# Research on Sustainable Design of Urban Green Spaces

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**Abstract.** Facing the increasingly deteriorating urban environment, urban green spaces play a significant positive role in mitigating the urban heat island effect. This study adopts a whole life cycle energy valuation method to assess the ecological sustainability of urban green spaces in the city of Chenzhou. The research findings indicate that the emergy at different stages of urban green spaces change over time and exhibit varying proportions. Particularly during the maintenance phase, urban green spaces require higher material flow, energy flow, and information flow, requiring special attention. Additionally, by calculating indicators such as emergy generation rate, environmental load rate, and emergy sustainability indicators, the ecological sustainability of urban green spaces is quantitatively evaluated. This study provides useful insights for urban managers in the design of eco-friendly cities.

**Keywords:** Urban green space; Ecological emergy; Life cycle theory; Sustainable design.

## 1 Introduction

Urban green spaces are an integral part of the natural environment in cities, including parks, green belts, and street flower beds. They play a crucial role in urban sustainability and human well-being[1-6]. Here is an overview of the benefits of urban green spaces: Firstly, urban green spaces are essential for mitigating the urban heat island effect. Due to the presence of extensive urban buildings and roads, the surface temperature in cities is higher than the surrounding rural areas. However, green spaces help lower the city's temperature through evapotranspiration, shading, and natural ventilation, thus alleviating the impact of the heat island effect. Secondly, urban green spaces contribute to improving air quality. Plants absorb carbon dioxide through photosynthesis and release oxygen, thereby purifying the air. Green spaces also filter and absorb particulate matter and pollutants, reducing the level of air pollution. This is crucial for enhancing people's health and comfort. Thirdly, urban green spaces provide habitats for urban biodiversity. The process of urbanization has led to the destruction of natural


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habitats, posing a threat to many species' survival. Urban green spaces offer safe havens, providing food and shelter for wildlife. By conserving and restoring biodiversity, cities can achieve more sustainable development. Additionally, urban green spaces serve as places for recreation and leisure. Parks, gardens, and outdoor sports facilities provide opportunities for people to relax, exercise, and enjoy themselves. This helps improve people's quality of life, promote social interactions, and enhance community cohesion. Lastly, urban green spaces play a crucial role in water resource management. Vegetation can absorb rainwater and reduce runoff, thus relieving the pressure on urban drainage systems. Green spaces also filter and purify rainwater, reducing the risk of water pollution. Overall, urban green spaces contribute significantly to urban sustainability by mitigating the heat island effect, improving air quality, supporting biodiversity, providing recreational spaces, and aiding water resource management[7-12].

In conclusion, urban green spaces play a crucial role in urban sustainability. They not only mitigate the heat island effect and improve air quality but also provide habitats for biodiversity conservation and offer recreational spaces for people. By appropriately planning and managing urban green spaces, we can create more livable and sustainable urban environments.

## 2 Methods and Case

### 2.1 LCA-Emergy introduction

The LCA-emergy method can be applied to assess the ecological sustainability of urban green spaces, aiding in understanding their energy efficiency and environmental impacts throughout their lifecycle. Based on the evaluation results using the LCA-emergy method, recommendations can be provided to decision-makers regarding green space planning, vegetation selection, and maintenance management, aiming to maximize the ecological sustainability of urban green spaces. Additionally, it can provide guidance to policymakers, promoting greater ecological benefits and social value of urban green spaces within overall urban development. Therefore, the LCA-emergy method offers a comprehensive approach for evaluating the ecological sustainability of urban green spaces, assisting in achieving sustainable development and ecological conservation goals for these areas[13-14].

### 2.2 Evaluation procedure

When evaluating the ecological sustainability of urban green spaces using the LCA-emergy method, the following aspects need to be considered:

(1) Green space design and planning: Assess the impact of green space design and planning on energy use, biodiversity, and ecosystem functionality. This includes factors such as green space types, vegetation selection, and landscape layout.

(2) Green space construction and maintenance: Evaluate the energy consumption, material use, and potential environmental impacts associated with green space construction and maintenance. This includes land preparation, planting, irrigation, maintenance, and management.

(3) Green space services and benefits: Assess the ecosystem services and social benefits provided by green spaces, such as air quality improvement, water resource protection, temperature regulation, and community interaction.

(4) Green space recycling: Evaluate the handling of green spaces at the end of their lifespan, including site transformation, recycling, and ecological restoration measures.

By combining LCA and emergy analysis, it is possible to comprehensively consider the material and energy flows of urban green spaces and measure the embodied energy within them. This helps in conducting a comprehensive assessment of energy efficiency, resource utilization, and environmental impacts of urban green spaces, supporting more ecologically sustainable green space design and management.

## 2.3 Sustainable indicators

This article adopts three ecological emergy indicators, namely emergy yield rate(EYR), environmental load rate(ELR), and emergy sustainability indicators(ESI).

The emergy yield rate is a measure of how efficiently energy is produced. It can be calculated using the following formula:

Energy Yield Rate = (Emergy Output / Emergy Input) x 100%

where: Emergy Output refers to the amount of usable emergy generated or obtained from a system or process. Energy Input represents the total emergy inputted or consumed in the system or process.

Environmental load rate is an indicator that measures the burden imposed on the environment by a system or process. It can be used to assess the environmental impact of energy production or consumption. The calculation formula for environmental load rate is as follows:

Environmental Load Rate = (Environmental Impact Indicator / Economic Output Indicator) x 100%

where: Environmental Impact Indicator refers to the quantity or extent of environmental impact associated with the system or process, such as pollutant emissions, resource consumption, etc. Economic Output Indicator represents the quantity or value of economic output generated by the system or process.

A higher value of environmental load rate indicates a greater burden on the environment by the system or process. Therefore, a lower environmental load rate signifies more environmentally friendly and sustainable operations.

The emergy sustainability parameter is an indicator that measures the sustainability of emergy production or consumption by considering both emergy output and environmental impact. It provides a quantitative assessment of the balance between emergy generation and its environmental consequences. The calculation formula for the emergy sustainability parameter is as follows:

Emergy Sustainability Parameter = EYR/ELR

A higher value of the energy sustainability parameter indicates a more sustainable energy system or process, as it signifies a greater energy output relative to the combined effects of environmental impact and energy input. This parameter helps in evaluating and comparing different energy systems or processes based on their overall sustainability performance.

### 2.4 Case introduction

Figure 1 represents the green space planning and design for Chenzhou City from 2010 to 2030. The types of green spaces include parklands, street landscapes, protective green areas, and more.

**Fig. 1.** Urban Green Spaces Planning in Chenzhou City from 2010 to 2030(self-draw)

## 3 Results

### 3.1 Sustainable indicators

The changing trend of sustainability indicators in Figure 2 represents the variations over time in sustainability-related metrics. It visually depicts the evolution or fluctuations of these indicators within a specific timeframe. By analyzing this trend, we can gain insights into the progress, improvements, or potential challenges related to sustainability.

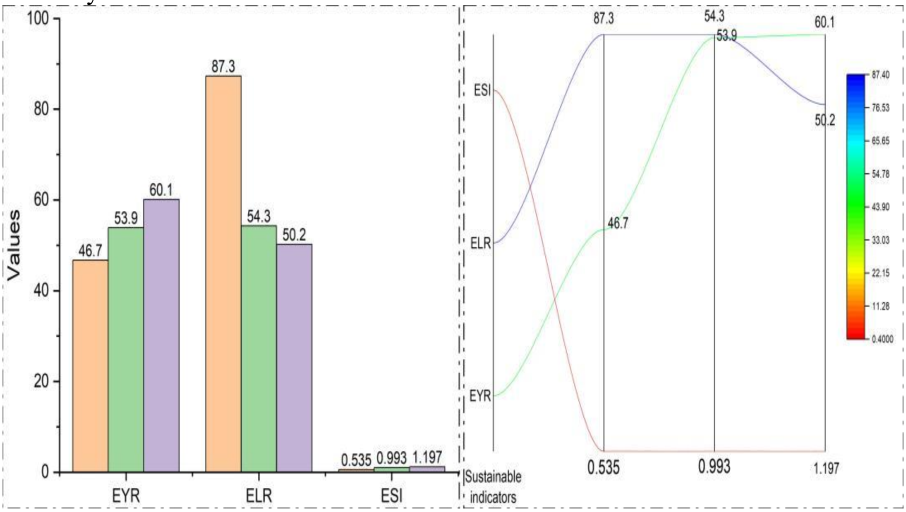


**Fig. 2.** The changing trend of sustainability indicators(self-draw)

Through the calculation of three indicators (EYR/ELR/ESI), the values of sustainability indicators were computed for the years 2010, 2020, and 2030. The calculations for 2010 and 2020 are based on actual data, while the computation for 2030 is simulated. Taking ESI as an example, the increase from 0.535 to 0.993 and further to 1.197 indicates that with the increase in green space design, the overall sustainability of Chenzhou City is improving.

Monitoring and analyzing the trend of sustainability indicators enables stakeholders to identify patterns, set targets, track progress, and make informed decisions to support long-term sustainable development.

### 3.2 Sensitivity analysis

Sensitivity analysis is a method used to evaluate the sensitivity of a model to changes in input parameter, which is essential for establishing reliable models, identifying key parameters, evaluating uncertainty, and supporting decision-making. Figure 3 represents the sensitivity analysis for three types of indicators.

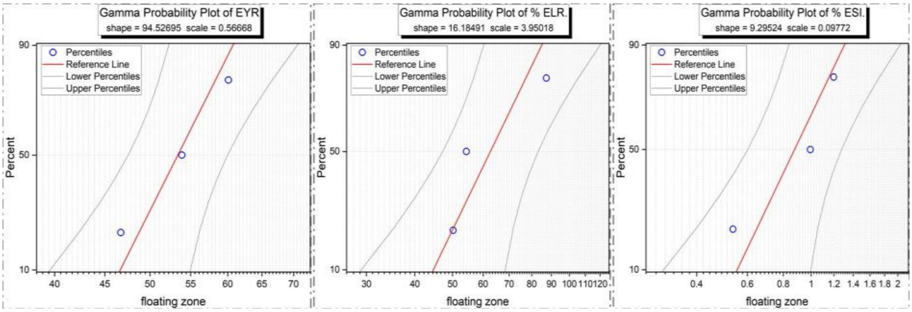


**Fig. 3.** the sensitivity analysis of sustainable indicators(self-draw)

Figure 3 displays the sensitivity trends of the EYR/ELR/ESI indicators. Overall, the sensitivity changes show a linear pattern, with EYR exhibiting stronger correlation compared to the other two indicators.

## 4 Conclusions

In response to the abnormal climate situation in urban areas, Chenzhou City has carried out planning and design for urban green spaces. From an ecological perspective, the increase in urban green spaces is beneficial for the construction of an ecological city. This study utilizes the energy value method to quantitatively assess the sustainable changes in Chenzhou City's green spaces, providing urban managers with a new approach.

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