

Research on the sustainability assessment of sponge cities

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Abstract. Faced with abnormal global climate change, sponge cities are an effective response. The design of sponge cities can enhance the sustainability of the entire city, although specific quantitative effects are yet to be determined. According to the emergy theory, this article conducts a sustainability study on selected sponge city facilities in Zhenjiang City. The research results show a significant improvement in the sustainability of the study objects. Using the sustainable parameter of emergy as an evaluation criterion, there is a noticeable improvement from an initial value of 0.07 to 1.21 after the implementation of sponge measures. Additionally, the overall project design has significantly improved the sustainability of the design.

1. Introduction

With the ongoing trend of urbanization, cities are faced with a multitude of challenges including urban heat islands, solid waste and water pollution, air pollution, and traffic congestion. Chinese cities, in particular, grapple with issues stemming from outdated infrastructure, urban congestion, water and air pollution, public health crises, waste gas and solid pollution, as well as the urban heat island effect [1]. In order to tackle these challenges, it is imperative to embrace and implement sustainable development practices. Before embarking on initiatives for sustainable urban renewal and governance, conducting a comprehensive evaluation of the current state of urban development becomes paramount. As a result, urban sustainability assessment has emerged as a crucial field of research.

The sustainability of cities has garnered significant research interest, with scholars extensively investigating the concept of eco-cities from diverse perspectives. This body of research has produced a multitude of findings and insights in various areas.

Some of these areas of study include: Ecological security: Research has focused on understanding and ensuring the stability and integrity of ecological systems within cities [2-4]. Measurement of ecological footprint: Scholars have developed methods to assess the environmental impact and resource consumption of cities, known as the ecological footprint [5-6]. Urban symbiosis: The promotion of urban symbiosis involves creating interconnected systems that facilitate resource sharing and waste management among different urban sectors [7]. Ecological civilization construction: This area of research explores the development and implementation of policies and practices that contribute to the formation of an ecological civilization, balancing economic growth

with environmental protection [8]. Ecological networks: Researchers have emphasized the importance of establishing interconnected networks of green spaces, ecological corridors, and biodiversity-friendly habitats in urban areas [9]. Environmental quality assessment: Studies have focused on evaluating the overall environmental quality of cities, considering factors such as air pollution, water pollution, noise levels, and waste management [10]. Ecological smart cities: This field investigates the integration of technology and data-driven approaches to enhance urban sustainability, efficiency, and livability [11-12]. Ecological livability evaluation: Research aims to develop assessment frameworks and indicators to measure the livability and quality of life in eco-cities [13]. Emergy analysis: This approach evaluates the energy flows and resource utilization within urban systems to assess their sustainability and efficiency [14]. Ecological literacy: Scholars have emphasized the need to enhance public awareness and understanding of ecological principles and sustainable practices for effective urban governance [15]. Study of ecological patterns: Research in this area focuses on analyzing the spatial distribution of ecosystems, biodiversity, and natural resources within urban environments [16]. Exploration of ecological risks: Scholars investigate potential risks and vulnerabilities associated with urbanization, such as climate change impacts, natural disasters, and loss of ecosystem services [17]. These areas of research contribute to our understanding of eco-city development and provide guidance for policymakers, urban planners, and stakeholders in addressing the challenges faced by Chinese cities and promoting sustainable urban renewal and governance.

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1.1. Research framework design

In this study, a framework for Emergy evaluation of eco-cities has been developed. The framework is illustrated

in Figure 1. Figure 2 shows the block diagram of a feedback system, while Figure 3 illustrates the data processing framework.

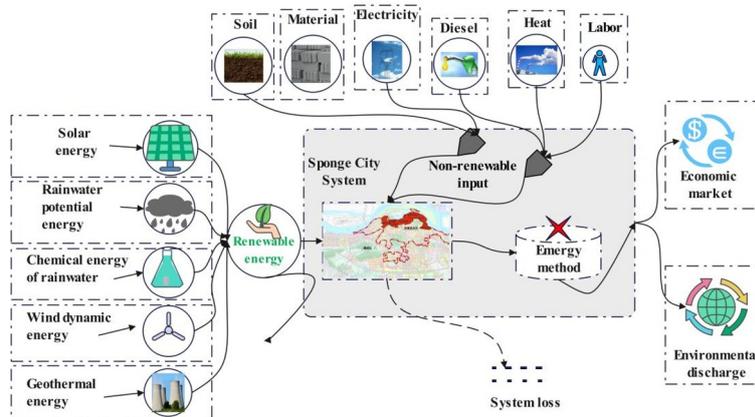


Fig.1. Research framework design

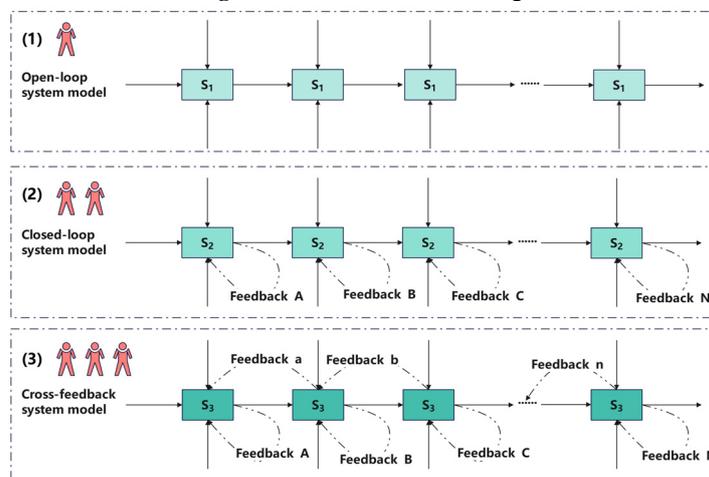


Fig. 2. Three typical feedback systems

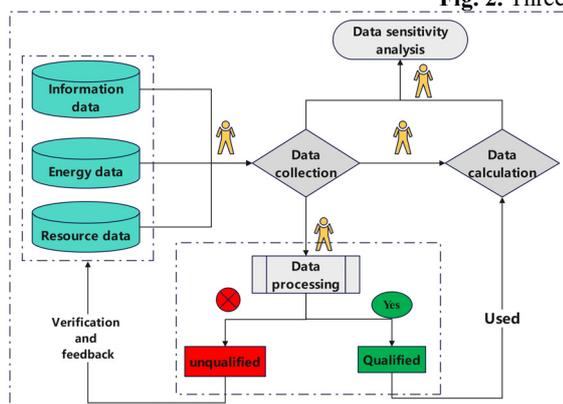


Fig. 3. Data processing structure

Figures 1 to 3 provide a clear theoretical framework for this research. The feedback structure ensures the precision of the study topic, while the data processing framework enables accurate data collection.

The framework provides a systematic approach to collecting and processing data, ensuring that the collected data is reliable, consistent, and accurate. This ensures consistency across different datasets and allows for easier comparison and replication of results. A well-designed data processing framework streamlines the data handling process, making it more efficient. It helps in automating repetitive tasks, reducing manual effort, and

improving overall data processing speed. This efficiency enables researchers to analyze larger datasets and derive insights more effectively. The framework incorporates various quality control measures to detect and address data anomalies, errors, or inconsistencies. These measures can include data validation checks, outlier detection algorithms, and data cleaning techniques. By implementing such quality control steps, researchers can ensure the reliability and validity of their findings. Overall, the data processing framework plays a crucial role in supporting sound data analysis and interpretation, leading to reliable and meaningful research outcomes.

1.2. Emergy introduction

Emergy was initially introduced by H.T. Odum and offers a distinct advantage in assessing the value of resources and services in view of available solar energy. Transformity, expressed as seJ/g or seJ/ \$ for each unit of product or service, enables the comparison of different types of energy [18]. By employing the emergy method, various systems have successfully conducted efficient comparative calculations on a unified platform, providing valuable resource management strategies. In this study, the emergy baseline is established at 12.0E+24sej/year, avoiding repetition of information[19].

2. Results and Discussion

2.1. Study area



Fig. 4. Land Use of Different Plots

Zhenjiang is located in the eastern section of the Ningzhen Mountains and belongs to a low mountain and hilly area. The southern part consists of low mountain areas, the central part is characterized by hilly valleys, and the northern part along the river is a flood plain. The mountainous structure formed by the Ningzhen Mountains and Maoshan Mountains serves as the framework, with hills, plateaus, and plains distributed on both sides of the mountains. The extensive forest vegetation provides a vast, open green background space, laying the foundation for the basic framework of the integrated urban-rural green space system. Numerous water systems within the city are closely connected to the Yangtze River (Figure 4).

The southwestern part of Zhenjiang is undulating with continuous mountains, among which Dahua Mountain is the highest peak at an elevation of 437.2 meters. The highest peak in the urban area is Shili Changshan, standing at 349 meters above sea level. The ancient canal meanders from the southeast to the northwest, flowing into the Yangtze River. The urban area is located south of the Yangtze River, situated on both sides of the ancient canal. The Yunliang Canal runs parallel to the Yangtze River in the western part of the city, connecting to the Yangtze River at both ends. The water system in Zhenjiang is divided into the Beihu Yangtze River system in the north, the eastern Taihu Lake West Water System, and the western Qinhuai River Water System. The Yangtze River flows through the city for a distance of 108 kilometers. Within the Grand Canal, it covers a total length of 42.6 kilometers, intersecting with the Yangtze River at Jianbi. The total capacity of artificial reservoirs and ponds in the city exceeds 500 million cubic meters, including 101 registered reservoirs with a capacity of over 100,000 cubic meters, totaling 331.83 million cubic meters.

Cultivated land in Zhenjiang is widely distributed, mainly in the northern part of the city, surrounding the east-west Ningzhen Mountains. It is also found in the southwestern part of the city, in the agricultural area of Maoshan Hills on the western and northern sides of Maoshan Mountains. Along the northern and northeastern edges of the city, there are paddy fields in the along-river polder agricultural area. A large area of arable land exists in the eastern part of the city's Taihu agricultural area and a portion of Menghe Plain. Additionally, the Taoge Plain and Chishan Lake agricultural area also have extensive farmland

distribution. The total area of cultivated land in Zhenjiang City is 2,121.2 square kilometers, with approximately 378.11 square kilometers of dry land, accounting for about 17.8% of the total cultivated land area. The majority of rice paddies make up 82.2% and are distributed across most areas of the city. Zhenjiang City has 68 basic farmland protection zones, with a high protection rate of 95.27%.

2.2. Main contributor analysis

The emergy calculation for Zhenjiang city in 2020 reveals that the building emergy holds the highest value of $3.61E+25$ sej. This implies that the primary factor will be crucial in driving sustainable change for the city in 2020. Other factors, on the other hand, possess relatively smaller emergy values and have a lesser impact on the overall sustainability of the Zhenjiang city system in 2020.

When analyzing the emergy values for 2000 and 2010 using the same calculation model, similar patterns are evident. These results highlight the importance of both biodiversity and buildings in determining the sustainability of Zhenjiang city over time. It underscores the need for sustainable development strategies that not only protect biodiversity but also foster urbanization to attain long-term sustainability objectives.

2.3. Ecological indicator analysis

The evaluation of the overall emergy sustainability index (ESI) has been concluded, ranging from 0.07 to 1.21, indicating a positive trend in the most significant sustainability indicators from 2000 to 2020. This finding signifies that despite encountering environmental challenges, the urban development of Zhenjiang is consistently advancing in a favorable and sustainable manner over the extended period.

2.4. Sensitivity analysis

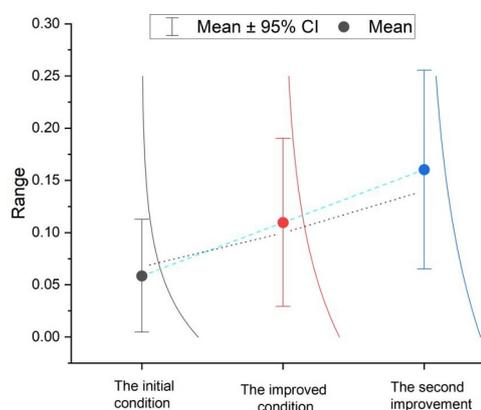


Fig. 5. Sensitivity analysis of former and latter

The sensitivity analysis before and after the improvements is shown in Figure 5. From the trends observed, it can be seen that there is a significant improvement in sensitivity from the initial state to the two subsequent improvements. This indicates that the

overall system is becoming more accurate in terms of sustainability. This increase in sensitivity is a result of the data collection becoming more precise and closer to the real-world conditions.

3.Conclusion

This article takes the sponge city plan in Zhenjiang as a starting point and uses the ecological emergy method to quantitatively assess its sustainability. Through the calculation of emergy sustainability parameters, it is found that its ecological sustainability is improving. This effectively proves the correctness of the sponge city design strategy. However, a focused sensitivity analysis is needed to obtain more accurate results.

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