

Landscape Character Assessment and Sustainable Development Strategies Under the Urban-Water Integration Perspective: A Case Study of Dongting Lake Area, Hunan Province, China

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Abstract

Dongting Lake is an important storage lake in the Yangtze River Basin and a vital national ecological security barrier in China. The Dongting Lake area of Hunan province, centered around Dongting Lake, comprises 25 urban spaces and covers an area of 46,300 square kilometers. Influenced by the human-land relationship, this region has developed a distinctive urban-water integrated spatial pattern by the interactive adaptation of the urban spaces growth and its river and lake systems. There are a variety of natural and cultural landscape, and urban residents live according to the water.

In recent years, the total population volume and the level of urbanization in the Dongting Lake area have been rising steadily. In order to balance the synchronous development of urban and natural space and realize the overall protection and sustainable utilization of urban space in Dongting Lake area, it is necessary to seek a system to identify, describe and assess the characteristics of the basic units of the ecosystem in the region, and put forward the corresponding sustainable development strategies.

Based on the theory of Landscape Character Assessment(LCA), the research of the sustainable development of urban space in Dongting Lake area has been carried out through literature review, field research, GIS analysis, spatial clustering and other methods. The research contents are as follows: 1) Constructing a set of methods for assessing the landscape character of the area under the "urban-water" integrated spatial pattern. 2) Considering the cultural and social indicators at the urban level and the natural geographical indicators at the water level to identify, classify and describe the characteristic elements of Dongting Lake area. 3) Assessing the value of the characteristic areas through literature analysis and expert scoring method. Then, dividing them into high value characteristic area, medium value characteristic area and low value characteristic area.4) Providing regional sustainable development strategies based on the assessment, in order to build a livable and resilient town space. The research results also provide guidance for sustainable development with similar urban space.

Keywords

Urban-water integration, Landscape character assessment, Dongting lake area, Sustainable development strategy

1. Introduction

Dongting Lake is an important storage lake in China's Yangtze River basin and an important national ecological security barrier (Yu *et al.*, 2023, Yuan *et al.*, 2024). Due to the continuous urban-water interaction, the Dongting Lake area presents a special human environment (Liang *et al.*, 2021). It generates spatial heterogeneity and has high natural and humanistic multiple values. So it is a key area for landscape protection and development. In recent years, the total population and urbanization level of the Dongting Lake area have been steadily increasing (Xiong *et al.*, 2022, Zhu and He, 2021). In the existing researches, the researches for the Dongting Lake area mainly focus on ecological protection (Yuan *et al.*, 2024), water body management (Niu, Yu and Jiang, 2015, Wang *et al.*, 2018), etc., which can not provide a clear target orientation for the habitat environmental protection under the urban-water system in the Dongting Lake area. So identifying, describing and evaluating the spatial heterogeneity of the lake area and proposing corresponding sustainable development strategies are the key prerequisites for realizing the inheritance, protection and development of the town space in the Dongting Lake area.

Landscape character, defined as the pattern of unique, recognizable and consistent elements in a landscape, is one of the effective methods for identifying spatial heterogeneity, providing a methodology and research framework for the evaluation and management of spatial heterogeneity (Butler and Akerskog, 2014, Pan *et al.*, 2022). Since the first application of Landscape Character Assessment (LCA) in the UK in 1991, and the formal definition of the concept of landscape character assessment in Landscape Character Assessment Guidance for England and Scotland in 2002, LCA has been widely used in research (Butler and Akerskog, 2014, Herlin, 2016, Terkenli, Gkoltsiou and Kavrouidakis, 2021). And with the multi-scale effect, many scholars have conducted landscape character assessment at different scales, such as national (Butler and Berglund, 2014), watershed (Koc and Yilmaz, 2020), natural areas (Ding *et al.*, 2020), urban areas (Lu *et al.*, 2022), village areas (Lokocz, Ryan and Sadler, 2011).

In order to achieve accurate landscape classification, with the development of technology, many spatial clustering methods have been introduced into LCA, such as bidirectional indicator species analysis (TWINSpan), K-means, Som, two-step clustering method, etc (She, Liu and Chen, 2024, Zhao, Lu and Jiang, 2023). The limitation of TWINSpan is that it can process up to 25,000 objects (Yang *et al.*, 2020), which makes it impossible to properly process large sample data. K-means and Som can only identify continuous variables, which also has certain limitations. Two-step clustering is widely used because it can handle large scale data and cluster categorical variables and continuous variables simultaneously.

Based on the theory of Landscape Character Assessment (LCA), this paper carried out the research on the sustainable development of the town space in Dongting Lake area through literature review, field research, GIS analysis, spatial clustering, etc. It proposed the corresponding sustainable development strategy by identifying, describing and evaluating the landscape character assessment in the area. In order to construct a livable and resilient town space in the lake area. The research results also provide guidelines for the sustainable development of town spaces with similar characteristics.

2. Method

2.1. Study area: Dongting lake area of Hunan province

Dongting Lake is an important regulation lake in the Yangtze River basin and the second largest freshwater lake in China (Deng and Lin, 2024). This paper takes Dongting Lake area as the research scope, with Dongting Lake as the center, covering three cities and one district (Yueyang, Changde and Yiyang cities, Wangcheng District). The geographical locations are 111 53 ' to 113 05 ' E and 28 44 ' to 29 35 ' N

(Figure 1). It is a typical representative of the combination of cross-administrative divisions and natural divisions(Xiong *et al.*, 2022). It covers an area of 46,300 square kilometers.

The unique habitat of the Dongting Lake area exemplifies a complex urban-water system, shaped by the interplay between urban expansion and the adaptive relationship of rivers and lakes. The distinct regional characteristics of the lake area are the result of a dynamic coupling of various natural and human factors, including human activity, land use patterns, management practices, climate, hydrology, and topography.

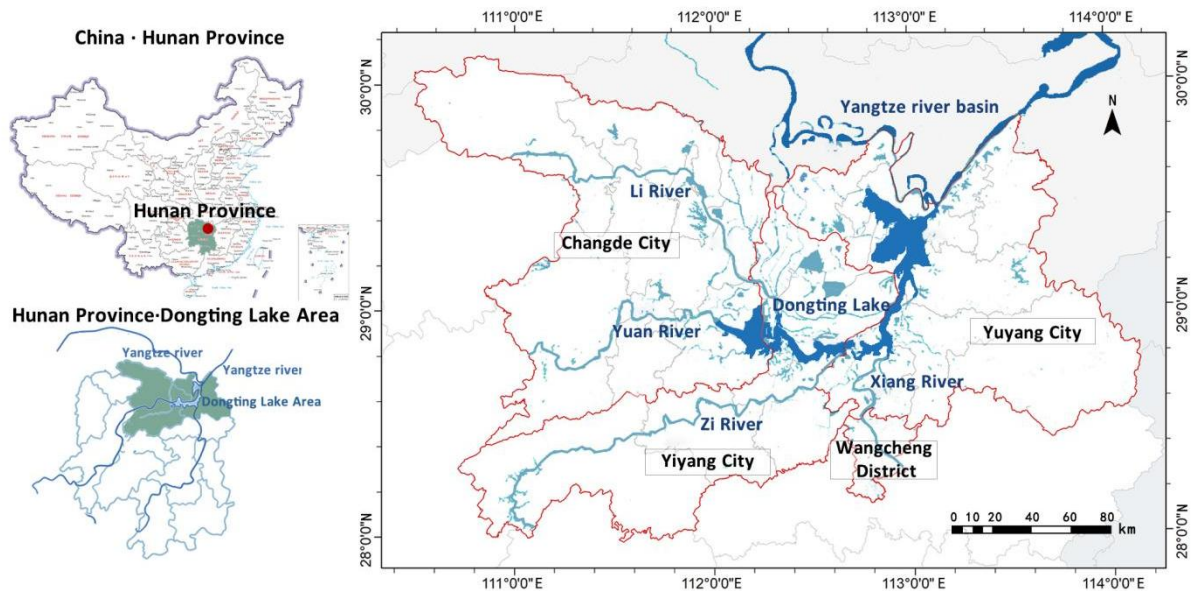


Figure 1. Study area: Dongting Lake Area of Hunan Province. Source: Author self-painted.

2.2. Framework

LCA is clearly defined in the Landscape Character Assessment Guidance for England and Scotland (LCA Guidance). Under the urban-water system, the landscape character assessment process of Dongting Lake area is as follows three steps: character description, value assessment and sustainable development strategies.

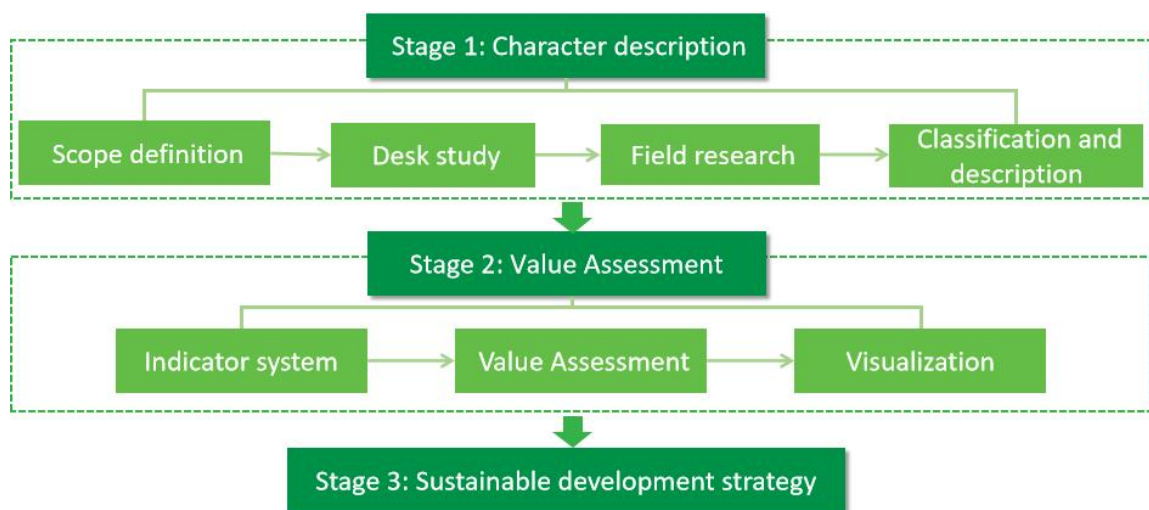


Figure 2. Framework. Source: Author self-painted.

2.3. Method

2.3.1. Evaluation of the indicators and the data sources

To accurately capture the landscape characteristics within the urban-water system, indicators from both urban and water dimensions were selected, encompassing human-social and natural geographic factors. These indicators include the spatial density of built-up areas, rural settlements, water area and wetland, geomorphic features and river-lake system zone. Together, these six indicators provide a comprehensive description of landscape characteristics within the urban-water system.

Table 1. Indicators in Landscape character. Source: Author self-painted.

Level	Name of Indicators	Unit	Source
Urban Level	Spatial density of urban built-up area	Number of points/km ²	The Center for Resource and Environmental Science and Data Research, Chinese Academy of Sciences(http://www.resdc.cn/)
	Spatial density of rural settlements		
Water level	Spatial density of water area	-	Dongting Lake meteorological zoning DB43/T 2076-2021
	Spatial density of wetland		
	Geomorphic features		
	River-lake system zoning		

2.3.2. Classification methods for Landscape Character

The Two-Step Cluster is a hybrid clustering technique that integrates both hierarchical and non-hierarchical methods, making it especially effective for handling large datasets with mixed data types (both continuous and categorical variables). This approach involved a two-stage process: an initial pre-clustering followed by a final clustering phase. In this study, we utilized the SPSS platform to conduct second-order clustering for the study area.

Table 2. Cluster method in Landscape character. Source: Author self-painted.

Cluster method	Type of variable	Number of categories	Sample
TWINSpan	Categorical variables	Automatically determined	Less than 25,000 objects
K-mean cluster	Continuous variables	Fixed classification number	large sample
Two-Step Cluster	Continuous variables + Categorical variables	Automatically determined	large sample

2.3.3. Method for Landscape Character Assessment

To effectively evaluate the landscape value of the region while accommodating diverse value orientations, two primary indicators were selected: natural landscape value and humanistic landscape value. These were supported by five secondary indicators: ecological importance, degree of ecological protection, natural originality, density of important settlements, and density of cultural heritage. By individually calculating and normalizing each indicator, and then overlaying them with equal weights for hierarchical visualization, we derived a comprehensive landscape value index for the lake area, along with separate indexes for natural and humanistic values.

$$\text{Comprehensive value} = a_1EI_i + a_2EP_i + a_1NP_i + a_1SD_i + a_1CHD_i$$

$$\text{Natural value} = a_1EI_i + a_2EP_i + a_1NP_i$$

$$\text{Humanistic value} = a_1SD_i + a_1CHD_i$$

Table 3. Indicators in landscape character assessment. Source: Author self-painted.

First-level index	Weight	Second-level index	Weight	Description	Assess	Value
Natural landscape value	0.5	Ecological importance (EI)	0.2	Sorting and assigning by using the Invest habitat quality assessment	Good	3
					Medium	2
					Poor	1
		Degree of ecological protection (EP)	0.15	Sorting and assigning values using protected areas	Protected	1
					Unprotected	0
Humanistic landscape value	0.5	Natural primitiveness (NP)	0.15	Using land use, population distribution, and road traffic to identify natural patches , and assigns values based on size.	Undamaged	1
					damaged	0
		Settlements density (SD)	0.25	Using the nuclear density ranking assigned to historical-cultural cities, towns and villages.	Good	3
					Medium	2
					Poor	1
		Cultural heritage density (CHD)	0.25	Sorting and assigning values by using cultural heritage kernel density	Good	3
					Medium	2
					Poor	1

3. Results

3.1. Landscape character zoning under the urban-water system

Fourteen categories of landscape characteristics within the urban-water system were identified and documented in the ArcGIS platform database. Four categories cover over 10 percent of the area, representing the most distinctive landscapes of the Dongting Lake region: low-altitude mountainous landscape near the river (cluster 10), plain landscape surrounding the lake (cluster 4), mid-altitude mountainous landscape (cluster 14), and platform landscape around the lake (cluster 7).

Table 4. Landscape character zoning. Source: Author self-painted.

Cluster	Name	Rate of area
1	Hills landscape around the lake	6.29%
2	Low-altitude mountains landscape around the lake	9.57%
3	Plain lake landscape	5.39%
4	Plain landscape around the lake	12.80%
5	Low-altitude urban landscape	1.28%
6	Low-altitude village landscape around the lake	3.79%

7	Platform landscape around the lake	10.06%
8	Village landscape in the platform around the lake	2.42%
9	Hills landscape near the river	7.21%
10	Low-altitude mountains landscape near the river	13.85%
11	Plain landscape near the river	4.61%
12	Plain wetland landscape	3.33%
13	Platform landscape near the river	9.04%
14	Mid-altitude mountain landscape	10.35%

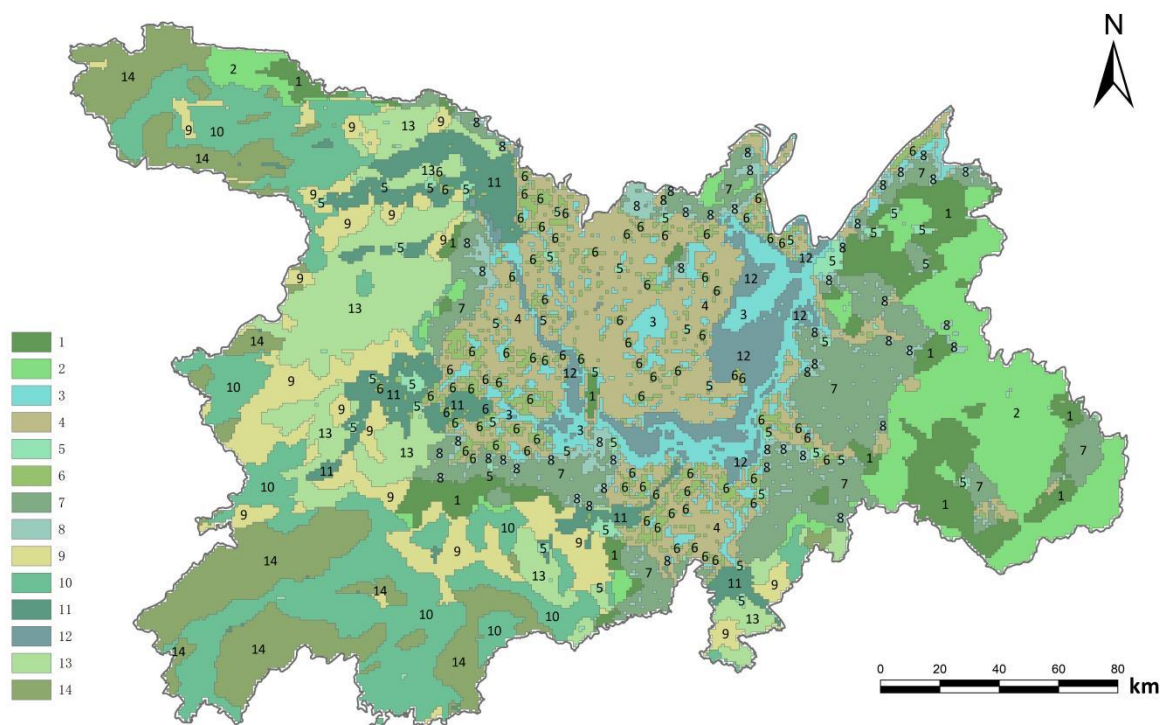


Figure 3. Landscape character zoning. Source: Author self-painted.

3.2. Landscape Character Assessment Results

The natural, humanistic, and comprehensive values of the character area were evaluated through literature analysis and expert scoring, with each divided into 5 grades. Our analysis revealed that landscape types with high natural value include plain lake landscapes (cluster 3), plain wetland landscapes (cluster 12), and mid-altitude mountain landscapes (cluster 14). In contrast, landscapes with high humanistic value encompass low-altitude urban landscapes (cluster 5) and plain landscapes near rivers (cluster 11). By integrating natural and humanistic values, we identified comprehensive value zones, comprising 2 high-value zones, 4 slightly high-value zones, 4 medium-value zones, 1 slightly low-value zone, and 3 low-value zones.

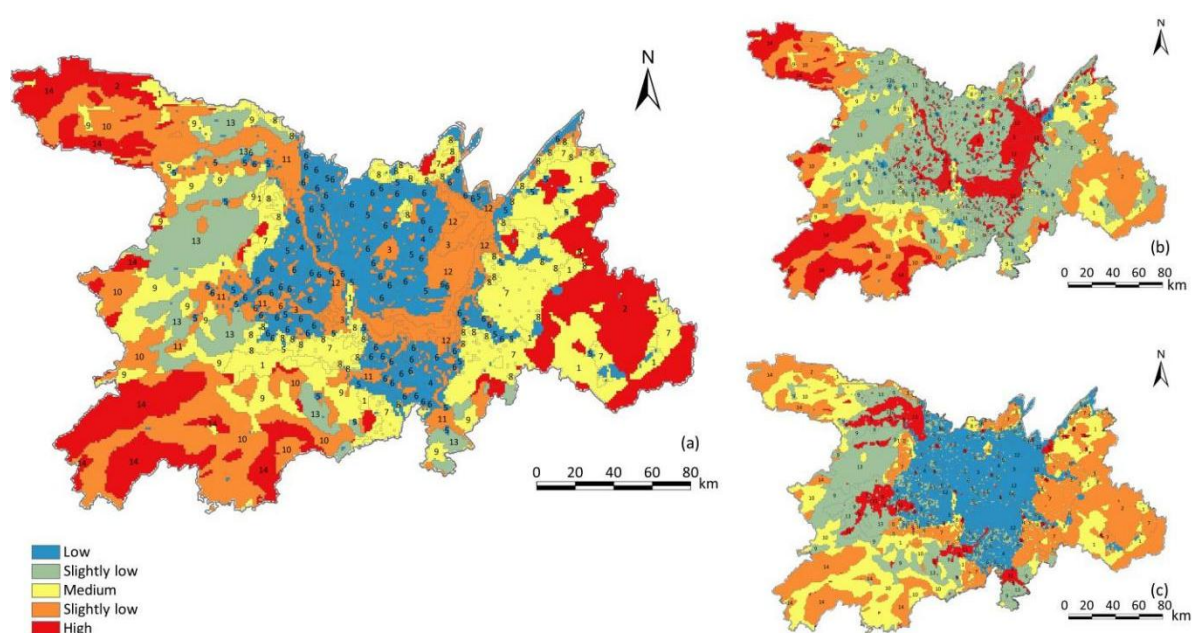


Figure 4. Landscape character assessment zoning. Source: Author self-painted.

(a)Comprehensive value area. (b)Natural value area. (c)Humanistic value area.

Table 5. Landscape character assessment. Source: Author self-painted.

Cluster	Humanistic value	Natural value	Comprehensive value
1	Medium	Medium	Medium
2	Slightly high	Slightly high	High
3	Low	High	Slightly high
4	Low	Slightly low	Low
5	High	Low	Low
6	Slightly low	Slightly low	Low
7	Slightly high	Slightly low	Medium
8	Medium	Medium	Medium
9	Slightly low	Medium	Medium
10	Medium	Slightly high	Slightly high
11	High	Slightly low	Slightly high
12	Low	High	Slightly high
13	Slightly low	Slightly low	Slightly low
14	Slightly high	High	High

3.3. Regional Sustainable Development Strategies

On the basis of the assessment, regional sustainable development strategies were proposed with a view to constructing a livable and resilient town space in the lake area. The results of the study also provided guidelines for the sustainable development of town spaces with similar characteristics.

3.3.1. Protecting the regional landscape features

The primary strategy was to protect regional landscape features. In the Dongting Lake area, the comprehensive high-value zones (clusters 2 and 14) and the slightly high-value zones (clusters 3, 10, 11, and 12) represent the core of the regional landscape characteristics within the urban-water system and

require focused protection. Protective measures for these zones include the designation of specialized protected areas and the establishment of long-term monitoring and evaluation mechanisms. Additionally, landscape changes should be regularly monitored using remote sensing, ground observation, and community feedback to promptly identify potential threats and ensure the effectiveness of protection efforts.

3.3.2. Developing Partition Management Strategies

In order to rationalize the use of multiple resources, areas were zoned based on landscape value assessments, allowing for targeted management approaches. For instance, natural high-value landscape areas are subject to stricter ecological protection and management, while natural low-value areas may permit moderate development or renovation. Humanistic high-value areas focus on preserving cultural heritage, such as historic buildings and traditional villages, through restoration and conservation, ensuring these sites remain integral to modern society as iconic regional features. In contrast, humanistic low-value areas can be further explored and developed to enhance their cultural significance.

3.3.3. Strengthening policy guarantees

The results of landscape character assessment can guide the preparation of upper-level planning, and ensure that landscape characteristics are preserved through the implementation of related regulations. For example, in the face of major changes in territorial spatial planning, LCA can be an important means to protect the natural resource background characteristics and resource endowment. It can guide the landscape control, functional area division and development orientation of the land space planning in Dongting Lake area. By guiding the planning process, LCA helps to rationalize land use, optimize urban and rural spatial layouts, improve ecological quality, and provide a scientific foundation for sustainable economic and social development. Additionally, LCA can direct special planning for nature reserves; comprehensive high-value areas may be designated as nature reserves or scenic spots, while natural high-value areas can be identified for various nature parks based on their primary vegetation types.

3.3.4. Promoting eco-tourism

Ecotourism transforms the landscape's intrinsic value into economic value, raising conservation awareness among local residents and management. Sustainable development can be achieved by creating specialized tourist routes, constructing eco-friendly facilities, and designing sustainable transportation options. Furthermore, ecotourism planning not only helps preserve ecological balance but also strengthens cultural identity among local residents, fostering sustainable regional development.

4. Conclusion

The Dongting Lake area under the urban-water system has a unique habitat. Identifying regional landscape characteristics and drawing a landscape base map with Dongting Lake characteristics is essential for ensuring comprehensive ecosystem protection and the sustainable use of natural resources. This study identified 14 landscape character zones in the Dongting Lake area and assessed each zone's value by integrating natural resource and cultural heritage factors. The findings included 2 comprehensive high-value zones, 4 higher-value zones, 4 medium-value zones, 1 lower-value zone, and 3 low-value zones. Based on these findings, four sustainable development strategies are proposed: protecting regional landscape characteristics, implementing zoning management, enhancing policy protections, and promoting ecotourism.

This study provides a framework for an understanding the landscape characteristics of the lake area, scientific guidance for the protection, construction and development of multiple resources, as well as for

the preparation of relevant plans. However, a limitation of this study is that it focuses solely on first-level characterization of the urban-water spatial structure, without addressing plant and animal biodiversity. Future research will aim to further refine this study by incorporating second-level characterization under the urban-water system in greater detail.

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