction and intensity of human activities.
Landscape Fragmentation	SPLIT	SPLIT is an 'Aggregation metric'. It describes the number of patches if all patches the landscape would be divided into equally sized patches.

2.6 Statistical Analysis

In order to quantify the relationship and influence between landscape pattern and park carbon storage, this study used Pearson correlation analysis to calculate the correlation between the two. In the correlation analysis results, the degree of correlation and the nature of correlation are judged based on the magnitude, positive and negative of the correlation coefficient (r).

3. Results

3.1 Overview of carbon sinks in Zhengzhou city parks

First, the results showed that the total carbon storage capacity of 123 parks in Zhengzhou was 108.5 Gg C, and the carbon storage density was 5.36 kg C m^{-2}.

Secondly, among the 123 studied parks in Zhengzhou, the top ten parks with the largest areas were Park ID11,87,84,12,91,122,82,110,123,10. Among them, parks ID11,87 and 84 have an area of 321.6 ha, 233 ha and 232 ha, respectively.

However, in contrast, the 10 parks with the highest annual carbon sequestration density were Park ID 20, 24,25,26,61,40,27,99,30. The annual carbon sequestration densities of parks 20, 24 and 25 were 2.63 kg C m^{-2} y^{-1}, 2.62 kg C m^{-2} y^{-1} and 2.33 kg C m^{-2} y^{-1}, respectively (Fig 3-1).

It was concluded from the comparison of the list of top 10 parks with park area and top 10 parks with carbon sink capacity that park area does not directly equate to the carbon sink capacity of a park. In other words, a park with a large area does not always have a high carbon sequestration capacity.

For example, the park with the largest area, ID 11, has an annual carbon sequestration density of only 1.21 kg C m^{-2} y^{-1}, ranking 16th among all parks. this result suggests that we can explore the factors affecting the size of carbon sinks by analyzing parks with small areas but high carbon sink capacity, and thus improve the carbon sink capacity of parks. In addition, this result also indicates that the potential of carbon sink enhancement in parks is huge and the study of carbon enhancement in parks is fully feasible.

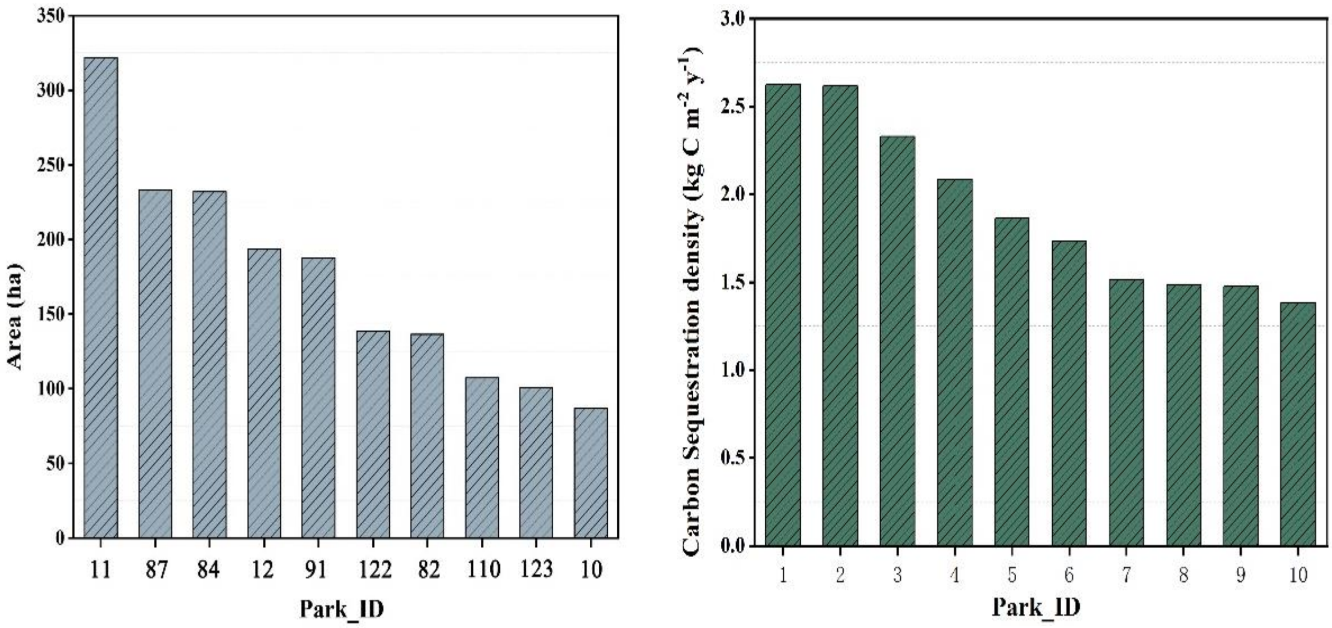


Fig 3-1 Top 10 park IDs in area (left) and top 10 park IDs in carbon sink capacity (right).

Source: by author

3.2 Differences in carbon sinks of different types of parks

Figure 3-1 has shown that there are obvious differences in carbon sinks among different parks. By classifying the parks according to different criteria (Table 2) and then comparing them item by item, it is important to study the carbon storage heterogeneity of parks and its causes in a deeper way.

3.2.1 Differences in carbon sinks in different characteristics parks

Based on the Chinese park green space classification standard, this study classified parks in Zhengzhou into street parks, community parks, belt parks, integrated parks, and theme parks.

The median carbon sequestration density of street parks, community parks, strip parks, comprehensive parks and theme parks were 0.38 kg C m^{-2} y^{-1}, 0 .34 kg C m^{-2} y^{-1}, 0.41 kg C m^{-2} y^{-1}, 0.5 kg C m^{-2} y^{-1} and 0.69 kg C m^{-2} y^{-1}, respectively. Theme parks had the strongest carbon sink capacity and community parks had the weakest, with a difference of 0.35 kg C m^{-2} y^{-1} between them (Figure 3-2).

This difference may be since these two types of parks have different functions and serve different populations, which indirectly leads to the difference in their carbon sinks.

For theme parks, in China they are mostly zoos, botanical gardens, sculpture parks and so on. These parks are generally characterized by large area and greenery. In addition, these parks generally have a large number of plants, a wide range of species, and a high planting density. In some botanical gardens, landscape architects will carefully design dense three-dimensional plant communities to increase the aesthetics of the garden, such as trees, shrubs, and herbs planted together. This, on the other hand, also increases the park's carbon sink capacity.

For community parks, this type of park is generally located near urban neighborhoods with a high density of urban residents. Since community parks mainly serve the surrounding residents, they have the characteristic of being frequently used by a large number of people. Therefore, this type of park generally has the characteristics of small area and many service facilities (impervious surface). Therefore, the corresponding green area is reduced, the number of plants is reduced, and the carbon sink capacity of the parks is relatively weak.

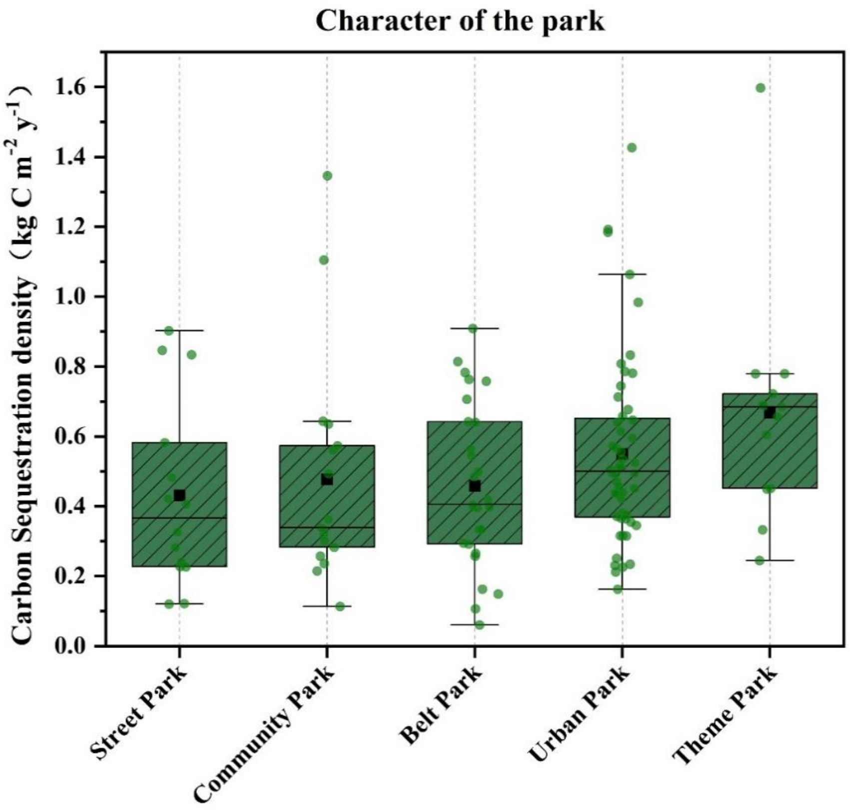


Fig 3-2 Differences in carbon sink capacity of different character parks. Source: by author

3.2.2 Differences in carbon sinks in different locations of parks

Based on the location of the parks in the urban loop, the parks were classified into 1st, 2nd, 3rd, 4th, and 5th parks.

The median carbon sequestration density of 1st, 2nd, 3rd, 4th, and 5th parks were 0.49 kg C m^{-2} y^{-1}, 0.51 kg C m^{-2} y^{-1}, 0.42 kg C m^{-2} y^{-1}, 0.48 kg C m^{-2} y^{-1}, and 0.5 kg C m^{-2} y^{-1}, respectively. The carbon sink capacity was higher in the parks located in the center of the city (1st and 2nd) and weaker in the parks located at the edge of the city (Figure 3-3).

The reason for this difference may be the difference in park characteristics in different locations in the city.

For parks in urban centers, they tend to be more frequently used and people pay more attention to park design and maintenance. Therefore, landscape architects are more likely to design parks to be richer in plants, which directly means more plant species and a denser plant set. In addition, more attention is paid to the maintenance of parks in urban centers, which means that plants have better growth conditions. The plants in urban centers are healthier and less susceptible to disease than those in urban fringe parks.

However, for plants in urban fringe parks, these parks tend to be larger in size and have a large number of plants but a single species. Also, the attention to plant maintenance is not as high as that of urban center parks.

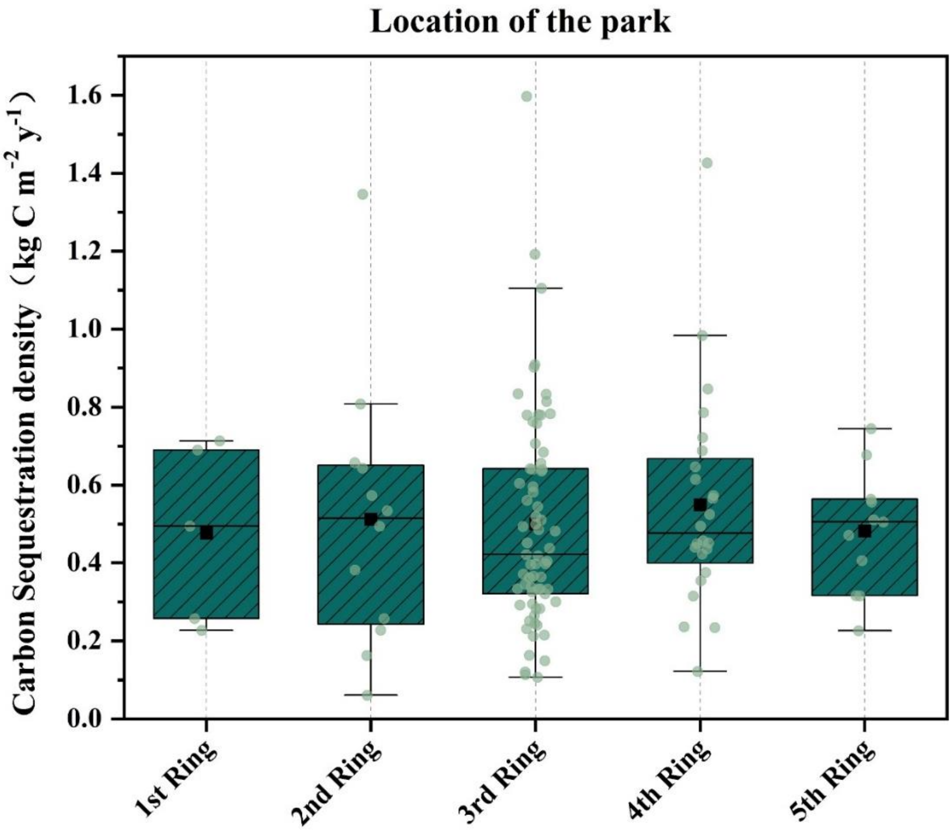


Fig 3-3 Differences in carbon sink capacity of parks in different locations. Source: by author

3.2.3 Differences in carbon sinks in different size parks

Based on the different park areas, the parks in Zhengzhou were classified into < 2 ha park, 2-5 ha park, 5-10 ha park, 10-50 ha park and >50 ha park in this study.

The median carbon sequestration density of < 2 ha park, 2-5 ha park, 5-10 ha park, 10-50 ha park and >50 ha park were 0.41 kg C m^{-2} y^{-1}, 0 .49 kg C m^{-2} y^{-1}, 0.39 kg C m^{-2} y^{-1}, 0.52 kg C m^{-2} y^{-1} and 0.50 kg C m^{-2} y^{-1}, respectively. It is noteworthy that The results of the study indicate that the carbon sink capacity of the park does not consistently increase with the increase in park area. (Figure 3-4)

The reason for this difference may be because there are many factors that affect the carbon sink capacity of parks, such as landscape structure, plant species, and plant density. A large park area often equates to a large green area and a large number of plants, but a denser planting, a more scientific selection of carbon sequestering plant species, and a more reasonable spatial structure can significantly improve the carbon sink capacity of a park. Therefore, in Zhengzhou City, a large park area is not absolutely better than a small park area in terms of carbon sink capacity.

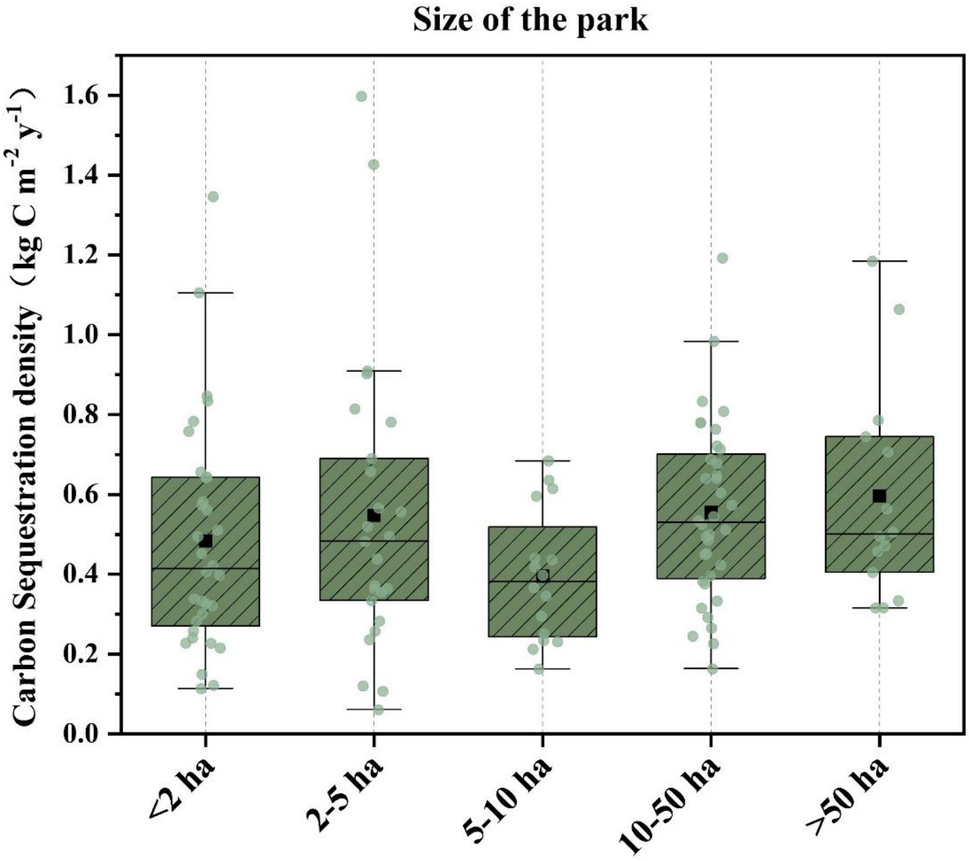


Fig 3-4 Differences in carbon sink capacity of different size parks. Source: by author

3.2.4 Differences in carbon sinks in parks with and without water

Based on the presence or absence of rivers, lakes and streams in the park, the park in Zhengzhou was classified into with water park and without water park.

The results showed that the median carbon sequestration density of with water park and without water park were 0.53 kg C m^{-2} y^{-1} and 0.44 kg C m^{-2} y^{-1}, respectively. The carbon sink capacity of with water park was significantly higher than that of without water park (Figure 3-5).

The reason for this difference may be that plants in with water park grow faster and are healthier because they are irrigated with sufficient water. It is also possible that the with water park has a large number of aquatic plants. And the landscape architects usually design the current green space and dense vegetation at the water's edge. These measures indirectly increase the carbon sink of with water park.

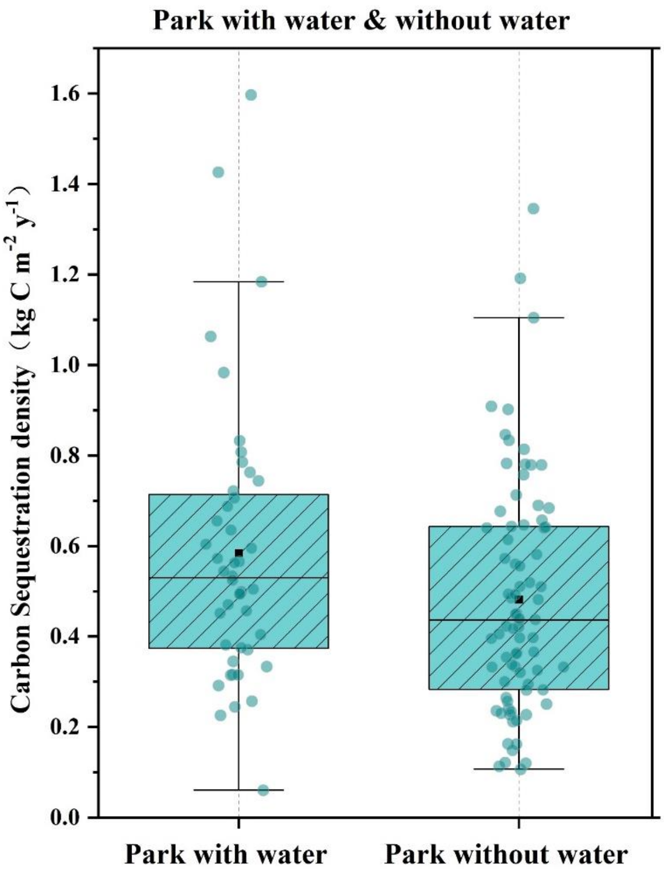


Fig 3-5 Differences in carbon sinks between parks with and without water. Source: by author

3.3 Correlation between landscape pattern index and park carbon sink

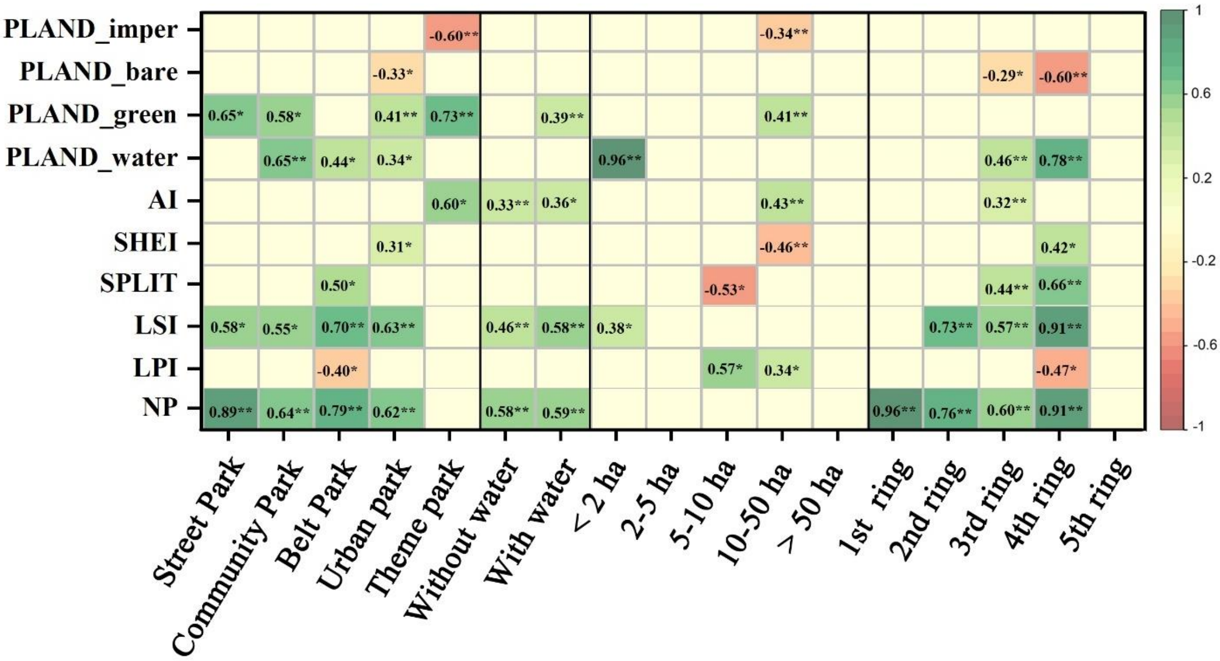


Fig 3-6 Results of Pearson correlation analysis of carbon sink and landscape pattern indices in different types of parks. Source: by author

Through Pearson correlation analysis, this chapter calculates the correlation between carbon sinks of different types of parks and the landscape pattern index. The results show that almost every type of park carbon sink is significantly correlated with the landscape pattern index. And the landscape pattern indices associated with different types of parks are different (Figure 3-6).

Firstly, for the different park types, almost all of them are significantly and positively correlated with PLAND_green, LSI and NP.

In more detail, for street parks, carbon sinks are significantly and positively correlated with PLAND_green, LSI and NP, with correlation indices (r) of 0.65, 0.58 and 0.89, respectively.

For community parks, carbon sinks were significantly and positively correlated with PLAND_green, PLAND_water, LSI and NP with correlation indices (r) of 0.58, 0.65, 0.55 and 0.64, respectively. carbon sinks in community parks were significantly and positively correlated with PLAND_water, SPLIT, LSI and NP (r = 0.44, 0.50, 0.70 ,0.79, respectively). In addition, the carbon sink of community park was significantly and negatively correlated with LPI with a correlation index of -0.40.

For Urban Park, there were more landscape pattern indices with significant positive correlation, namely PLAND_green, PLAND_water, SHEI, LSI and NP, with correlation indices of 0.41, 0.34, 0.31, 0.63 and 0.62, respectively. PLAND_bare is negatively correlated with Urban Park, with a correlation index of -0.33;

Lastly, for Theme Park, PLAND_imper was significantly negatively correlated with carbon sink (r= -0.60), while PLAND_green and AI were significantly positively correlated with carbon sink (r=0.73 and 0.60).

Secondly, the landscape pattern indices associated with both with water park and without water park were basically similar.

For the carbon sinks in the without water park, AI, LSI and NP were significantly and positively correlated (r = 0.33, 0.46 and 0.58, respectively).

For with water park, the landscape pattern indices with significant positive correlations with carbon sinks were PLAND_green, AI, LSI and NP, with correlation indices of 0.39, 0.36, 0.58 and 0.59, respectively.

Third, for carbon sinks in parks of different sizes, the landscape pattern indices associated with them vary greatly, and there are even two types of parks that do not correlate with all landscape pattern indices.

For parks smaller than 2 ha, only two landscape pattern indices were significantly and positively correlated, namely PLAND_water and LSI (r = 0.96 and 0.38).

For parks 5-10 ha in size, LPI was significantly positively correlated with park carbon sink (r = 0.57). SPLIT was significantly negatively correlated with park (r = -0.53).

For the 10-50 ha park carbon sink, the landscape pattern indices with significant positive correlation were PLAND_green, AI and LPI with correlation indices of 0.41, 0.43 and 0.34, respectively. the landscape pattern indices with significant negative correlation were PLAND_imper and SHEI with correlation indices of -0.34 and -0.46, respectively. 0.34 and -0.46, respectively.

However, no landscape pattern was correlated for parks with area of 2-5 ha and those with area larger than 50 ha.

Finally, the landscape pattern indices associated with the classification of parks located in different loops of the city also differed significantly and were mostly concentrated in the parks in the 3rd and 4th loops.

For parks located in the first ring road of the city, only one landscape index was significantly and positively correlated with park carbon sinks, and that was NP ($r = 0.96$).

for the parks located in the 2nd urban ring road, LSI and NP were significantly positively correlated with park carbon sinks with correlation indices of 0.73 and 0.76, respectively.

For the park in the third ring road, the landscape pattern indices that were significantly and positively correlated with the park carbon sink were PLAND_water, AI, SPLIT, LSI and NP, with correlation indices of 0.46, 0.32, 0.44, 0.57 and 0.60, respectively. In addition, PLAND_bare was significantly and negatively correlated with this type of park ($r = -0.29$).

For parks in the 4th urban ring road, their carbon sinks were significantly and positively correlated with PLAND_water, SHEI, SPLIT, LSI and NP, with correlation indices of 0.78, 0.42, 0.66, 0.91 and 0.91, respectively. In addition, the landscape pattern indices that were significantly and negatively correlated with the parks were PLAND_bare and LPI, with correlation indices of - 0.60 and -0.47, respectively.

Lastly, the park in the 5th ring road of the city did not have any landscape pattern indices associated with it.

In general, landscape pattern indices are significantly correlated with park carbon sinks with certain patterns. In more detail, among the landscape pattern indices related to park carbon sinks, PLNAD_imper, PLAND_bare and LPI generally showed significant negative correlations, while NP, LSI, AI, PLAND_green and PLAND_water generally showed significant positive correlations. This indicates that it is feasible to increase park carbon sinks by adjusting the spatial pattern of park landscape, and different adjustment strategies need to be proposed according to different types of parks.

4. Proposal

4.1 Carbon sink enhancement strategies for different types of parks from spatial structure

Firstly, in Zhengzhou City, parks with large areas do not equate to parks with high carbon sink capacity, which means that the carbon sink capacity of parks in Zhengzhou City has great potential for improvement.

Secondly, there are significant differences in carbon sink density among different types of parks, and the landscape pattern indices associated with carbon sinks in various types of parks are different. This directly indicates that park carbon sink enhancement should propose different strategies according to the characteristics of different types of parks.

Finally, based on the results of the correlation analysis of carbon sinks and landscape pattern indices for different types of parks in Zhengzhou, this chapter proposes corresponding carbon sink enhancement strategies for each type of parks in Zhengzhou from the perspective of spatial configuration.

4.1.1 Spatial design strategies for parks with different characteristics

4.1.1.1 Street Park

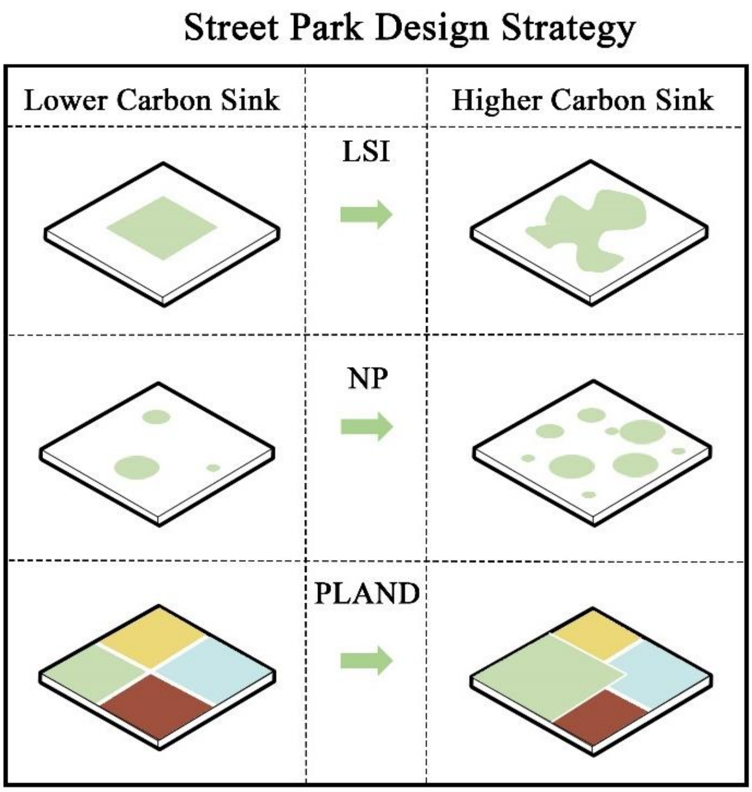


Fig 4-1 Illustration of Street Park design strategy. Source: by author

The landscape pattern indices correlated with the carbon sink of Street park are PLAND_green, LSI and NP (Figure 3-6). Therefore, the spatial design strategies of the street park are mainly (Figure 4-1):

1) Increase the proportion of green space in the space. a higher value of PLAND_green, the proportion of green space, means a larger proportion of green space in the space. the carbon sink of Street park has a significant positive correlation with PLAND_green, which means that the higher the proportion of green space patches in Street park, the higher the carbon sink.
2) Increase the complexity of patches in the space. higher value of LSI (Landscape Shape Index) means more complex shape of patches. the carbon

sink of Street park has a significant positive correlation with LSI, which means the more complex shape of patches in Street park, the higher the carbon sink.

3) Increase the number of patches in the space, NP, the number of patches index, the larger the value means the more the number of patches, the carbon sink of Street park has a significant positive correlation with NP index, which means the more the number of patches in Street park, the higher the carbon sink.

In conclusion, for Street park, the spatial design carbon sink enhancement strategy is mainly to increase the complexity of patches, the number of patches and the proportion of green space patches.

4.1.1.2 Community Park

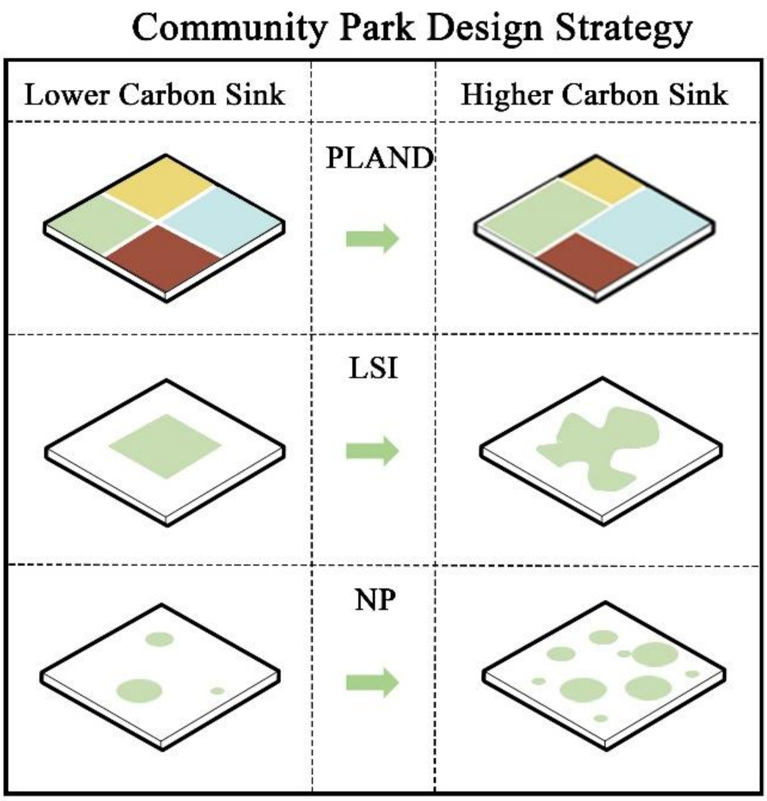


Fig 4-2 Illustration of Community Park design strategy. Source: by author

The landscape pattern indices associated with the carbon sink of Community Park are PLAND_green, PLAND_water, LSI and NP (Figure 3-6). Therefore, the spatial design strategies of Community Park are (Figure 4-2):

1) Increase the proportion of green space in the space, PLAND_green, the proportion of green space, the larger the value means the larger the proportion of green space in the space. the carbon sink of Community park has a significant positive correlation with PLAND_green, which means the higher the proportion of green space in the Community park, the higher the carbon sink.
2) Increase the proportion of water bodies in the space. PLAND_water, the proportion of water bodies in the space, means the larger the proportion of water bodies in the space.
3) Increase the complexity of patches in the space. higher value of LSI (patch shape index) means more complex shape of patches. the carbon sink of Community park has a significant positive correlation with LSI, which means the more complex shape of patches in Community park, the higher the carbon sink.
4) Increase the number of patches in the space, NP, the number of patches index, the higher the value means the more the number of patches, the carbon sink of Community Park has a significant positive correlation with NP index, which means the more the number of patches in Community park, the higher the carbon sink.

In conclusion, for Community Park, the spatial design carbon sink enhancement strategy is mainly to increase the proportion of green space and water body patches. The complexity and number of patches are enhanced.

4.1.1.3 Belt Park

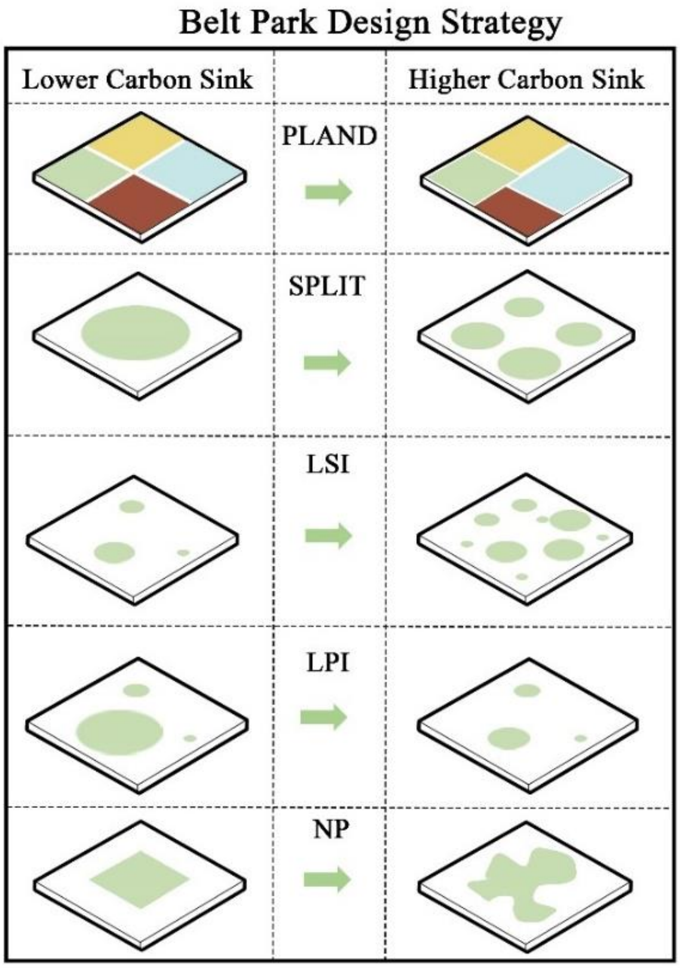


Fig 4-3 Illustration of Belt Park design strategy. Source: by author

The landscape pattern indices associated with the Belt park carbon sink are PLAND_water, SPLIT, LSI, LPI and NP (Figure 3-6). Therefore, the spatial design strategies of Belt park are mainly (Figure 4-3):

1) Increase the proportion of water bodies in the space. a larger value of PLAND_water, the proportion of water bodies, means a larger proportion of water body area in the space. the carbon sink of Belt park has a significant positive correlation with PLAND_water, which means the higher the proportion of water body patches in the Belt park, the higher the carbon sink.
2) Increase the fragmentation of patches in space. higher value of SPLIT

(Landscape Fragmentation Index) means higher fragmentation of patches in space. the carbon sink of Belt park has a significant positive correlation with SPLIT, which means that the more fragmented patches in Belt park, the higher the carbon sink.

3) Increase the complexity of patches in space. higher value of LSI (patch shape index) means more complex shape of patches. the carbon sink of Belt park has a significant positive correlation with LSI, which means the more complex shape of patches in Belt park, the higher the carbon sink.
4) Reduce the area of the largest patch in the space. a larger value of LPI (Landscape Maximum Patch Index) means a larger area of the largest patch in the space. the carbon sink of Belt park has a significant negative correlation with LPI, which means the smaller the area of the largest patch in Belt park, the higher the carbon sink.
5) Increase the number of patches in the space, NP, the number of patches index, the higher the value means the number of patches, the carbon sink of Belt park has a significant positive correlation with NP index, which means the more the number of patches in the Belt park, the higher the carbon sink.

In conclusion, for Belt park, the spatial design carbon sink enhancement strategy is mainly to increase the proportion of water body patches. Enhance the fragmentation, complexity and number of patches. In addition, the area of the largest patch can be reduced appropriately.

4.1.1.4 Urban Park

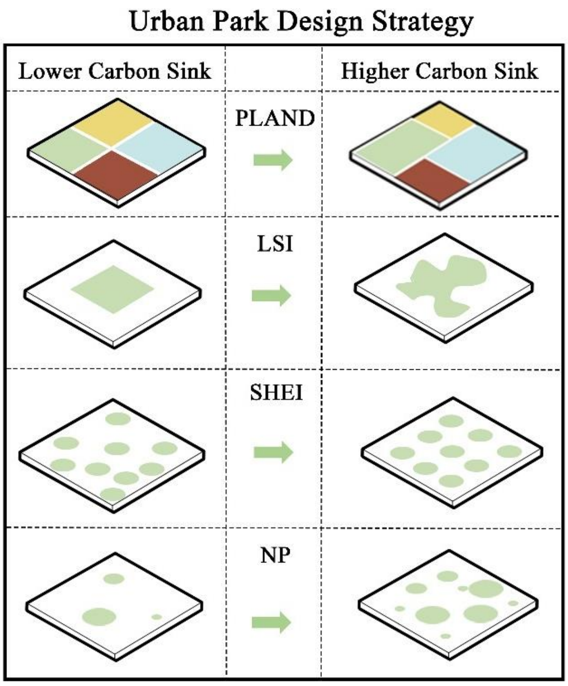


Fig 4-4 Illustration of Urban Park design strategy. Source: by author

The landscape pattern indices associated with the carbon sink of Urban park are PLAND_bare, PLAND_green, PLAND_water, SHEI, LSI and NP (Figs. 3-6). Therefore, the spatial design strategies of Urban Park are mainly (Figure 4-4):

1) Reduce the proportion of bare land in the space. higher value of PLAND_bare, the proportion of bare land, means the proportion of bare land in the space is larger. the carbon sink of Urban Park has a significant negative correlation with PLAND_bare, which means the higher the proportion of bare land patches in Urban park, the higher the carbon sink.
2) Increase the proportion of green space in the space. PLAND_green, the proportion of green space, means that the proportion of green space in the space is larger.
3) Increase the proportion of water bodies in the space, PLAND_water, the proportion of water bodies, the larger the value means the larger the proportion of water bodies in the space, and the carbon sink of Urban park has a significant positive correlation with PLAND_water, which means the higher

the proportion of water body patches in Urban park, the higher the carbon sink.

4) Increase the uniformity of spatial patch distribution, SHEI (Landscape Patch Evenness Index), a larger value means a more uniform distribution of spatial patches.

5) Increase the complexity of patches in the space. higher value of LSI means more complex shape of patches. the carbon sink of Urban park has a significant positive correlation with LSI, which means the more complex shape of patches in Urban park, the higher the carbon sink.

6) Increase the number of patches in the space, NP, the number of patches index, the higher the value means the more the number of patches, the carbon sink of Urban park has a significant positive correlation with NP index, which means the more the number of patches in Urban park, the higher the carbon sink.

In conclusion, for Urban park, the spatial design carbon sink enhancement strategy is mainly to increase the proportion of water body and green space patches and reduce the proportion of bare land. Enhance the uniformity, complexity and number of patches.

4.1.1.5 Theme Park

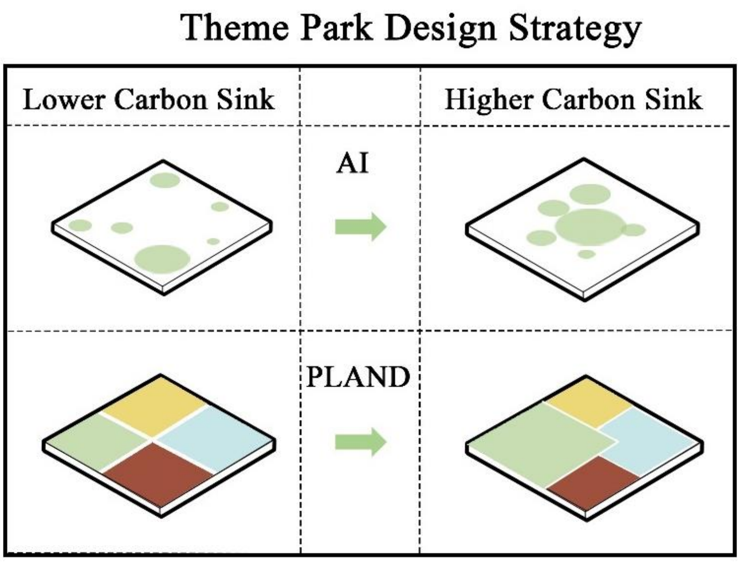


Fig 4-5 Illustration of Theme Park design strategy. Source: by author

The landscape pattern indices related to the carbon sink of Theme park are PLAND_imper, PLAND_green and AI (Figs. 3-6). Therefore, the spatial design strategies of Urban park are mainly (Figure 4-5):

1) Decrease the proportion of impervious area in the space. higher value of PLAND_imper, the proportion of impervious surface, means the greater the proportion of impervious surface in the space. the carbon sink of Theme park has a significant negative correlation with PLAND_imper, which means the higher the proportion of impervious surface in Theme park, the higher the carbon sink.
2) Increase the proportion of green space in the space. PLAND_green, the proportion of green space, means that the proportion of green space in the space is larger.
3) Increase the degree of aggregation of patches in the space, AI (landscape patch aggregation index), the higher the value means the more aggregated patches in the space, and the carbon sink of Theme park has a significant positive correlation with AI, which means the higher the degree of aggregation of patches in Theme park, the higher the carbon sink.

In conclusion, for Theme park, the spatial design carbon sink enhancement strategy is mainly to reduce the proportion of impervious surface and increase the proportion of green space patches. In addition, the degree of aggregation of patch distribution should be enhanced.

4.1.2 Spatial design strategies for parks with and without water

4.1.2.1 Without water park

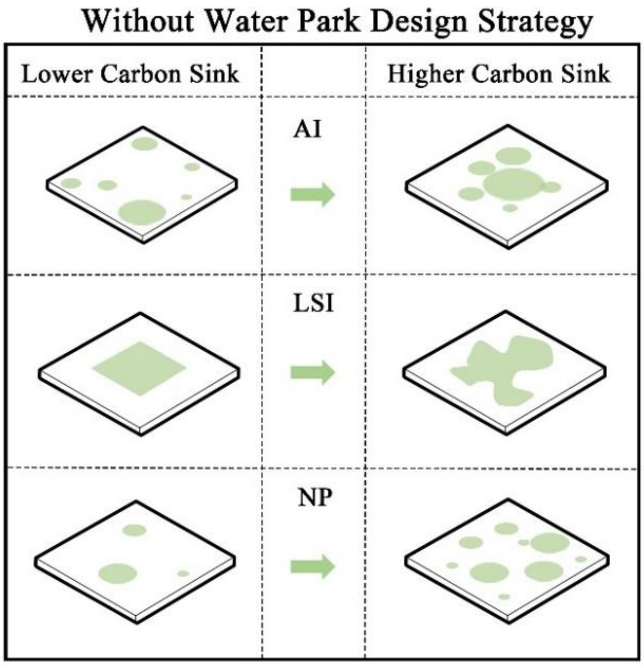


Fig 4-6 Illustration of Without Water Park design strategy. Source: by author

The landscape pattern indices associated with the carbon sink of Without water park are AI, LSI and NP (Figs. 3-6). Therefore, the spatial design strategy of Without water park is mainly (Figure 4-6) to

1) Increase the degree of aggregation of patches in the space. a larger value of AI, the landscape patch aggregation index, means that the patches in the space are more aggregated. the carbon sink of Without water park has a significant positive correlation with AI, which means that the higher the aggregation of patches in Without water park, the higher the carbon sink.
2) Increase the complexity of patches in space. higher value of LSI (patch shape index) means more complex shape of patches. carbon sink of Without water park has a significant positive correlation with LSI, which means that the more complex shape of patches in Without water park, the higher carbon sink.
3) Increase the number of patches in the space, NP, the number of patches index, the higher the value means the more the number of patches, the carbon sink of Without water park has a significant positive correlation with NP index, which means the more the number of patches in Without water park, the higher the

carbon sink.

In conclusion, for Without water park, the spatial design carbon sink enhancement strategy is mainly to enhance the degree of aggregation, complexity and number of patches in the distribution of patches.

4.1.2.2 With Water Park

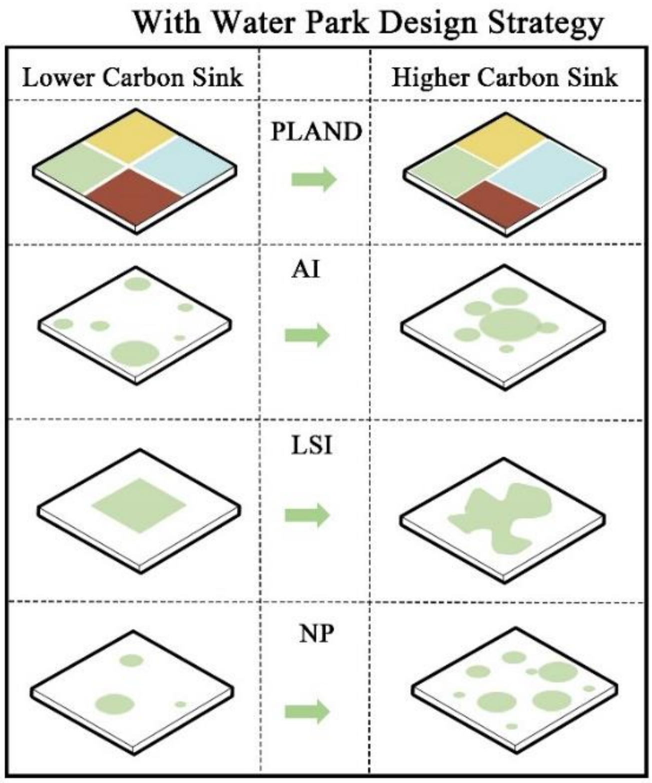


Fig 4-7 Illustration of With Water Park design strategy. Source: by author

The landscape pattern indices associated with the carbon sink of With water park are PLAND_green, AI, LSI and NP (Figs. 3-6). Therefore, the spatial design strategies of With water park are mainly (Figure 4-7):

1) Increase the proportion of green space in the space. a higher value of PLAND_green means a larger proportion of green space in the space. the carbon sink of With water park has a significant positive correlation with PLAND_green, which means that the higher the proportion of green space

patches in With water park, the higher the carbon sink.

2) Increase the degree of aggregation of patches in the space, AI (landscape patch aggregation index), the higher the value means the more aggregated patches in the space. the carbon sink of With water park has a significant positive correlation with AI, which means the higher the degree of aggregation of patches in With water park, the higher the carbon sink.
3) Increase the complexity of patches in space. higher value of LSI (patch shape index) means more complex shape of patches. carbon sink of With water park has significant positive correlation with LSI, which means the more complex shape of patches in With water park, the higher carbon sink.
4) Increase the number of patches in the space, NP, the number of patches index, the higher the value means the more the number of patches, the carbon sink of With water park has a significant positive correlation with NP index, which means the more the number of patches in With water park, the higher the carbon sink.

In conclusion, for With water park, the spatial design carbon sink enhancement strategy is mainly to increase the proportion of green space patches. In addition, the degree of aggregation, complexity and number of patches need to be enhanced.

4.1.3 Spatial design strategies for parks of different sizes

In the correlation analysis results (Figure 3-6), 2-5 ha Park and >50 ha Park did not have significantly correlated landscape pattern indices. Therefore, this section will focus on the design strategies of <2 ha park, 5-10 ha park and 10-50 ha park.

4.1.3.1 Less than 2 ha park

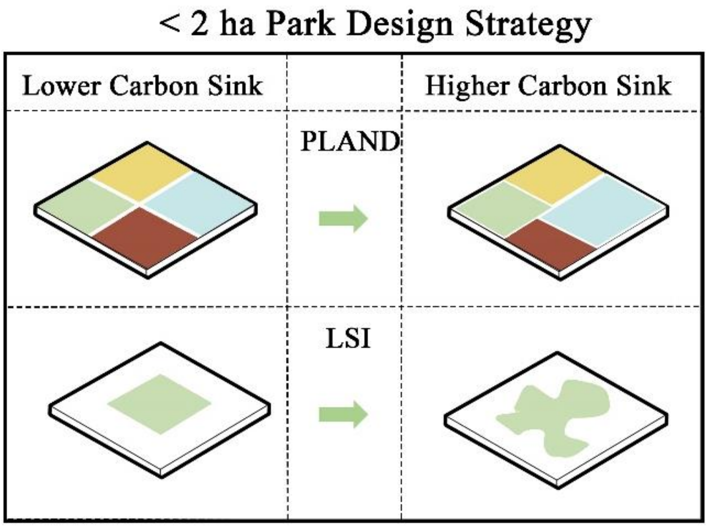


Fig 4-8 Illustration of Less than 2 ha Park design strategy. Source: by author

The landscape pattern indices associated with the carbon sink of < 2 ha park are PLAND_water and LSI (Figs. 3-6). Therefore, the spatial design strategies for < 2 ha park are mainly (Figure 4-8):

1) Increase the proportion of water bodies in the space. higher value of PLAND_water, the proportion of water bodies, means a larger proportion of water bodies in the space. The carbon sink of < 2 ha park has a significant positive correlation with PLAND_water, implying that the higher the proportion of water body patches in < 2 ha park, the higher the carbon sink.
2) Increase the complexity of patches in space. higher value of LSI, patch shape index, implies more complex shape of patches. The carbon sink of < 2 ha park has a significant positive correlation with LSI, implying that the more complex the shape of patches in < 2 ha park, the higher the carbon sink.

In conclusion, for < 2 ha park, the spatial design carbon sink enhancement strategy is mainly to increase the proportion of water body patches. In addition, the complexity of the patches needs to be enhanced.

4.1.3.2 5-10 ha park

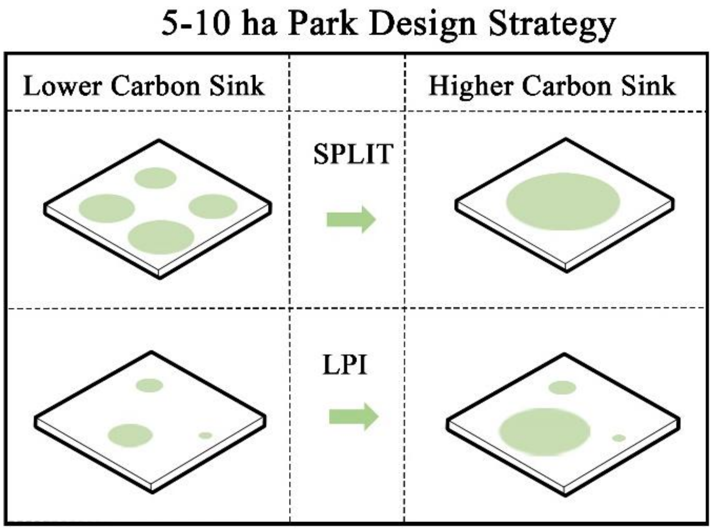


Fig 4-9 Illustration of 5-10 ha Park design strategy. Source: by author

The landscape pattern indices associated with the carbon sink of 5-10 ha park are SPLIT and LPI (Figs. 3-6). Therefore, the spatial design strategies for 5-10 ha park are mainly (Figure 4-9):

1) Reduce the fragmentation of patches in the space. a larger value of SPLIT (landscape fragmentation index) means a higher fragmentation of patches in the space. the carbon sink of 5-10 ha park has a significant negative correlation with SPLIT, which means that the more complete the patches are in 5-10 ha park, the higher the carbon sink is.
2) Increase the area of the largest patch in the space. a larger value of LPI, the landscape maximum patch index, means a larger area of the largest patch in the space. the carbon sink of 5-10 ha park has a significant positive correlation with LPI, which means the larger the area of the largest patch in 5-10 ha park, the higher the carbon sink.

In conclusion, for 5-10 ha park, the spatial design carbon sink enhancement strategy is mainly to reduce the fragmentation of patches and increase the area of the largest patches.

4.1.3.3 10-50 ha Park

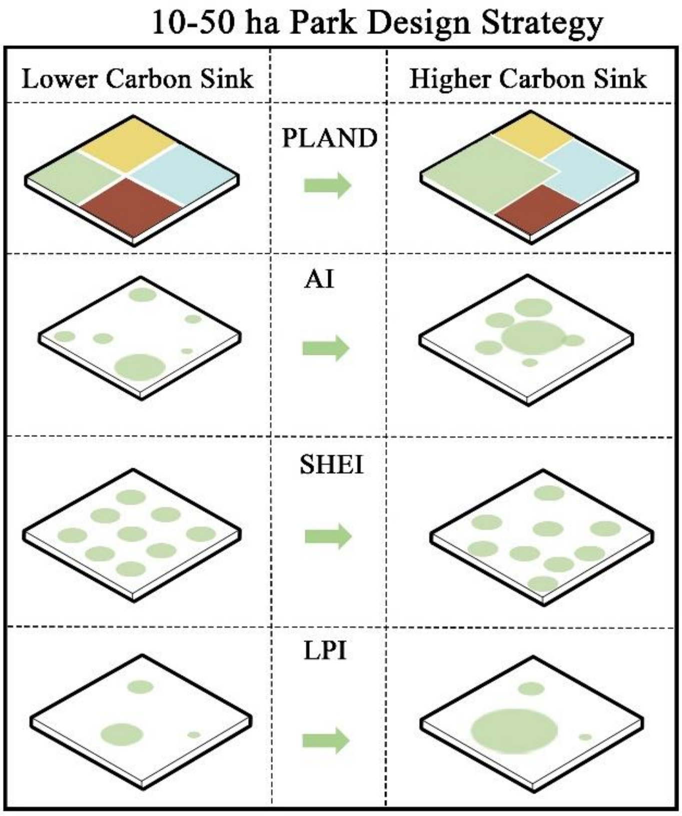


Fig 4-10 Illustration of 10-50 ha Park design strategy. Source: by author

The landscape pattern indices associated with the carbon sink of 10-50 ha park are PLAND_imper, PLAND_green, AI, SHEI and LPI (Figs. 3-6). Therefore, the spatial design strategies for the 10-50 ha park are mainly (Figure 4-10):

1) Decrease the proportion of impervious area in the space. higher value of PLAND_imper, the proportion of impervious surface, means the greater the proportion of impervious surface in the space. the carbon sink of 10-50 ha park has a significant negative correlation with PLAND_imper, which means the higher the proportion of impervious surface in 10-50 ha park, the higher the carbon sink.
2) Increase the proportion of green space in the space. PLAND_green, the

proportion of green space, means the proportion of green space in the space is larger. 10-50 ha park has a significant positive correlation between carbon sink and PLAND_green, which means the higher the proportion of green space patches in 10-50 ha park, the higher the carbon sink.

3) Increase the degree of aggregation of patches in the space. a larger value of AI, the landscape patch aggregation index, means that the patches in the space are more aggregated. the carbon sink of 10-50 ha park has a significant positive correlation with AI, which means that the higher the aggregation of patches in 10-50 ha park, the higher the carbon sink.
4) Decrease the uniformity of spatial patch distribution. higher value of SHEI (Landscape Patch Evenness Index) means more uniform patch distribution in the space. 10-50 ha park carbon sink has a significant negative correlation with SHEI, which means the more dispersed patch distribution in 10-50 ha park, the higher carbon sink.
5) Increase the area of the largest patch in the space, LPI (Landscape Maximum Patch Index), the larger the value means the larger the area of the largest patch in the space. 10-50 ha park's carbon sink has a significant positive correlation with LPI, which means the larger the area of the largest patch in 10-50 ha park, the higher the carbon sink.

In conclusion, for the 10-50 ha park, the spatial design carbon sink enhancement strategy is mainly to reduce the proportion of impervious surface and increase the proportion of green space patches. In addition, the aggregation degree of patch distribution should be enhanced, the area of the largest patch should be increased, and the uniformity of the patch should be reduced.

4.1.4 Spatial design strategies for parks in different locations

In the correlation analysis results (Figures 3-6), there is no significant correlation of landscape pattern index for 5th Park. Therefore, this section will focus on the design strategies of 1st park, 2nd park, 3rd and 4th park.

4.1.4.1 1st Ring Park

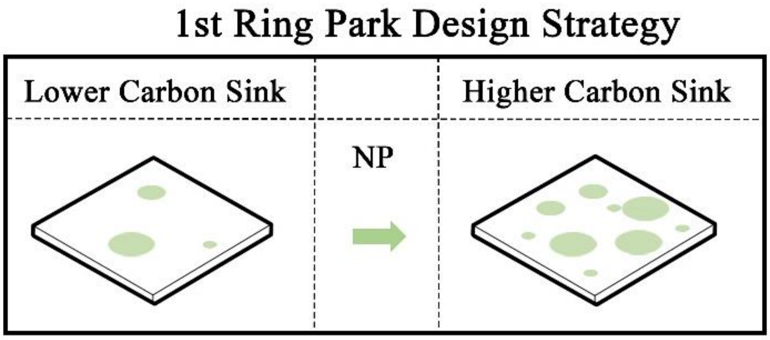


Fig 4-11 Illustration of 1st Ring Park design strategy. Source: by author

The landscape pattern index associated with the carbon sink located in 1st Ring park in city is NP (Figure 3-6). Therefore, the spatial design strategy of With water park is mainly (Figure 4-11):

1) Increase the number of patches in the space; the higher the value of NP, the higher the number of patches, the higher the number of patches. 1st Ring park's carbon sink is significantly and positively correlated with NP index, which means that the higher the number of patches in 1st Ring park, the higher the carbon sink.

In conclusion, for 1st Ring park, the spatial design carbon sink enhancement strategy is mainly to increase the number of patches.

4.1.4.2 2nd Ring Park

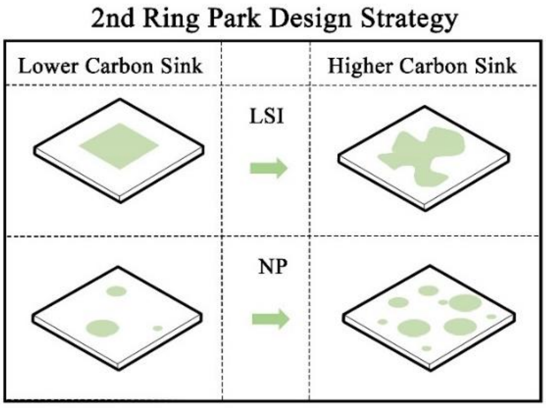


Fig 4-12 Illustration of 2nd Ring Park design strategy. Source: by author

The landscape pattern indices associated with the 2nd Ring park carbon sink are LSI and NP (Figs. 3-6). Therefore the spatial design strategies for 2nd Ring park k are mainly (Figure 4-6):

1) Increase the complexity of the patches in the space. a larger value of LSI, the patch shape index, means the more complex the shape of the patches. the carbon sink of 2nd Ring park has a significant positive correlation with LSI, which means the more complex the shape of the patches in 2nd Ring park, the higher the carbon sink.
2) Increase the number of patches in the space. nP, the number of patches index, the higher the value means the more the number of patches. the carbon sink of 2nd Ring park has a significant positive correlation with NP index, which means the more the number of patches in 2nd Ring park, the higher the carbon sink.

In conclusion, for 2nd Ring park, the spatial design carbon sink enhancement strategy is mainly to enhance the complexity of patches and the number of patches.

4.1.4.3 3rd Ring Park

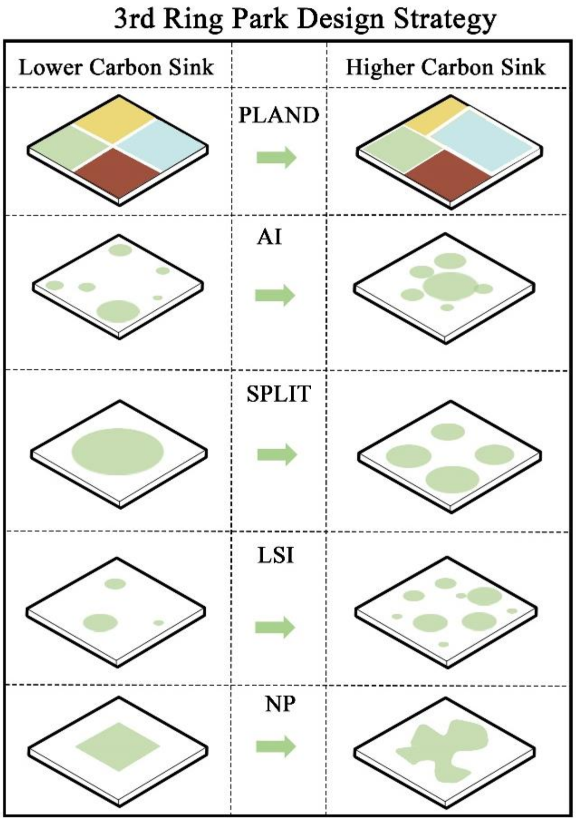


Fig 4-13 Illustration of 3rd Ring Park design strategy. Source: by author

The landscape pattern indices associated with the 3rd Ring park carbon sink are PLAND_bare, PLAND_water, AI, SPLIT, LSI and NP (Figure 3-6). Therefore, the spatial design strategies of Urban park are mainly (Figure 4-13):

1) Reduce the proportion of bare land in the space. higher value of PLAND_bare, the proportion of bare land, means that the proportion of bare land in the space is larger. the carbon sink of 3rd Ring park has a significant negative correlation with PLAND_bare, which means that the higher the proportion of bare land patches in 3rd Ring park, the higher the carbon sink.
2) Increase the proportion of water bodies in the space. PLAND_water, the proportion of water bodies, means the proportion of water bodies in the space is larger. 3rd Ring park's carbon sink has a significant positive correlation with PLAND_water, which means the higher the proportion

of water body patches in 3rd Ring park, the higher the carbon sink.

3) Increase the aggregation of patches in the space. AI, the aggregation index of patches in the landscape, means the higher the aggregation of patches in the space. 3rd Ring park's carbon sink has a significant positive correlation with AI, which means the higher the aggregation of patches in 3rd Ring Park, the higher the carbon sink.
4) Increase the fragmentation of patches in the space. higher value of SPLIT (Landscape Fragmentation Index) means higher fragmentation of patches in the space. 3rd Ring park's carbon sink has a significant positive correlation with SPLIT, which means the more fragmented patches in 3rd Ring park, the higher the carbon sink.
5) Increase the complexity of patches in the space. higher value of LSI (patch shape index) means more complex shape of patches. 3rd Ring park's carbon sink is significantly and positively correlated with LSI, implying that the more complex shape of patches in 3rd Ring park, the higher carbon sink.
6) Increase the number of patches in the space, NP, the number of patches index, the higher the value means the more the number of patches, the carbon sink of 3rd Ring park has a significant positive correlation with NP index, which means the more the number of patches in 3rd Ring park, the higher the carbon sink.

In conclusion, for 3rd Ring park, the spatial design carbon sink enhancement strategy is mainly to reduce the proportion of bare land and increase the proportion of water bodies and the number of patches. In addition, the degree of aggregation, fragmentation and complexity of the patches should be enhanced.

4.1.4.4 4th Ring Park

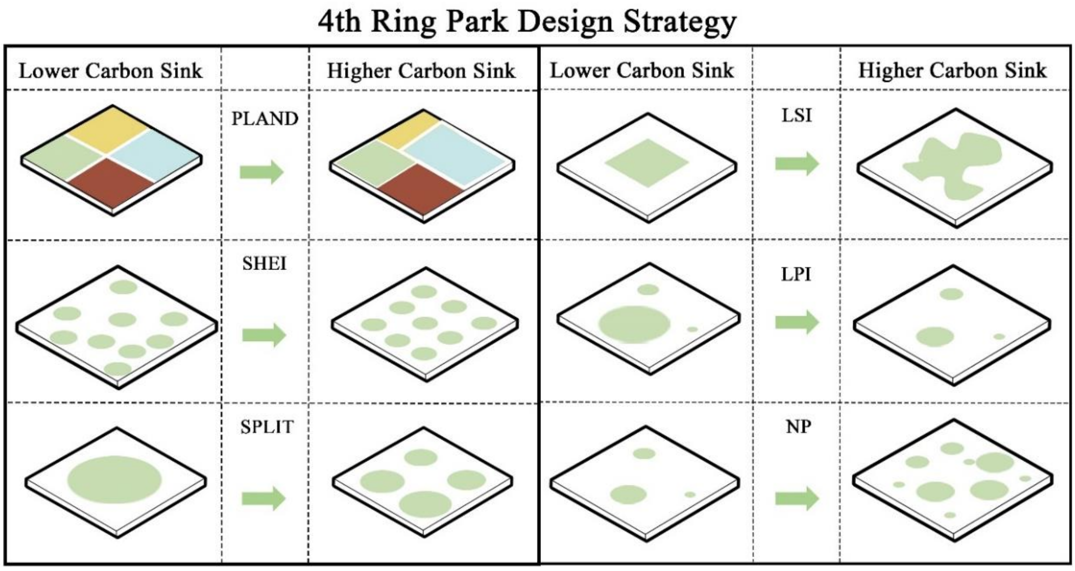


Fig 4-14 Illustration of 4th Ring Park design strategy. Source: by author

The landscape pattern indices associated with the 4th Ring park carbon sink are PLAND_bare, PLAND_water, SHEI, SPLIT, LSI,LPI and NP (Figure 3-6). Therefore, the spatial design strategies of Urban park are mainly (Figure 4-14):

1) Reduce the proportion of bare land in the space. higher value of PLAND_bare, the proportion of bare land, means that the proportion of bare land in the space is larger. the carbon sink of 4th Ring park has a significant negative correlation with PLAND_bare, which means that the higher the proportion of bare land patches in 4th Ring park, the higher the carbon sink.
2) Increase the proportion of water bodies in the space. a larger value of PLAND_water means a larger proportion of water bodies in the space. the carbon sink of 4th Ring park has a significant positive correlation with PLAND_water, which means that the higher the proportion of water body patches in 4th Ring park, the higher the carbon sink.
3) Increase the uniformity of patch distribution in space. higher value of SHEI (landscape patch evenness index) means more uniform patch

distribution in space. the carbon sink of 4th Ring park has a significant positive correlation with SHEI, which means the more uniform patch distribution in 4th Ring park, the higher the carbon sink.

4) Increase the fragmentation of patches in the space. higher value of SPLIT (Landscape Fragmentation Index) means higher fragmentation of patches in the space. the carbon sink of 4th Ring park has a significant positive correlation with SPLIT, which means that the more fragmented patches in 4th Ring park, the higher the carbon sink.
5) Increase the complexity of patches in the space. higher value of LSI (patch shape index) means more complex shape of patches. carbon sink of 4th Ring park is significantly and positively correlated with LSI, which means the more complex shape of patches in 4th Ring park, the higher carbon sink.
6) Decrease the area of the largest patch in the space. a larger value of LPI, Landscape Maximum Patch Index, means a larger area of the largest patch in the space. the carbon sink of 4th Ring park has a significant negative correlation with LPI, which means that the smaller the area of the largest patch in 4th Ring park, the higher the carbon sink.
7) Increase the number of patches in the space. nP, the number of patches index, the higher the value means the more the number of patches. the carbon sink of 4th Ring park has a significant positive correlation with the NP index, which means the more the number of patches in 4th Ring park, the higher the carbon sink.

In conclusion, for 4th Ring park, the spatial design carbon sink enhancement strategy is mainly to reduce the proportion of bare land and increase the proportion of water bodies and the number of patches. Second, it is also necessary to enhance the fragmentation and complexity of the patches. In addition, it is also necessary to focus on enhancing the uniformity of patch distribution and reducing the area of the largest patch.

4.2 Spatial Design Proposal

Based on the results of the study, five types of parks are selected in this chapter to apply the proposed spatial design carbon sink enhancement strategies. These five types of parks are street parks, community parks, belt parks, urban parks, and theme parks.

For each type of park, a real site located within a park in Zhengzhou City will be selected for design enhancement. The design principle is to retain the original function of the design area and focus only on the transformation of the spatial structure to apply the research results. The design steps include pre-analysis, design strategy, master plan and corresponding design drawings, such as Section, Visualization and Plantation.

4.2.1 Street Park

4.2.1.1 Analysis

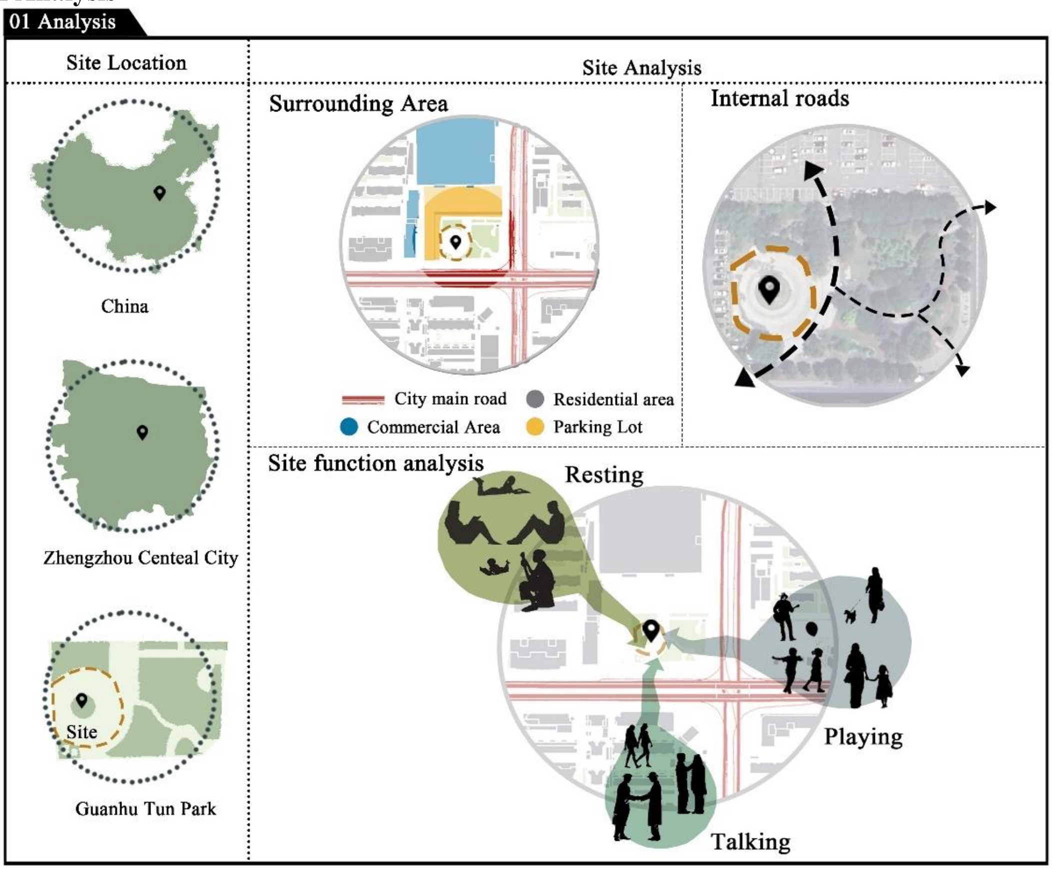


Fig 4-15 Guanghutun Park Site Location and Analysis. Source: by author

Guanghutun Park is located in Zhengzhou City, China, with a total area of 8,000 m^2. The park is a typical street park with the main traffic roads in the east and south of the city. The buildings around the park function mainly as residential and commercial areas. In addition, to the east and north of the adjacent park are parking lots for commercial areas.

The design area is located in the southwest of Guanghutun Park, with a total area of $1600m^2$. The main form of the park is a prototype square with a small circular green area in the center. The eastern part of the design area is the main road inside the park, which is used for the flow of people between the north and the south of the park.

The main functions of this design area are rest, recreation and communication (Figure 4-15).

4.2.1.2 Design Strategy

For this design area, the design strategy is to increase the proportion of green space and the number of patches in the area as well as to enhance the complexity of the patches. The specific diagram is shown in Figure 4-1

4.2.1.3 Master Plan

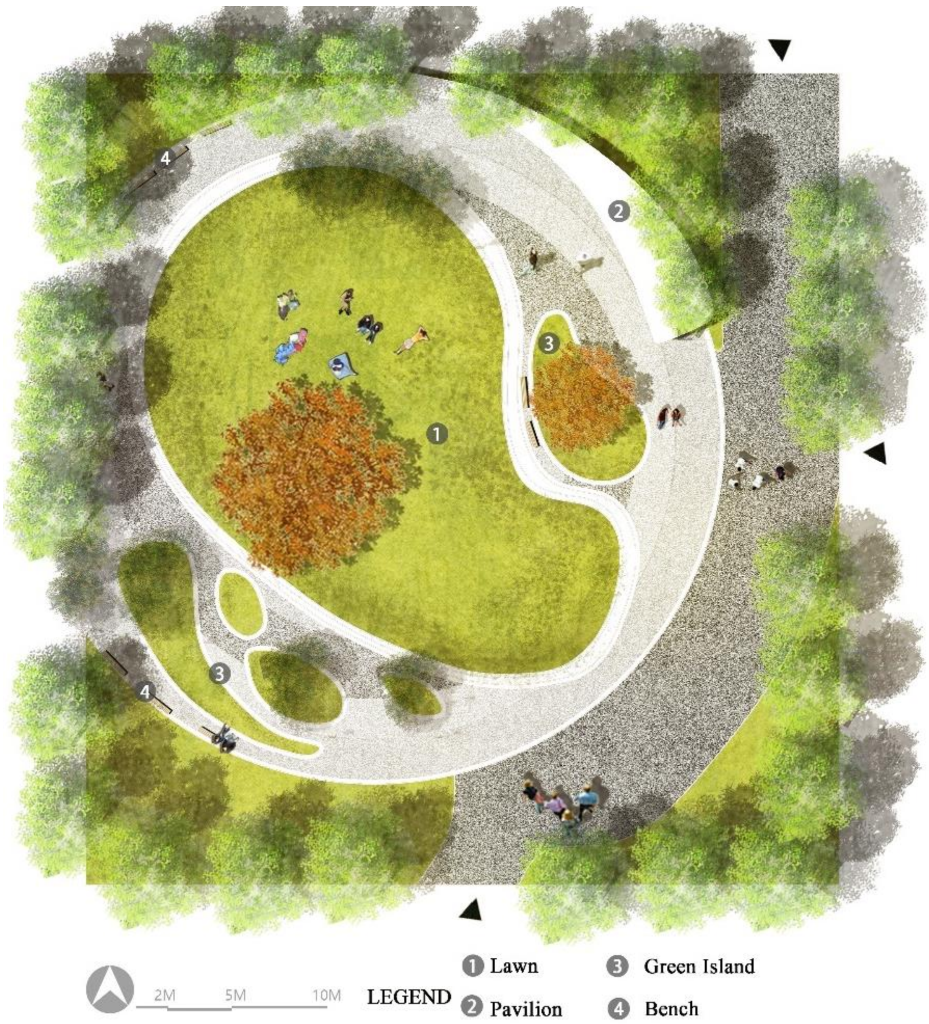


Fig 4-16 New master plan of Guanghutun Park design area. Source: by author

In the new master plan of this design area, in order to increase the proportion of green space, a central lawn is designed in the center of the area, while several green space islands are added in the surrounding paved area; in order to increase the number of patches, all green spaces in the area are divided into different green space patches, currently there is one large green space patch and four small green space patches. Finally, in order to enhance the complexity of the shape of the patches, the original regular circular green space is planned as irregular oval green space, and several islands of irregularly shaped green space are added. In addition, Pavilion, seating and central lawn are designed to cater and enhance the original functions of the site (rest, play and communication) (Figure 4-16).

4.2.1.4 Section

Fig 4-17 Section of Guanghutun Park design area 1:200. Source: by author

In this section, the sinking of the central lawn is shown. Two outdoor steps can be seen around the central lawn, and users can choose to rest and enjoy the view at the steps around the lawn. At the same time, users can also read, communicate and play while lying down in the lawn. A tall tree is designed in the middle of the lawn to provide shade for the users. In addition, new seats are added around the green islands for users to rest (Figure 4-17).

4.2.1.5 Visualization and Plantation

Fig 4-18 Visualization of Guanghutun Park design area. Source: by author

This Visualization is from the southern part of the central lawn, which is visible to users as they walk around the interior of the park, with the beautiful giant solitary tree in the middle. Users can choose to quickly cross the lawn from the pathway at the edge of the lawn, or they can choose to step into the lawn. On the lawn users can rest on the steps around the perimeter, or they can choose to walk or lie down in the lawn and feel the shadows under the trees or the sunlight outside the trees (Figure 4-18).

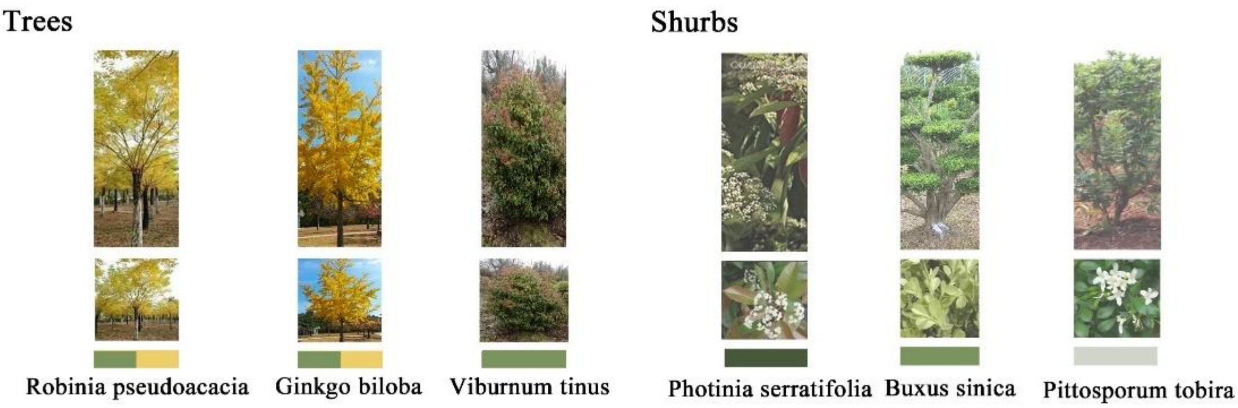


Fig 4-19 Plantation of Guanghutun Park design area. Source: by author

The plant design of the area is mainly divided into trees and shrubs. Among the trees are *Robinia pseudoacacia* and *Ginkgo biloba* and *Viburnum tinus*; the shrubs are *Photinia serratifolia, Buxus sinica* and *Pittosporum tobira* (Figure 4-19).

Fig 4-20 Comparison between before and after enhancement (left: before enhancement; right: after enhancement). Source: by author

The comparison shows that the enhanced space has an increased percentage of green space, an increased number of patches as well as a more complex patche shape. The design strategy is practically practiced while retaining the function of the space (Figure 4-20).

4.2.2 Community Park

4.2.2.1 Analysis

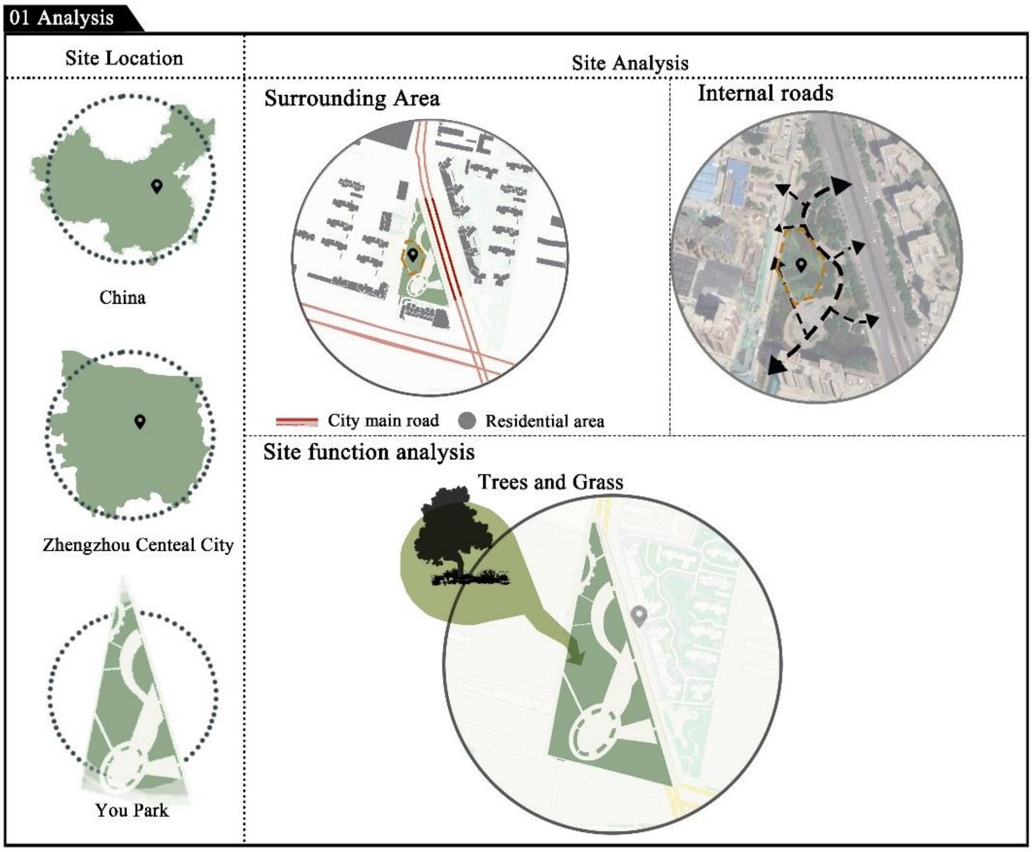


Fig 4-21 You Park Site Location and Analysis. Source: by author

You Park is located in Zhengzhou City, China, with a total area of 10,550 m^2. The park is bounded to the east, south and north by the main traffic roads of the city. The buildings surrounding the park function mainly as residential areas and are recognized as community parks by the city of Zhengzhou. The internal roads of the park consist of one main road running north-south and several secondary roads.

This design area is located in the middle of You Park, with a total area of 1800m^2.The area is an irregular type of green space. The southern part of this design area is adjacent to the main square of the park. The eastern part is the main road of the park for the flow of people between the north and south of the park. The interior of this design area currently consists of trees and grass (Figure 4-21).

4.2.2.2 Design Strategy

For this design area, the design strategy is mainly to increase the percentage of green space and enhance the complexity and number of patches. The specific diagram is shown in Figure 4-2

4.2.2.3 Master Plan

Fig 4-22 New master plan of You Park design area. Source: by author

In the new master plan of the design area, in order to increase the number of patches, all the green areas in the area were divided into 5 green areas patches with forest paths in the middle for users to walk through; to enhance the complexity of the shape of the patches, a whole green area was planned as an irregular green area, and several flower beds were added; to increase the proportion of green areas, the number of plants and the planting density were increased, such as adding several flower beds planted under the trees (Figure 4-22).

4.2.2.4 Section

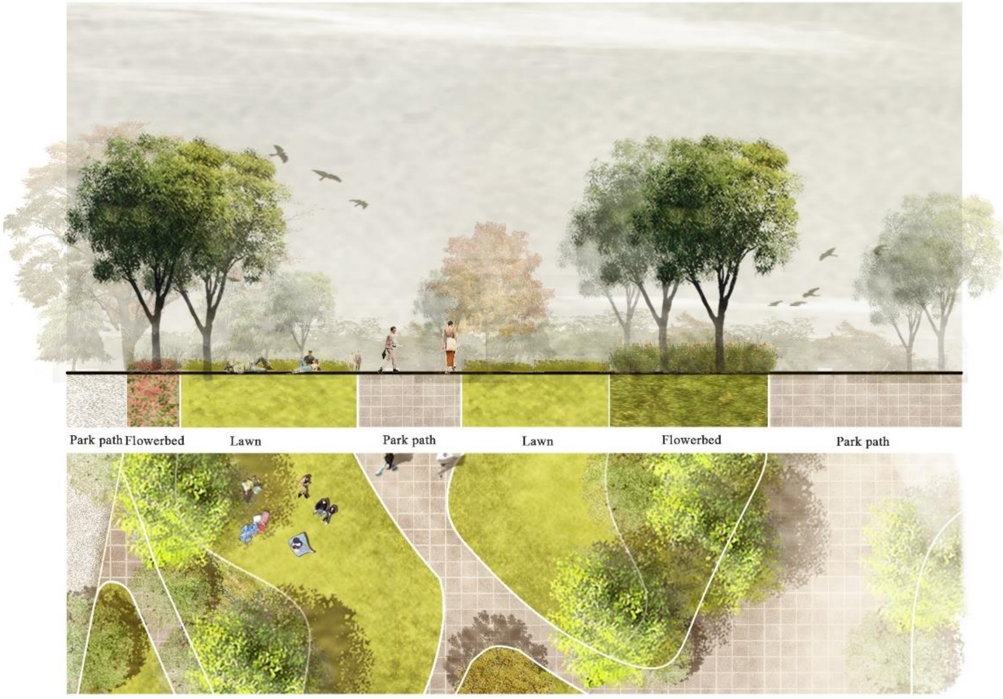


Fig 4-23 Section of You Park design area 1:200. Source: by author

In this section, the multi-layered planting design is shown. It can be seen that flowers are planted on part of the lawn and trees are planted on top of the flowers, creating multiple levels of planting. In the green space, there is a lawn where users can choose to rest and enjoy the view. At the same time, users can also lie down in the lawn to read, communicate and play. Tall trees are designed next to the lawn to provide shade for the users (Figure 4-23).

4.2.2.5 Visualization and Plantation

Fig 4-24 Visualization of You Park design area. Source: by author

The Visualization is from the southern part of the design area, and as users walk through the interior of the park, they can see the lawn, beautiful giant trees and flowers under the trees. The user can choose to cross quickly from the path at the edge of the lawn or to step into the lawn. On the lawn users can rest, enjoy the view, and touch the flowers (Figure 4-24).

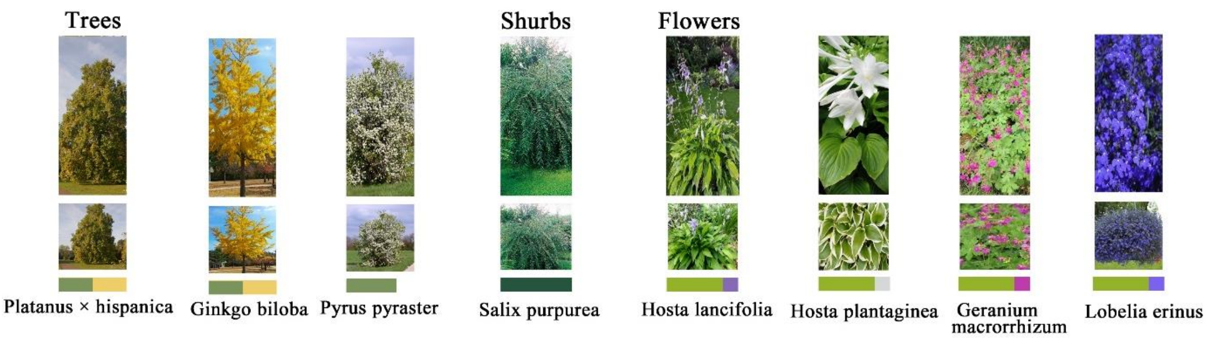


Fig 4-25 Plantation of You Park design area. Source: by author

The plant design of the area is mainly divided into trees, shrubs and flowers. The trees are *Platanus × hispanica* and *Ginkgo biloba* and *Pyrus pyraster*; the shrubs are

Salix purpurea; the flowers are *Hosta lancifolia, Hosta plantaginea, Geranium macrorrhizum* and *Lobelia erinus* (Figure 4-25).

Fig 4-26 Comparison between before and after enhancement (left: before enhancement; right: after enhancement). Source: by author

The comparison shows that the enhanced space has an increased percentage of green space, an increased number of patches as well as a more complex shape of patches. The design strategy is practically practiced while retaining the function of the space (Figure 4-26).

4.2.3 Belt Park

4.2.3.1 Analysis

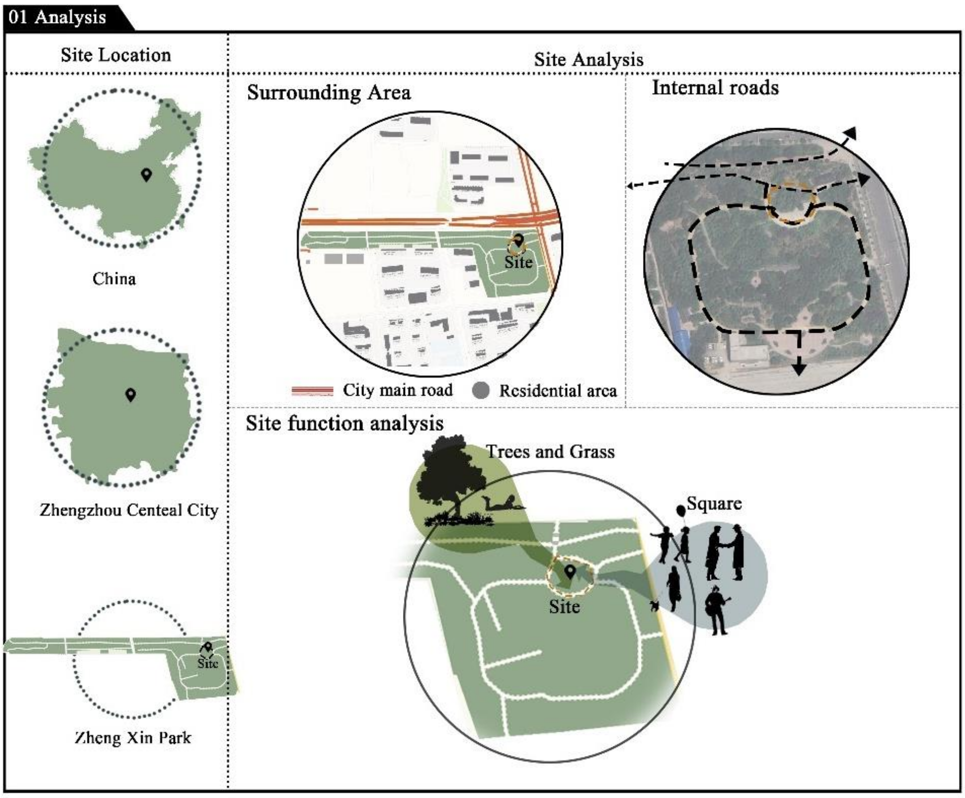


Fig 4-27 Zhengxin Park Site Location and Analysis. Source: by author

Zhengxin Park is located in Zhengzhou City, China, with a total area of 68,749 m^2. To the east and north of the park are the main traffic roads of the city. The buildings around the park function mainly as residential areas. The park as a whole has a narrow east-west installation, with the western part narrow and adjacent to two blocks.

The design area is located on the east side of Zhengxin Park near the entrance, with a total area of 2,000 m^2. The main form is circular, with a small irregular green area in the center. To the east and south of the design area are the main roads within the park. The design area is mainly a green space and square with the functions of rest, recreation and communication (Figure 4-27).

4.2.3.2 Design Strategy

For this design area, the design strategy is mainly to increase the percentage of water bodies and enhance the fragmentation, complexity and number of patches. In addition, the area of the largest patches was appropriately reduced. The specific diagram is shown in Figure 4-3

4.2.3.3 Master Plan

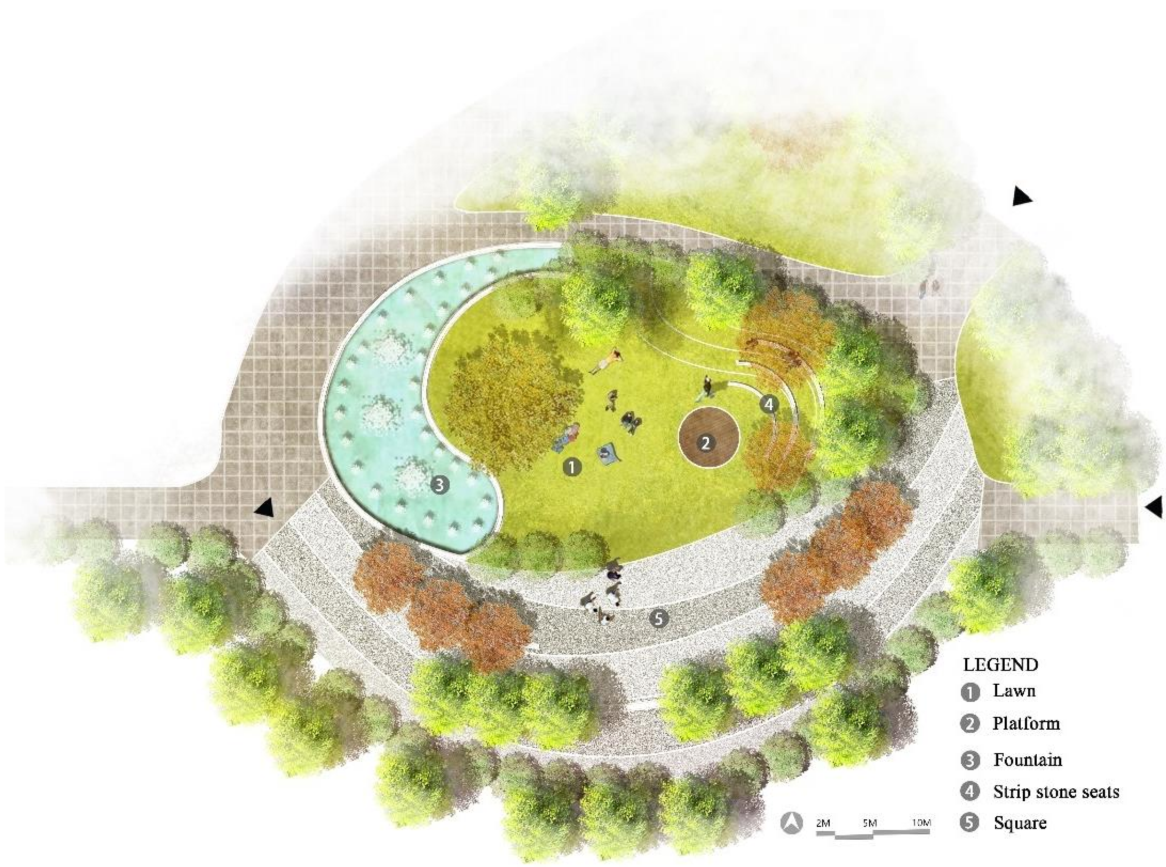


Fig 4-28 New master plan of Zhengxin Park design area. Source: by author

In the new master plan for this design area, irregular-shaped ponds and fountains were added on the west side of the site adjacent to the parkway in order to increase the proportion of water bodies; at the same time, the shape of the original green space within the site was adjusted, and platforms and boulders were installed within the green space, and strips of green space were added in the plaza area. These initiatives helped to enhance the fragmentation, complexity and number of patches in the site. In order to reduce the area of the largest patch, the original largest patch (green space) was divided into pools, platforms and green spaces. In addition, the original function of the site was catered and enhanced through the design of pools, decks, strips and striped trees within the plaza (Figure 4-28).

4.2.3.4 Section

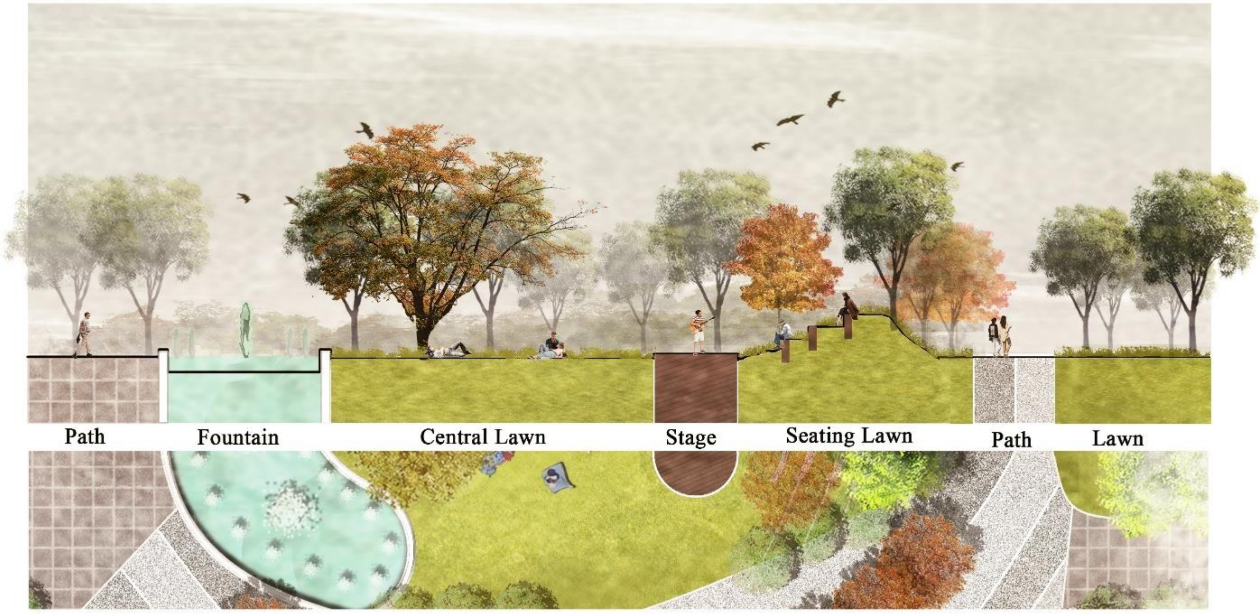


Fig 4-29 Section of Zhengxin Park design area 1:200. Source: by author

In this section, the pond, the central lawn, the terrace and the lawn with height difference are mainly shown. As you can see, when users approach the site, the pool and fountain are the first thing they see. Next, users can choose to rest, read or talk on the lawn. They can also choose to perform on the stage in the lawn or enjoy the performance from the surrounding stone seats. All of these offer many possibilities for the use of the site. Meanwhile, around and in the middle of the lawn, tall trees are planted to provide shade. Within the plaza, there are also striped trees with seating underneath for users to rest (Figure 4-29).

4.2.3.5 Visualization and Plantation

Fig 4-30 Visualization of Zhengxin Park design area. Source: by author

This Visualization focuses on the stage in the lawn and the striped stone seating with height difference. Through the different heights and the form of surrounding center, a small stage is created for users to perform and watch. At the same time, the seating material is stone, which can fit perfectly with the surrounding lawn, creating a harmonious natural space in the lawn. Tall trees and low shrubs are planted around the stage to provide shade and coolness for some of the seats (Figure 4-30).

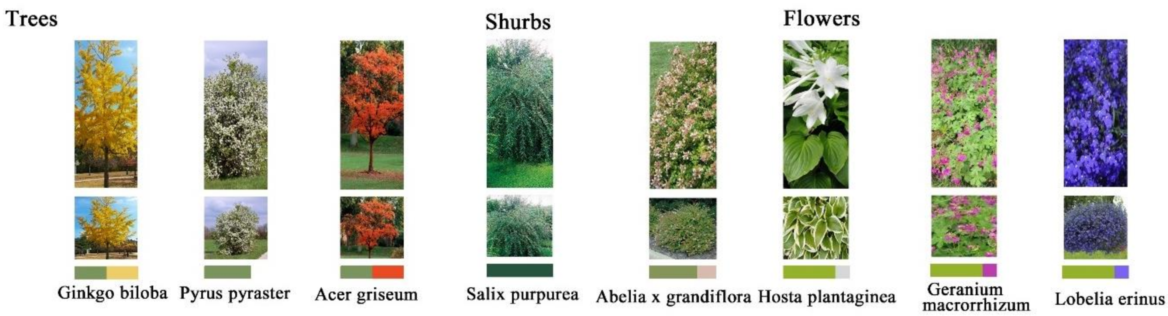


Fig 4-31 Plantation of Zhengxin Park design area. Source: by author

The plant design of the area is mainly divided into trees, shrubs and flowers. The trees are *Ginkgo biloba, Pyrus pyraster* and *Acer griseum*; the shrubs are *Salix purpurea* and *Abelia x grandiflora*; the flowers are *Hosta plantaginea, Geranium macrorrhizum* and *Lobelia erinus* (Figure 4-31).

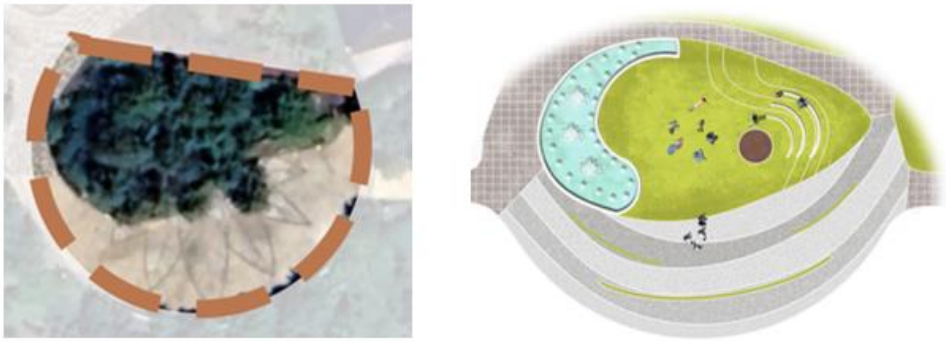


Fig 4-32 Comparison between before and after enhancement (left: before enhancement; right: after enhancement). Source: by author

From the comparison, we can see that the percentage of water bodies in the enhanced space increases and the number of patches increases. And the patch shapes are more complex, and the patches are more fragmented. The design strategy is practically practiced while retaining the function of the space (Figure 4-32).

4.2.4 Urban Parks

4.2.4.1 Analysis

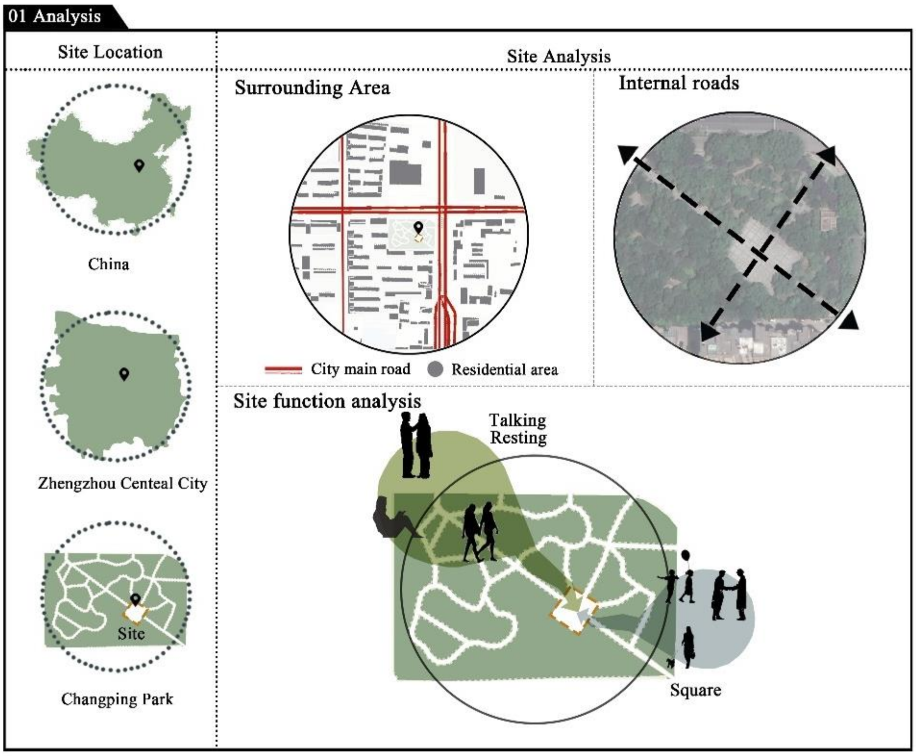


Fig 4-33 Changping Park Site Location and Analysis. Source: by author

Changping Park is located in the main city of Zhengzhou, Henan Province, China, covering an area of 9,720m^2. The park is surrounded by residential areas and the main users are residents of the surrounding residential areas. To the north and east of the park are the main roads of the city. The main roads in the park are two intersecting straight lines. At the intersection of the straight lines is a small square, which is the design area.

The spatial form of the design area is a square square, located in the center of the park, with an area of 1000m^2. The main function is to walk through, communicate and rest (Figure 4-33).

4.2.4.2 Design Strategy

For this design area, the spatial design carbon sink enhancement strategy is mainly to increase the proportion of water bodies and green space patches and reduce the proportion of bare land. Enhance the uniformity of patch distribution, complexity and number of patches. The specific diagram is shown in Figure 4-4.

4.2.4.3 Master Plan

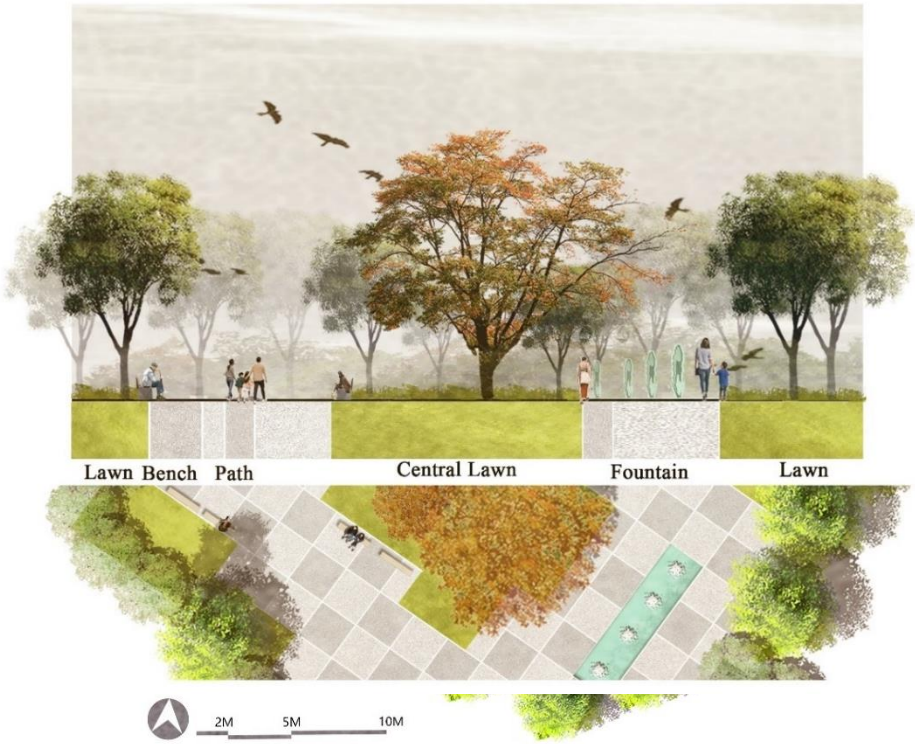


Fig 4-34 New master plan of Changping Park design area. Source: by author

In the master plan, small green areas have been added around the square and in the central area to increase the proportion of green space in the space. Small ponds and fountains are added at the entrances of the square to increase the proportion of water bodies in the space. These measures also increase the number of patches and the degree of homogeneity in the space. In addition, the green space and water patches are designed in irregular shapes to increase the complexity of the patches in the space. Finally, new seats were added to the site and some landscape trees were added to enhance the usability of the plaza (Figure 4-34).

4.2.4.4 Section

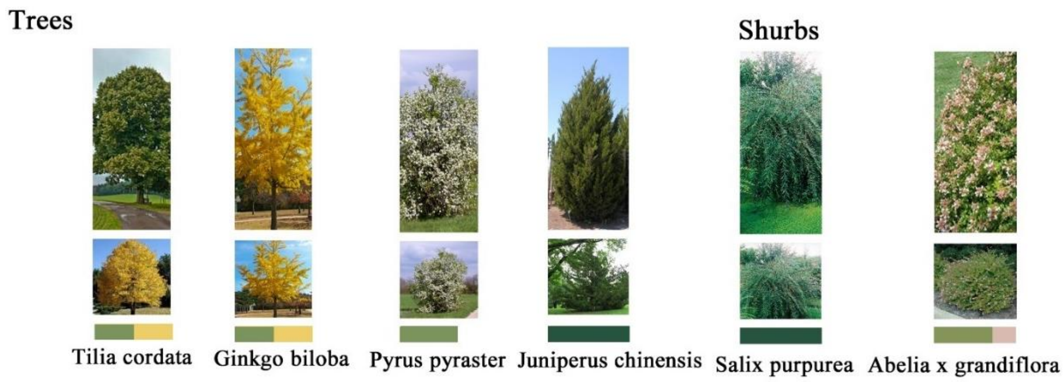
Fig 4-35 Section of Changping Park design area 1:200. Source: by author

In the section, the lawn and pond are mainly displayed. Around the lawn, both the central lawn and the peripheral lawn, beautiful landscape trees are planted and additional seats are installed to facilitate users to stay and rest. Also show the fountain facilities within the water body to increase the proportion of water bodies in the site (Figure 4-35).

4.2.4.5 Visualization and Plantation

Fig 4-36 Visualization of Changping Park design area. Source: by author

The Visualization shows the three-dimensional effect in the design area. It includes the specific shape of the central irregular lawn, and the height and shape of the deciduous trees in the central lawn. In addition, seats are set up around the lawn for



users to rest and stay. Also shown are the green space patches in the area around the plaza, which are enclosed by a series of trees and provide shade for the seating (Figure 4-36).

Fig 4-37 Plantation of Changping Park design area. Source: by author

The plant design of the area is mainly divided into trees and shrubs. The trees are *Tilia cordata, Ginkgo biloba, Pyrus pyraster* and *Juniperus chinensis*, and the shrubs are *Salix purpurea* and *Abelia x grandiflora* (Figure 4-37).

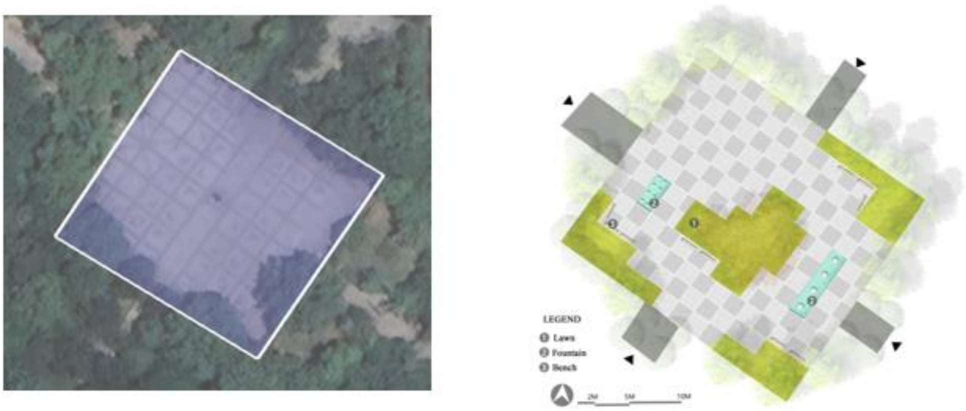


Fig 4-38 Comparison between before and after enhancement (left: before enhancement; right: after enhancement). Source: by author

From the comparison, it can be seen that the percentage of green space and water bodies increases, and the number of patches increases after the enhancement. And the shape of the patches is more complex, and the distribution of patches is more dispersed. The design strategy is practically practiced while retaining the function of the space (Figure 4-38).

4.2.5 Theme Park

4.2.5.1 Analysis

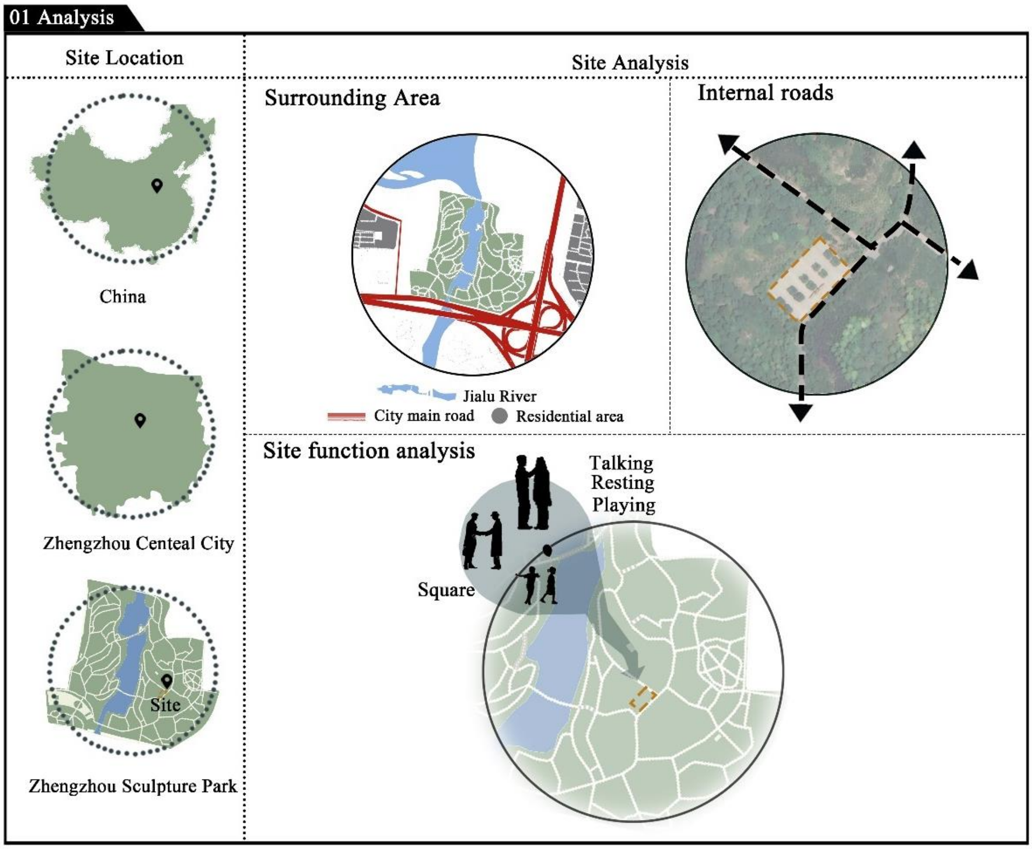


Fig 4-39 Zhengzhou Sculpture Park Site Location and Analysis. Source: by author

Zhengzhou Sculpture Park is located in Zhengzhou City, Henan Province, China, covering an area of 28.4 ha. The park is a typical theme park with a large number of sculptures in the park. The park is divided into two parts by the Jalu River, which is connected by a bridge. The southern and eastern parts of the park are the main traffic roads of the city, and the surrounding buildings are mostly residential areas.

The design area is located in the center of the eastern half of the park, with an area of 1100 m^2. The area is a small square, enclosed on three sides and adjacent to the park road on one side. A statue is located at the entrance of the square, and behind the statue are 10 small, regularly distributed square green space patches (Figure 4-39).

4.2.5.2 Design Strategy

For this design area, the main design strategy is to reduce the percentage of impervious surfaces and increase the percentage of green space patches. In addition, the degree of aggregation of the patch distribution needs to be enhanced. Specific illustrations can be seen in Figures 4-5

4.2.5.3 Master Plan

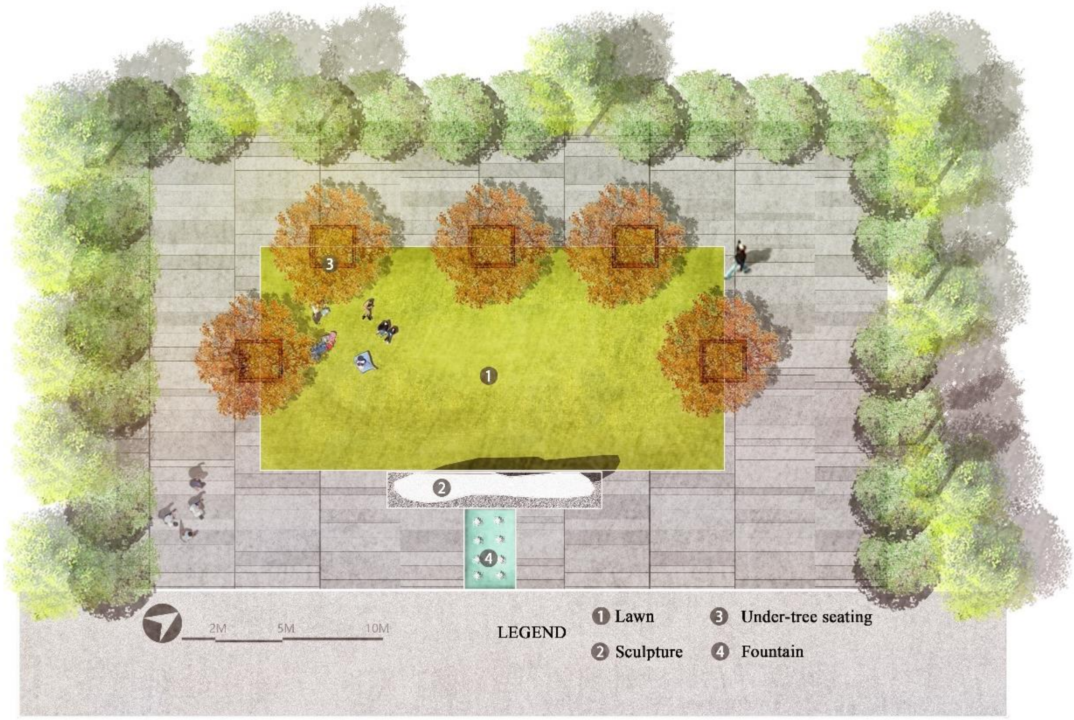


Fig 4-40 New master plan of Zhengzhou Sculpture Park design area. Source: by author

In the new master plan, in order to reduce the percentage of imperviousness and increase the percentage of green space, the original green space was expanded and a central lawn was installed. At the same time, a small pond and fountain are added in front of the sculpture at the entrance of the square to further reduce the proportion of impervious space. In order to enhance the aggregation of the patches, the original 10 scattered green patches are combined into one central lawn. Finally, in order to cater and enhance the usage function of the square, tree pools with seats are set up on three sides of the lawn for users to rest (Figure 4-40).

4.2.5.4 Section

Fig 4-41 Section of Zhengzhou Sculpture Park design area 1:200. Source: by author

In this section, the main display is the lawn, sculpture and seating with tree pond. The design retains the original sculpture on the site and adds a pond with a small fountain in front of the sculpture. A tree pond with under-tree seating is installed around the central lawn. Yellow deciduous trees are planted around the lawn. Evergreen trees were installed around the plaza to enclose the plaza (Figure 4-41).

4.2.5.5 Visualization and Plantation

Fig 4-42 Visualization of Zhengzhou Sculpture Park design area. Source: by author

The Visualization mainly shows the three-dimensional effect in front of the square sculpture. A small pond with a fountain can be seen in front of the sculpture, placed directly in front of the sculpture and at the only entrance to the square. In addition is the central lawn behind the sculpture, as well as the tree pond around the lawn (Figure 4-42).

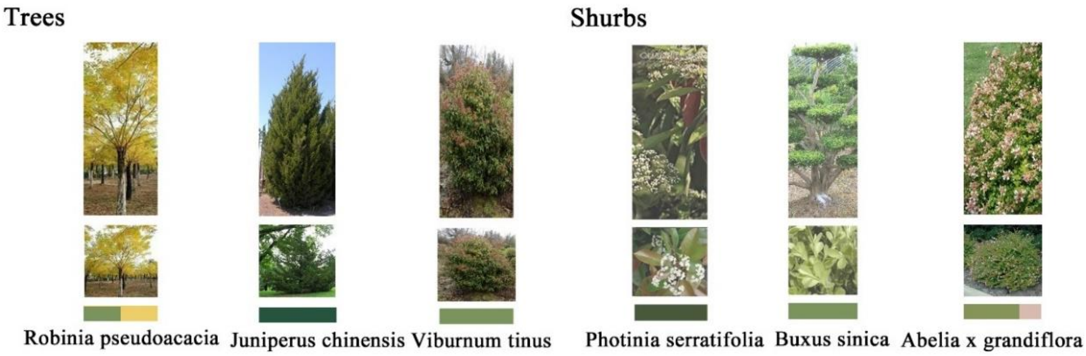


Fig 4-43 Plantation of Zhengzhou Sculpture Park design area. Source: by author

The plant design of the area is mainly divided into trees and shrubs. Among the trees are *Robinia pseudoacacia, Juniperus chinensis* and *Viburnum tinus*; the shrubs are *Photinia serratifolia, Buxus sinica* and *Abelia x grandiflora* (Figure 4-43).

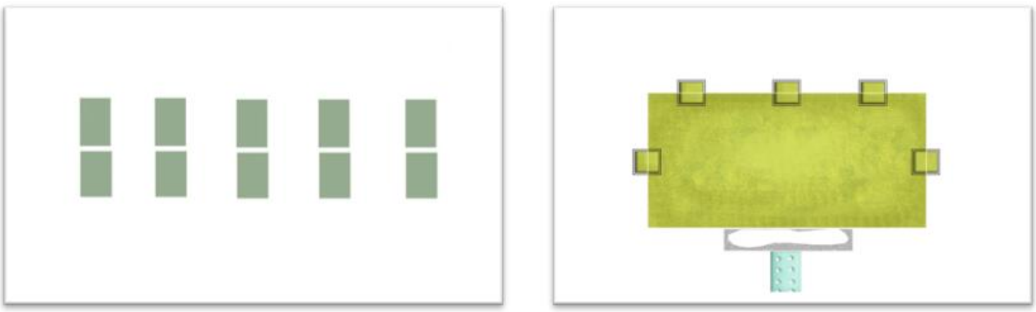


Fig 4-44 Comparison between before and after enhancement (left: before enhancement; right: after enhancement). Source: by author

The comparison shows an increase in the percentage of green space and a decrease in the percentage of impervious surfaces in the enhanced space. And the distribution of patches is more aggregated. The design strategy is practically practiced while retaining the function of the space (Figure 4-44).

5. Conclusion

5.1 Main findings

This study quantifies the carbon sink capacity of park green spaces in Zhengzhou City and explores the differences in carbon sinks among different types of parks based on satellite remote sensing and actual measurement data. In addition, the correlation between park landscape pattern index and park carbon sink was explored by combining the landscape pattern index and Pearson correlation analysis. Finally, based on the results of the study, measures to enhance the carbon sink capacity of park green spaces in Zhengzhou are proposed from the perspective of spatial structure and some categories are selected for design optimization.

In detail, the main findings of this study are as follows:

1) The total carbon storage of 123 parks in Zhengzhou is 108.5 Gg C, and the carbon storage density is 5.36 kg C m^{-2}.
2) The larger parks in Zhengzhou do not match the parks with high carbon sink capacity, and the potential for carbon sink enhancement in Zhengzhou's parks is huge.
3) There are obvious differences in carbon sink capacity among different types of parks in Zhengzhou. Among the parks with different characteristics, theme parks have the highest carbon sink capacity and community parks have the lowest carbon sink capacity; among the parks located in different locations in the city, the carbon sink capacity of parks located in the center of the city is higher and the carbon sink capacity of parks located at the edge of the city is relatively weaker; when analyzing the differences in carbon sinks of parks with different areas, the results show that the carbon sink capacity of parks does not consistently increase with the increase in park area. In addition, the carbon sink capacity of parks containing water is significantly higher than that of parks without

water.

4) The carbon sink capacity of parks in Zhengzhou was significantly correlated with the landscape pattern index with certain patterns. Among them, PLNAD_imper, PLAND_bare and LPI generally showed significant negative correlations, while NP, LSI, AI, PLAND_green and PLAND_water generally showed significant positive correlations.
5) Based on the results, corresponding spatial design carbon sink enhancement strategies were proposed for each type of park.Based on the proposed spatial design carbon sink enhancement strategies, detailed design proposals including site analysis, design strategy, master plan and corresponding design drawings such as Section, Visualization and Plantation are proposed for street parks, community parks, strip parks, integrated parks and theme parks.

5.2 Limitations and suggested future research

The study shows that the method of estimating the carbon sink capacity of urban park green space based on remote sensing data and actual measurement data is feasible. There is a correlation between park carbon sink and park spatial structure, and it is practical to enhance the carbon sink capacity of parks from spatial structure.

However, due to the influence factors and statistical methods, there are three types of parks in the correlation analysis results that do not have the landscape pattern index associated with them. This leads to the fact that these three types of parks do not have corresponding spatial carbon sink enhancement strategies. In addition, this study only argues the possibility of enhancing carbon sinks in parks from the perspective of spatial structure, but in fact, there are many factors that affect carbon sinks in parks, such as plant species selection, plant diversity index, socio-economic and natural environmental factors.

Therefore, in future studies, the relationship between carbon sinks and influencing factors can be quantified by selecting more appropriate correlation analysis methods or using regression analysis methods. It is also possible to try to incorporate more influencing factors into the study to analyze the driving mechanisms of carbon sinks in parks more comprehensively and to give more detailed and comprehensive strategies to enhance them.

Acknowledgement

At this moment, the thesis is coming to an end. For me, the completion of this thesis means the end of two years in Hungary. Soon I will return to China to start the next part of my life. Therefore, I would like to express my sincere gratitude to some people who are very important to me.

I'm extremely grateful to Prof. István Valánszki, who helped me a lot with my thesis. This help was not only in terms of respecting the topic I chose for my thesis, teaching presentation skills, and controlling the details of my research. It also included opening to my stress, quick responses to emails and humorous verbal discussions. With his support and assistance, I can confidently continue to work on my topic and successfully complete my master's thesis.

I am also deeply indebted to Prof. Shidong Ge, my Chinese supervisor, for bringing me into the real world of research. I am also grateful for his help with this thesis, including but not limited to original ideas, data provision and various guidance during the process.

Thanks should also go to the Hungarian University of Agriculture and Life Sciences, which provided me with a wonderfully fulfilling overseas MLA program, and to Henan Agricultural University in China, which gave me the opportunity and platform to apply for this MLA program.

Special thanks to the China Scholarship Council and the Stipendium Hungaricum Scholarship for funding me to study in Hungary without the pressure of survival.

Finally, once again, I would like to express my sincere gratitude and highest respect to all those who have helped me.

Lists of Figures

Lists of Tables

References

Anonymous. (2021, October 3). *A New Vision for the US Climate Agenda*. IMF. https://www.imf.org/en/Blogs/Articles/2021/03/10/blog-a-new-vision-for-the-us-climate-agenda

Ariluoma, M., Ottelin, J., Hautamäki, R., Tuhkanen, E.-M., & Mänttäri, M. (2021). Carbon sequestration and storage potential of urban green in residential yards: A case study from Helsinki. *Urban Forestry & Urban Greening*, *57*, 126939. https://doi.org/10.1016/j.ufug.2020.126939

Bolin, B. (1977). Changes of Land Biota and Their Importance for the Carbon Cycle. *Science*, *196*(4290), 613–615. https://doi.org/10.1126/science.196.4290.613

Cai, E., Bi, Q., Lu, J., & Hou, H. (2022). The Spatiotemporal Characteristics and Rationality of Emerging Megacity Urban Expansion: A Case Study of Zhengzhou in Central China. *Frontiers in Environmental Science*, *10*. https://www.frontiersin.org/articles/10.3389/fenvs.2022.860814

Carbon neutral. (n.d.). Retrieved 2 May 2023, from https://www.solar-ledlights.com/portable-solar-power-station-future/

Chen, A., Yao, L., Sun, R., & Chen, L. (2014). How many metrics are required to identify the effects of the landscape pattern on land surface temperature? *Ecological Indicators*, *45*, 424–433. https://doi.org/10.1016/j.ecolind.2014.05.002

Churkina, G. (2016). The Role of Urbanization in the Global Carbon Cycle. *Frontiers in Ecology and Evolution*, *3*. https://doi.org/10.3389/fevo.2015.00144

Dhakal, S. (2010). GHG emissions from urbanization and opportunities for urban carbon mitigation. *Current Opinion in Environmental Sustainability*, *2*(4), 277–283. https://doi.org/10.1016/j.cosust.2010.05.007

Dorendorf, J., Eschenbach, A., Schmidt, K., & Jensen, K. (2015). Both tree and soil carbon need to be quantified for carbon assessments of cities. *Urban Forestry & Urban Greening*, *14*(3), 447–455. https://doi.org/10.1016/j.ufug.2015.04.005

Du, C., Song, P., Wang, K., Li, A., Hu, Y., Zhang, K., Jia, X., Feng, Y., Wu, M., Qu, K., Zhang, Y., & Ge, S. (2022). Investigating the Trends and Drivers between Urbanization and the Land Surface Temperature: A Case Study of Zhengzhou, China. *Sustainability*, *14*(21), 13845. https://doi.org/10.3390/su142113845

EU's Goal. (n.d.). Retrieved 1 March 2023, from https://www.consilium.europa.eu/en/5-facts-eu-climate-neutrality/

Getter, K. L., Rowe, D. B., Robertson, G. P., Cregg, B. M., & Andresen, J. A. (2009). Carbon Sequestration Potential of Extensive Green Roofs. *Environmental Science & Technology*, *43*(19), 7564–7570. https://doi.org/10.1021/es901539x

Gong, P., Li, X., Wang, J., Bai, Y., Chen, B., Hu, T., Liu, X., Xu, B., Yang, J., Zhang, W., & Zhou, Y. (2020). Annual maps of global artificial impervious area (GAIA) between 1985 and 2018. *Remote Sensing of Environment*, *236*, 111510. https://doi.org/10.1016/j.rse.2019.111510

Gregg, J. S., Andres, R. J., & Marland, G. (2008). China: Emissions pattern of the world leader in CO2 emissions from fossil fuel consumption and cement production. *Geophysical Research Letters*, *35*(8). https://doi.org/10.1029/2007GL032887

Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., & Briggs, J. M. (2008). Global Change and the Ecology of Cities. *Science*, *319*(5864), 756–760. https://doi.org/10.1126/science.1150195

Jia, W., & Zhao, S. (2020). Trends and drivers of land surface temperature along the urban-rural gradients in the largest urban agglomeration of China. *Science of The Total Environment*, *711*, 134579. https://doi.org/10.1016/j.scitotenv.2019.134579

Jo, H.-K., Kim, J.-Y., & Park, H.-M. (2019). Carbon reduction and planning strategies for urban parks in Seoul. *Urban Forestry & Urban Greening*, *41*, 48–54. https://doi.org/10.1016/j.ufug.2019.03.009

Li, H., Wang, G., Tian, G., & Jombach, S. (2020). Mapping and Analyzing the Park Cooling Effect on Urban Heat Island in an Expanding City: A Case Study in Zhengzhou

City, China. *Land*, *9*(2), 57. https://doi.org/10.3390/land9020057

Li, X., Gong, P., Zhou, Y., Wang, J., Bai, Y., Chen, B., Hu, T., Xiao, Y., Xu, B., Yang, J., Liu, X., Cai, W., Huang, H., Wu, T., Wang, X., Lin, P., Li, X., Chen, J., He, C., … Zhu, Z. (2020). Mapping global urban boundaries from the global artificial impervious area (GAIA) data. *Environmental Research Letters*, *15*(9), 094044. https://doi.org/10.1088/1748-9326/ab9be3

Liu, Y., Zhou, G., Du, H., Berninger, F., Mao, F., Li, X., Chen, L., Cui, L., Li, Y., Zhu, D., & Xu, L. (2018). Response of carbon uptake to abiotic and biotic drivers in an intensively managed Lei bamboo forest. *Journal of Environmental Management*, *223*, 713–722. https://doi.org/10.1016/j.jenvman.2018.06.046

Luo Xinyue;Chen Mingxing; (2019). Research Progress on the Impact of Urbanization on Climate Change. *Advances in Earth Science.*, *09 vo 34*, 984–997.

Lv, H., Wang, W., He, X., Xiao, L., Zhou, W., & Zhang, B. (2016). Quantifying Tree and Soil Carbon Stocks in a Temperate Urban Forest in Northeast China. *Forests*, *7*(9), Article 9. https://doi.org/10.3390/f7090200

Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S. L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M. I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J. B. R., Maycock, T. K., Waterfield, T., Yelekçi, Ö., Yu, R., & Zhou, B. (Eds.). (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. https://doi.org/10.1017/9781009157896

McPherson, G. E., Nowak, D. J., & Rowntree, R. A. (1994). Chicago's urban forest ecosystem: Results of the Chicago Urban Forest Climate Project. *Gen. Tech. Rep. NE-186. Radnor, PA: U. S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 201 p.*, *186*. https://doi.org/10.2737/NE-GTR-186

Nowak, D. J. (1993). Atmospheric Carbon Reduction by Urban Trees. *Journal of Environmental Management*, *37*(3), 207–217. https://doi.org/10.1006/jema.1993.1017

Nowak, D. J., & Crane, D. E. (2002). Carbon storage and sequestration by urban trees in the USA. *Environmental Pollution*, *116*(3), 381–389. https://doi.org/10.1016/S0269-7491(01)00214-7

Nowak, D. J., Greenfield, E. J., Hoehn, R. E., & Lapoint, E. (2013). Carbon storage and sequestration by trees in urban and community areas of the United States. *Environmental Pollution*, *178*, 229–236. https://doi.org/10.1016/j.envpol.2013.03.019

Park, H.-M., & Jo, H.-K. (2021). Ecological Design and Construction Strategies through Life Cycle Assessment of Carbon Budget for Urban Parks in Korea. *Forests*, *12*(10), 1399. https://doi.org/10.3390/f12101399

Pasher, J., McGovern, M., Khoury, M., & Duffe, J. (2014). Assessing carbon storage and sequestration by Canada's urban forests using high resolution earth observation data. *Urban Forestry & Urban Greening*, *13*(3), 484–494. https://doi.org/10.1016/j.ufug.2014.05.001

Photosynthesis Process. (n.d.). Shutterstock. Retrieved 2 May 2023, from https://www.shutterstock.com/image-vector/photosynthesis-process-plant-diagram-all-factors-607249862

Ren, Z., Zheng, H., He, X., Zhang, D., Shen, G., & Zhai, C. (2019). Changes in spatio-temporal patterns of urban forest and its above-ground carbon storage: Implication for urban CO2 emissions mitigation under China's rapid urban expansion and greening. *Environment International*, *129*, 438–450. https://doi.org/10.1016/j.envint.2019.05.010

Russo, A., Escobedo, F. J., Timilsina, N., Schmitt, A. O., Varela, S., & Zerbe, S. (2014). Assessing urban tree carbon storage and sequestration in Bolzano, Italy. *International Journal of Biodiversity Science, Ecosystem Services & Management*, *10*(1), 54–70. https://doi.org/10.1080/21513732.2013.873822

Schreyer, J., Tigges, J., Lakes, T., & Churkina, G. (2014). Using Airborne LiDAR and QuickBird Data for Modelling Urban Tree Carbon Storage and Its Distribution—A Case Study of Berlin. *Remote Sensing*, *6*(11), Article 11. https://doi.org/10.3390/rs61110636

Seto, K. C., Güneralp, B., & Hutyra, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences*, *109*(40), 16083–16088. https://doi.org/10.1073/pnas.1211658109

Shadman, S., Ahanaf Khalid, P., Hanafiah, M. M., Koyande, A. K., Islam, Md. A., Bhuiyan, S. A., Sin Woon, K., & Show, P.-L. (2022). The carbon sequestration potential of urban public parks of densely populated cities to improve environmental sustainability. *Sustainable Energy Technologies and Assessments*, *52*, 102064. https://doi.org/10.1016/j.seta.2022.102064

Sharma, R., Pradhan, L., Kumari, M., & Bhattacharya, P. (2020). Assessment of Carbon Sequestration Potential of Tree Species in Amity University Campus Noida. *Environmental Sciences Proceedings*, *3*(1), Article 1. https://doi.org/10.3390/IECF2020-08075

Singkran, N. (2022). Carbon sink capacity of public parks and carbon sequestration efficiency improvements in a dense urban landscape. *Environmental Monitoring and Assessment*, *194*(10), 750. https://doi.org/10.1007/s10661-022-10432-x

Stoffberg, G. H., van Rooyen, M. W., van der Linde, M. J., & Groeneveld, H. T. (2010). Carbon sequestration estimates of indigenous street trees in the City of Tshwane, South Africa. *Urban Forestry & Urban Greening*, *9*(1), 9–14. https://doi.org/10.1016/j.ufug.2009.09.004

Sun, Y., Xie, S., & Zhao, S. (2019). Valuing urban green spaces in mitigating climate change: A city-wide estimate of aboveground carbon stored in urban green spaces of China's Capital. *Global Change Biology*, *25*(5), 1717–1732. https://doi.org/10.1111/gcb.14566

Szkop, Z. (2022). The value of air purification and carbon storage ecosystem services of park trees in Warsaw, Poland. *Environmental & Socio-Economic Studies*, *10*(3), 1–11. https://doi.org/10.2478/environ-2022-0012

Tammeorg, P., Soronen, P., Riikonen, A., Salo, E., Tikka, S., Koivunen, M., Salonen, A.-R., Kopakkala, T., & Jalas, M. (2021). Co-Designing Urban Carbon Sink Parks: Case Carbon Lane in Helsinki. *Frontiers in Environmental Science*, *9*, 672468. https://doi.org/10.3389/fenvs.2021.672468

United Kingdom. (n.d.). Retrieved 1 March 2023, from https://climateactiontracker.org/countries/uk/

Uuemaa, E., Antrop, M., Roosaare, J., Marja, R., & Mander, Ü. (2009). Landscape Metrics and Indices: An Overview of Their Use in Landscape Research. *Living Rev. Landscape Res.*, *3*. https://doi.org/10.12942/lrlr-2009-1

Vaccari, F. P., Gioli, B., Toscano, P., & Perrone, C. (2013). Carbon dioxide balance assessment of the city of Florence (Italy), and implications for urban planning. *Landscape and Urban Planning*, *120*, 138–146. https://doi.org/10.1016/j.landurbplan.2013.08.004

Wang, X., & Tomaney, J. (2019). Zhengzhou – Political economy of an emerging Chinese megacity. *Cities*, *84*, 104–111. https://doi.org/10.1016/j.cities.2018.07.011

Woodwell, G. M., Whittaker, R. H., Reiners, W. A., Likens, G. E., Delwiche, C. C., & Botkin, D. B. (1978). The Biota and the World Carbon Budget. *Science*, *199*(4325), 141–146. https://doi.org/10.1126/science.199.4325.141

World urbanization prospects: The 2018 revision. (2019). United Nations.

Yan Zhongwei;Ding Yihui. (2020). Re-assessing climatic warming in China since the last century. *Acta Meteorologica Sinica*, *03 vo 78*, 370–378.

Yao, Z., Liu, J., Zhao, X., Long, D., & Wang, L. (2015). Spatial dynamics of aboveground carbon stock in urban green space: A case study of Xi'an, China. *Journal of Arid Land*, *7*(3), 350–360. https://doi.org/10.1007/s40333-014-0082-9

Yao, Z.-Y., & Liu, J.-J. (2014). [Models for biomass estimation of four shrub species planted in urban area of Xi'an city, Northwest China]. *Ying Yong Sheng Tai Xue Bao = The Journal of Applied Ecology*, *25*(1), 111–116.

Yu, Y., & Wang, X. (2021). Estimation of urban green space carbon sink for ecosystem service function. *Journal of Xi'an University of Architecture & Technology(Natural*

Science Edition), *53*(01), 95–102. https://doi.org/10.15986/j.1006-7930.2021.01.013

Zhang, K., Yun, G., Song, P., Wang, K., Li, A., Du, C., Jia, X., Feng, Y., Wu, M., Qu, K., Zhu, X., & Ge, S. (2023). Discover the Desirable Landscape Structure of Urban Parks for Mitigating Urban Heat: A High Spatial Resolution Study Using a Forest City, Luoyang, China as a Lens. *International Journal of Environmental Research and Public Health*, *20*(4), Article 4. https://doi.org/10.3390/ijerph20043155

Zhang, X. (2019). The history of pollution elements in Zhengzhou, China recorded by tree rings. *Dendrochronologia*, *54*, 71–77. https://doi.org/10.1016/j.dendro.2019.02.004

Zhao, M., Kong, Z., Escobedo, F. J., & Gao, J. (2010). Impacts of urban forests on offsetting carbon emissions from industrial energy use in Hangzhou, China. *Journal of Environmental Management*, *91*(4), 807–813. https://doi.org/10.1016/j.jenvman.2009.10.010

Zhou, W., Qian, Y., Li, X., Li, W., & Han, L. (2014). Relationships between land cover and the surface urban heat island: Seasonal variability and effects of spatial and thematic resolution of land cover data on predicting land surface temperatures. *Landscape Ecology*, *29*(1), 153–167. https://doi.org/10.1007/s10980-013-9950-5

Zirkle, G., Lal, R., Augustin, B., & Follett, R. (2012). Modeling Carbon Sequestration in the U.S. Residential Landscape. In R. Lal & B. Augustin (Eds.), *Carbon Sequestration in Urban Ecosystems* (pp. 265–276). Springer Netherlands. https://doi.org/10.1007/978-94-007-2366-5_14

DECLARATION

on authenticity and public assess of mater's thesis

Student's name:	Du Chenyu
Student's Neptun ID:	WHLQMG
Title of the document:	Developing an Optimal Landscape Configuration of Urban Parks to Enhance Carbon Sink.
Year of publication:	2023
Department:	Department of Garden and Open Space Design

I declare that the submitted master's thesis is my own, original individual creation. Any parts taken from an another author's work are clearly marked, and listed in the table of contents.

If the statements above are not true, I acknowledge that the Final examination board excludes me from participation in the final exam, and I am only allowed to take final exam if I submit another master's thesis.

Viewing and printing my submitted work in a PDF format is permitted. However, the modification of my submitted work shall not be permitted.

I acknowledge that the rules on Intellectual Property Management of Hungarian University of Agriculture and Life Sciences shall apply to my work as an intellectual property.

I acknowledge that the electric version of my work is uploaded to the repository sytem of the Hungarian University of Agriculture and Life Sciences.

Place and date: Budapest . 2023 year May month 2 day

Du Chenyu

Student's signature

STATEMENT ON CONSULTATION PRACTICES

As a supervisor of Du Chenyu (Student's name) WHLQMG (Student's NEPTUN ID), I here declare that the master's thesis has been reviewed by me, the student was informed about the requirements of literary sources management and its legal and ethical rules.

I recommend/don't recommend[1] the final essay/thesis/master's thesis/portfolio to be defended in a final exam.

The document contains state secrets or professional secrets: yes no*[2]

Place and date: Budapest 2023 year May month 2 day

Internal supervisor

[1] Please underline applicable.

[2] Please underline applicable.