Comprehensive Benefit Valuation of Sponge City Development: A Case Study of Daguan Wetland Park, Guangzhou

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Abstract. Against the background of Sponge City development, the ecological performance of constructed wetlands has been widely demonstrated, yet their comprehensive benefits still lack an integrated accounting framework and empirical assessment. Taking Daguan Wetland Park in Guangzhou as a case study, this paper develops a monetary valuation framework for its comprehensive benefits. Based on real estate market transaction data from 2025, the 0–1500 m buffer zone is defined as the treatment group and the 1500–3000 m buffer zone as the control group. Sensitivity analyses are further incorporated to identify the net land value premium attributable to the wetland. At the same time, annual ecological flow benefits, including rainwater reuse, runoff control, and operation and maintenance cost savings, are quantified. These benefits are separately accounted for from the land value appreciation component, and a benefit–cost ratio (BCR) is calculated. The results show that over the 10-year operating period following the completion of Daguan Wetland Park, the project generated a total comprehensive benefit of CNY 581.8435 million, of which direct ecological benefits amounted to CNY 19.1644 million. Spatial spillover benefits amounted to CNY 562.6791 million, accounting for approximately 98% of the total benefits. Enterprises exhibited an implicit willingness-to-pay rate of 27.38% for the wetland-related ecological location premium, and the benefit–cost ratio reached 2.45. These findings confirm the significant economic viability of investing in urban sponge infrastructure. This study provides the first empirical valuation of a Sponge City wetland in a high-risk urban flooding area of the Greater Bay Area and offers strategic insights and practical references for the development and market-oriented investment of sponge infrastructure.

Keywords: Sponge City, constructed wetlands, comprehensive benefit valuation, monetization, Daguan Wetland Park.

1. Introduction

1.1. Research Background

With the rapid expansion of urbanization worldwide, conventional “grey” infrastructure systems that rely on rapid drainage have left cities increasingly vulnerable to urban flooding, water scarcity, and water pollution[1]. These challenges have been further intensified by climate change, as extreme weather events are becoming increasingly severe and high-intensity rainfall places greater pressure on conventional grey infrastructure.

In response to the challenges posed by climate change and growing urban water-related problems, the Chinese government officially elevated the Sponge City concept to a national strategy in 2015. Through ecological measures based on “infiltration, retention, storage, purification, utilization, and drainage”[2], sponge infrastructure is designed to replace or complement conventional grey infrastructure, thereby enhancing urban resilience, water-cycle management, and ecosystem service provision[1][3]. As a key component of urban green infrastructure, sponge infrastructure can not only effectively alleviate the pressure of urban flood control and drainage, but also generate substantial ecological benefits through functions such as carbon sequestration and water purification.

As a major coastal megacity in China and one of the cities that implemented sponge infrastructure at an early stage, Guangzhou has long faced substantial challenges in urban water management. The study area, Tianhe Smart City, is located in one of the earliest urbanized areas of Guangzhou and has

historically experienced frequent urban flooding, together with a range of typical urban problems associated with highly developed older urban areas. To address these challenges, the Guangzhou municipal government developed Daguan Wetland Park (now known as Tianhe Wetland Park) as a stormwater detention and retention corridor, with the aim of improving local water-related environmental conditions through sponge infrastructure.

This study takes Daguan Wetland Park as the case study and conducts a cost–benefit analysis over its 10-year operating period from 2015 to 2025. Based on a monetary valuation framework for Sponge City infrastructure, the study applies the replacement cost method and benefit–cost ratio (BCR) analysis to quantify the benefits generated by the wetland. The analysis seeks to assess the extent to which the ecological service functions and surrounding benefits generated by an urban wetland park can offset the costs of its construction, investment, and operation and maintenance.

1.2. Literature Review

As a key carrier of nature-based solutions (NBS) and green infrastructure (GI) within the Sponge City framework, urban wetlands have been increasingly studied beyond ecological performance assessment toward monetary valuation and decision-making to support urban climate resilience. The valuation of wetland ecosystem services was first systematically proposed by Costanza et al. (1997)[4].The Millennium Ecosystem Assessment (MEA, 2005)[5] and The Economics of Ecosystems and Biodiversity (TEEB, 2010)[6] further standardized wetland ecosystem services into four categories: provisioning, regulating, cultural, and supporting services. This classification has subsequently provided the basis for categorizing ecosystem services in a wide range of case studies.

Non-market valuation methods for wetlands have gradually developed into a relatively standardized methodological framework. Revealed preference methods, including the hedonic pricing method, travel cost method, and production function approach, and stated preference methods, including the contingent valuation method and choice experiment method, are commonly used to quantify less visible social benefits, such as flood regulation and water purification. Engineering-based replacement approaches, including the replacement cost method, shadow engineering method, and avoided damage cost method, are also widely applied to the valuation of regulating services (Boyer & Polasky, 2004)[7]. Ghermandi et al. (2010)[8] further distinguished the value structures of natural and constructed wetlands and developed a consistency-adjustment framework for wetland benefit assessment.

1.2.1. Ecological Benefits

The assessment of ecological benefits generated by Sponge City infrastructure has developed into an increasingly established framework for monetary valuation. Zhu et al. (2022)[9] conducted a life-cycle cost-benefit analysis (LCC-CBA) of low-impact development (LID) facilities in residential areas and on campuses. Their results showed that the direct benefits from replacing tap water with rainwater and reducing runoff, thereby lowering the load on drainage networks and wastewater treatment plants, could offset the initial investment within 5.6–12.4 years. Xu et al. (2024)[10] conducted a macro-scale life-cycle assessment of 16 national Sponge City pilot cities and found that, the investment payback period ranged from 3.9 to 7.5 years across different zones. Liang (2018)[11] used a static benefit–cost ratio (BCR) to assess the economic sustainability of Sponge City projects. The study showed that these projects were economically feasible from the government perspective, while their financial feasibility was insufficient from the perspective of private investors. Parallel studies on low-impact development (LID) in the United States, sustainable drainage systems (SuDS) in the United Kingdom, and water-sensitive urban design (WSUD) in Australia have reported similar findings (Zhu et al., 2022)[12]. Although these studies demonstrate that the ecological performance of sponge infrastructure can be quantified through monetary valuation, most have focused on regional-scale assessments rather than the economic valuation of individual facilities.

1.2.2. Land Value Premium

Research on land value premiums has largely been based on the hedonic pricing framework proposed by Rosen (1974)[13].Tapsuwan et al. (2009)[14] found that both the distance to the nearest wetland and the number of wetlands within 1.5 km had significant effects on housing prices, with the maximum radius of the premium zone estimated at approximately 1.7 km. Tong et al. (2022)[15] found that the capitalization rate of urban wetland ecosystem services into the real estate market in Xining was approximately 54.3% and identified a stable distance-decay pattern.

Although previous studies have examined different types of environmental amenities, including urban parks and green spaces, natural water landscapes, and wetlands, and have considered areas of different sizes, their findings generally indicate that the significant spatial influence on surrounding residential properties extends over a range of approximately 1.3–2.0 km.

1.3. Research Objectives and Potential Marginal Contributions

To date, empirical studies on individual urban wetlands constructed as Sponge City infrastructure remain relatively limited in China. Zhao et al. (2024)[16] examined Dianchi Lake and 11 surrounding wetlands by converting their ecological and environmental functions into incremental values of the water environmental functions of Dianchi Lake. At the same time, eight ecosystem services provided by the wetlands themselves were comprehensively valued using the market value method, shadow engineering method, replacement cost method, reference outcome method, and expenditure cost method. Although this study established a comprehensive monetary valuation of the ecological benefits generated by wetland restoration and management at the lake scale, it did not address the investment recovery of an individual wetland. Wang et al. (2019)[17] demonstrated the ecological performance of Daguan Wetland Park in Guangzhou, including improvements in water purification, habitat diversity, and public satisfaction. However, their analysis remained at the level of physical performance indicators and did not extend to monetary valuation or investment recovery.

This study aims to address these gaps by using the completed Daguan Wetland Park in Guangzhou as a case study. First, three categories of direct benefits—rainwater reuse, annual runoff control, and savings in near-natural vegetation maintenance—are monetized using the shadow price method, replacement engineering method, and differential analysis method, respectively. Second, drawing on previous findings regarding the spatial extent of land value impacts, the land value appreciation and the implied willingness-to-pay rate of enterprises are incorporated to estimate the static regional benefit–cost ratio (BCR). Sensitivity indices are further introduced to test the robustness of the spatial boundary specification. The study also systematically examines the potential carbon co-benefits associated with runoff control and low-maintenance management practices. Overall, this study seeks to establish a set of monetized benefit estimates that can provide a reference for assessing the returns on urban wetland investment, thereby extending existing research from the identification of ecological performance toward the validation of economic and market returns.

2. Study Area

Daguan Wetland Park (now known as Tianhe Wetland Park) is located in the eastern part of Tianhe District, Guangzhou, Guangdong Province, China, within the core area of Tianhe Smart City [18]. The study area has a subtropical monsoon climate, with a mean annual temperature of approximately 21.8 °C and annual precipitation of approximately 1675.5 mm[17] (see Fig.1). The region is warm and humid throughout the year, with a long rainy season and highly concentrated precipitation from April to September, making the area particularly prone to seasonal urban flooding.

The park is located at approximately 23°17′ N and 113°42′ E[19]. It has a narrow, elongated north–south configuration, extending approximately 3 km from LingTang Village in the north to the Guangzhou–Shenzhen Expressway in the south. The park covers an area of 46.8 ha and serves as an important ecological corridor connecting Huolu Mountain Forest Park to the north with the Pearl River water system to the south.

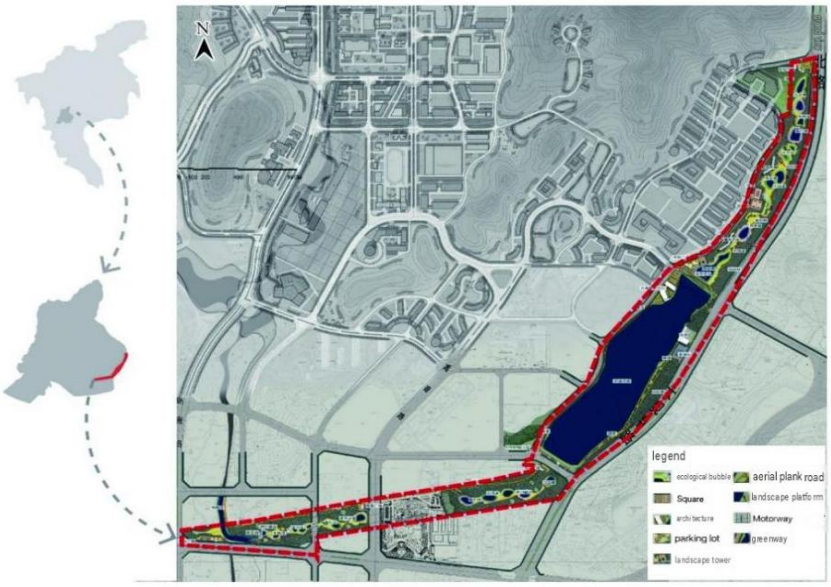


Fig. 1 Location and study boundary of Daguan Wetland
(Source: Adapted from "Post-construction Assessment of the Comprehensive Performance of an Urban Wetland Park: A Case Study of Daguan Wetland in Guangzhou"[17])

The study area is characterized by a typical subtropical hilly alluvial landscape, with an overall north-to-south downward gradient and a maximum elevation difference of 27 m[17]. Before construction, the site consisted of low-lying agricultural fields interspersed with fish ponds. The internal water system was fragmented, the ponds were heavily silted, and water quality was poor. The area also experienced frequent urban flooding[20].

The wetland project adopted the Sponge City approach and transformed the site into an urban stormwater wetland corridor[17]. Natural runoff is collected and conveyed into a series of interconnected ponds, which helps alleviate urban flooding and improve the quality of surface runoff. At the same time, the site was planned as a public open space that provides ecological benefits and accommodates recreational activities, sightseeing, environmental education, and physical exercise.

3. Methods

This case study draws on the Sponge City benefit monetization framework proposed by Dang et al. (2019)[3] and incorporates the spatial econometric approach developed by Chen et al. (2015)[21]for assessing the externalities of urban parks and green spaces. An integrated accounting framework is established to quantify both direct ecological benefits and the appreciation of residential and commercial land values. Given the complexity of urban stormwater and flood control and the non-market nature of ecological shoreline restoration, these two indicators are excluded from the analysis, and the study focuses on quantifiable and relatively certain benefits.

3.1. Methods for Estimating Direct Ecological Benefits

For the quantifiable ecosystem services provided by the wetland, the shadow/replacement engineering method and the market price method are used to convert ecological services into monetary values, thereby estimating their economic value as substitutes for conventional grey infrastructure.

3.1.1. Benefits of Rainwater Reuse

The shadow price method is adopted in this section. By collecting and treating rainwater, Daguan Wetland Park reduces the need for tap water used for non-domestic purposes and therefore avoids part of the corresponding water supply cost:

$$B_1=Q_{rain}\times P_{water} \quad (1)$$

where A represents the annual volume of rainwater reused (9.11×10^4 m³)[17], and B is the non-residential water tariff in Guangzhou, which is CNY 3.46/m³ and remained unchanged during the period from June 2015 to June 2025, and is therefore used as the shadow price.

3.1.2. Benefits of Total Annual Runoff Control

The replacement engineering method is adopted in this section. The wetland achieves an annual runoff volume control rate of 85%, which is equivalent to reducing the load on downstream municipal drainage networks and wastewater treatment plants:

$$B_2=V_{retain}\times(C_{pipe}+C_{treat}) \quad (2)$$

where (V_{retain}) represents the annual volume of runoff controlled (m³); (C_{pipe}) represents the operation and maintenance cost of the drainage network per unit volume; and (C_{treat}) represents the wastewater treatment cost per unit volume.

3.1.3. Savings in Green Space Maintenance Costs

The differential analysis method is adopted to compare the maintenance costs of a conventional municipal park with those of a near-natural wetland plant community with the same area:

$$B_3=S\times(C_{park}-C_{wetland}) \quad (3)$$

where (S) represents the wetland area (m^2); (C_{park}) represents the unit maintenance cost of a conventional urban park (CNY/m^2); and ($C_{wetland}$) represents the unit maintenance cost of the wetland (CNY/m^2).

3.2. Method for Estimating the Land Proximity Premium

Although Chen et al. (2015) [21] found that large urban parks have a significant positive effect on residential property prices, the present study does not construct a complex hedonic price regression model because of the complexity of micro-level locational factors. Instead, the "core–peripheral buffer zone comparison method" is used to estimate the spatial value premium associated with the wetland. Existing studies generally indicate that the influence of wetlands on land proximity premiums is concentrated within 3 km. Therefore, the maximum valuation area in this study is defined as the area within 3 km of the wetland.

3.2.1. Buffer Zone Delineation

Using the boundary of Daguan Wetland Park as the reference boundary, two concentric buffer zones are established:

Treatment group (premium zone): residential communities located within 0–1500 m of the park boundary;

Control group (baseline zone): comparable residential communities located within 1500–3000 m of the park boundary.

3.2.2. Calculation of the Land Value Appreciation Effect

The average second-hand housing transaction prices of the two groups in 2025 are collected to calculate the land value appreciation per unit area:

$$\Delta P=\overline{P}_{near}-\overline{P}_{far} \quad (4)$$

where (ΔP) represents the land value appreciation per unit area (CNY/m^2); ($\overline{P}_{near}$) and ($\overline{P}_{far}$) represent the average housing prices of the treatment and control groups, respectively.

The total land value appreciation is calculated as follows:

$$V_{land}=\Delta P\times S_{dev} \quad (5)$$

where (S_{dev}) represents the area of developed and constructed land within the treatment zone.

3.2.3. Sensitivity Analysis

To assess the robustness of the findings, sensitivity analyses are conducted with respect to both the statistical procedures and the distance boundaries, thereby examining whether the sample composition or buffer zone delineation affects the results.

For the statistical procedures, an outlier-exclusion sensitivity analysis is conducted to assess the influence of abnormal observations on the baseline results. A mean–median sensitivity analysis is performed to examine the influence of extreme values on the baseline results given the relatively small sample size. A leave-one-out sensitivity analysis is applied to the control group to determine whether any single observation has a disproportionate effect on the baseline results.

For the distance boundaries, the boundary of the treatment zone is adjusted and the treatment and control zones are re-compared to assess the robustness of the results to the selection of buffer zone boundaries.

3.3. Industrial Attraction Benefits

Because the original planning designation of the wetland in the master plan for Tianhe Smart City was an ecological functional zone, the "hedonic rent theory"[13]is adopted to evaluate enterprises' willingness to pay for the surrounding environmental conditions.

3.3.1. Willingness-to-Pay Rate (WTP Rate)

The rental prices of comparable office buildings in the core area of Tianhe Smart City adjacent to the wetland and in a non-wetland industrial park of similar development level are compared to estimate the rental premium that enterprises are willing to pay to obtain an "ecological location":

$$WTP_{rate}=\frac{R_{eco}-R_{ctrl}}{R_{ctrl}}\times 100\% \tag{6}$$

where (R_{eco}) represents the average office rent in the industrial parks surrounding Daguan Wetland (CNY/m^2/month), and (R_{ctrl}) represents the average rent in the control industrial park (CNY/m^2/month).

3.4. Method for Estimating Comprehensive Benefits

As this study is a regional case assessment and is constrained by the availability of empirical data, a simplified evaluation approach following Dang et al. (2019)[3] is adopted, with the static benefit–cost ratio (BCR) used as the primary evaluation indicator. By comparing the total benefits and total costs over the full life cycle of the project, the BCR reflects the economic feasibility of the green infrastructure.

3.4.1. Cost Accounting

The cost components mainly include the initial investment during the construction period and maintenance costs during the operation period.

$$C_{total}=C_{initial}+C_{operation}\times T \tag{7}$$

where ($C_{initial}$) represents the initial construction investment(CNY); ($C_{operation}$) represents the annual operation and maintenance cost(CNY), calculated based on the unit wetland maintenance cost; and (T) represents the operating period (10 years).

3.4.2. Benefit Accounting

The benefit components consist of two parts: direct ecological benefits (cash-flow savings) and spatial spillover benefits (land value appreciation). The willingness-to-pay rate is not included as a cash-flow benefit. Therefore:

$$B_{total}=(B_1+B_2+B_3)\times T+V_{land} \tag{8}$$

where (B_1+B_2+B_3) represents the sum of the annual benefits from rainwater reuse, runoff control, and maintenance cost savings calculated above; and (V_{land}) represents the total land value appreciation estimated using the buffer-zone method.

3.4.3. Benefit–Cost Ratio (BCR) Criterion

$$BCR=\frac{B_{total}}{C_{total}} \quad (9)$$

A BCR > 1 indicates that the economic value generated by the project over its full life cycle exceeds its investment cost, indicating that the project is economically feasible. If BCR < 1, further optimization of the operation and management model is required.

3.5. Data Sources

The data used to estimate direct ecological benefits were obtained from publicly disclosed government information and publicly available market prices in Guangzhou. Water tariffs were obtained from information disclosed by the Guangzhou Municipal Development and Reform Commission and the Guangzhou Municipal Water Affairs Bureau, based on the pricing system implemented since 2012[22]. Wastewater treatment charges were obtained from information publicly disclosed by the Guangzhou Municipal Development and Reform Commission and the Guangzhou Municipal Water Affairs Bureau for the period from 2015 to 2025. Green-space maintenance costs were derived from maintenance standards publicly disclosed by the Guangzhou Municipal Housing and Urban-Rural Development Bureau for 2015–2019 and were subsequently held constant at the 2019 level. Data on the area of green space were obtained from the 2025 tender documents for the landscaping maintenance project of Tianhe Wetland Park issued by the Tianhe District Housing, Construction and Landscape Bureau of Guangzhou[23].

The land value appreciation component was estimated using transaction prices collected in 2025 from housing transaction platforms, including Lianjia and Fang.com.

4. Results

4.1. Direct Ecological Benefit Accounting

4.1.1. Benefits of Rainwater Reuse(B_1)

According to the Regulatory Detailed Planning of the Core Area of Tianhe Smart City, the rainwater collected by Daguan Wetland Park is mainly used for irrigation of green spaces within the wetland, road watering, and replenishment of water resources within the park, and is not supplied for use outside the park. The non-residential water tariff in Guangzhou, CNY 3.46/m³, is used as the shadow price of rainwater. The wetland can collect 9.11×10^4 m³ of rainwater annually. According to Equation (3-1): B_1= CNY 315,200

4.1.2. Benefits of Total Annual Runoff Control(B_2)

The rainwater collected by the wetland park reduces the cost of wastewater treatment. The wastewater treatment charge for non-residential water use in central Guangzhou, (C_{treat}), is CNY 1.40/m³. Because the operation and maintenance cost of the drainage network is not publicly available, the value reported in comparable studies, (C_{pipe}) = CNY 0.08/m³, is adopted.

Based on the wetland area and the mean annual precipitation in Tianhe District, the total annual precipitation volume within the wetland park is estimated as: 46.8ha×1675.5mm = 46.8ha×1.6755m= 784,134 m³.

Given the annual runoff volume control rate of 85%, the total annual runoff controlled is:(V_{retain})= 666,513.9 m³.

According to Equation (3-2): B2= CNY 986,440

4.1.3. Savings in Green Space Maintenance Costs(B_3)

Because the current green-space maintenance prices in the study area are based on the 2019 standards, the average maintenance prices for 2015–2025 are used for the calculation. The average unit costs are CNY 11.854/m² for Level-II green-space maintenance and CNY 5.959/m² for Level-III maintenance. For water bodies, the average unit cost of Level-II water-body maintenance, CNY 6.448/m², is adopted according to the core landscape maintenance standard. Aquatic plants are valued using the commonly applied Level-III maintenance cost for near-natural wetlands. The maintenance costs are calculated separately according to the corresponding maintenance areas. Based on the publicly available maintenance grades and green-space areas, the annual unit maintenance costs are estimated as follows in Table 1:

Table 1. Summary of Maintenance Area Calculations [18]

Category	Name	Area m²	
Green space	Level-II green-space maintenance	22360.5	
	Level-III green-space maintenance	127372.5	170338
Water body	Aquatic plants	33017	20605
	Open water surface	12412	

Under a conventional municipal park scenario, the Guidelines for Green Space Maintenance in Shenzhen (Trial) (2013) specifies that the proportions of Level-I, Level-II, and Level-III artificially maintained green spaces in parks of the same grade should be 7:2:1. Water bodies are assumed to receive Level-I maintenance, with an average maintenance cost of CNY 9.299/m². The corresponding annual maintenance cost is therefore estimated as:

$S \times C_{wetland}$ = CNY 1.22689 million.

$S \times C_{park}$ = CNY 1.84169 million.

According to Equation (3-3): B_3 = CNY 614,800.

4.2. Land Proximity Premium Estimation

According to the publicly disclosed land parcels in Tianhe Smart City, Guangzhou, the area of land designated for residential-oriented development within the treatment zone is S_{dev}= 105,311.42 m²[24][25]. Based on publicly available map data, a total of nine residential community samples were identified in Table 2 and Table 3.

Table 2. Treatment Group Samples

No.	Residential Community	2025 Price (CNY/m²)
T1	Zhujiang Tianhe Duhui (3 phases)	48,000
T2	Guangzhou Urban Investment Tianxi (2 phases)	43,000
T3	Zhonghui Ruiyuan	51,410

Table 3. Control Group Samples

No.	Residential Community	2025 Price (CNY/m²)
C1	Nengjian Tianhe Luyu Mansion	46,000
C2	Agile Fuchun Shanju	39,986
C3	Poly Tianhui Phase I	38,660
C4	CSCEC Tianhe Jingcheng No. 1	48,750
C5	Longfu Hongyu Garden	25,608
C6	Fenghu Yujing	41,934.64

The calculated average housing prices were ($\overline{P}_{near0}$) = CNY 47,470/m² for the treatment group and ($\overline{P}_{far}$) = CNY 40,156.44/m² for the control group. Therefore, the estimated land value appreciation was $\Delta P_0 = \overline{P}_{near0} - \overline{P}_{far}$ = CNY 7,313.56/m².

Because sample T3 is a commercial villa development and differs in property type from the other samples, it was excluded from the analysis. After this exclusion, the average housing price for strictly residential developments in the treatment group decreased to ($\overline{P}_{near}$) = CNY 45,500/m², resulting in a revised land value appreciation of $\Delta P = \overline{P}_{near} - \overline{P}_{far}$ = CNY 5,343.56/m².

4.2.1. Sensitivity Analysis

4.2.1.1. Baseline Analysis

In the baseline analysis, the mean housing price for strictly residential developments in the treatment group is CNY 45,500/m², while that of the control group is CNY 40,156.44/m². The resulting unit land value appreciation is CNY 5,343.56/m², corresponding to a relative price premium of 13.31%.

To examine the robustness of this estimate, sensitivity analyses were conducted by excluding an extreme control-group observation, replacing the mean with the median, applying a leave-one-out procedure, and varying the treatment-zone boundary. The main results are summarized in Table 4.

Table 4. Sensitivity Analysis of Residential Land Value Appreciation

Sensitivity analysis	Scenario	Treatment-group price (CNY/m²)	Control-group price (CNY/m²)	Price difference (CNY/m²)	Change from baseline
Baseline	Mean;1.50 km boundary	45,500.00	40,156.44	5,343.56	—
Outlier exclusion	Excluding C5	45,500.00	43,066.13	2,433.87	−54.45%
Mean–median	Median of control group	45,500.00	40,960.32	4,539.68	−15.04%
Leave-one-out	Excluding C1	45,500.00	38,987.73	6,512.27	+21.87%
	Excluding C2	45,500.00	40,190.53	5,309.47	−0.64%
	Excluding C3	45,500.00	40,455.73	5,044.27	−5.60%
	Excluding C4	45,500.00	38,437.73	7,062.27	+32.17%
	Excluding C5	45,500.00	43,066.13	2,433.87	−54.45%
	Excluding C6	45,500.00	39,800.80	5,699.20	+6.66%
Distance boundary	1.25 km	48,000.00	40,562.66	7,437.34	+39.18%
	1.75 km	45,666.67	38,987.73	6,678.94	+24.99%
	2.00 km	44,246.50	38,738.16	5,508.34	+3.08%

Note: The baseline uses the mean housing prices of the treatment and control groups with a 1.50 km treatment-zone boundary. The outlier-exclusion analysis removes control-group observation C5 (CNY 25,608/m²). The leave-one-out analysis sequentially excludes each control-group observation. The distance-boundary analysis perturbs the treatment-zone boundary using a fixed step of 0.25 km.

4.2.1.2. Key Sensitivity Results

The sensitivity analyses show that the estimated price difference remains positive across all specifications. When the low-priced control observation C5 is excluded, the estimated land value appreciation decreases from CNY 5,343.56/m² to CNY 2,433.87/m², representing a 54.45% reduction from the baseline. This indicates that the magnitude of the baseline estimate is sensitive to the inclusion of C5.

When the median is used instead of the mean for the control group, the estimated price difference is CNY 4,539.68/m², with a relative price premium of 11.08%. The leave-one-out analysis produces positive price differences ranging from CNY 2,433.87/m² to CNY 7,062.27/m² across all control-group observations. The lowest estimate occurs when C5 is excluded and can therefore be used as a conservative lower-bound reference.

The distance-boundary analysis further shows that the estimated price difference remains positive when the treatment-zone boundary is shifted from the baseline 1.50 km to 1.25, 1.75, and 2.00 km, with corresponding estimates of CNY 7,437.34/m², CNY 6,678.94/m², and CNY 5,508.34/m², respectively. Because only one sample remains within the 1.25 km boundary, this scenario is treated as an extreme-boundary reference.

4.2.1.3. Robustness Conclusion

Overall, the estimated residential land value appreciation remains positive across alternative sample treatments, central-tendency measures, leave-one-out specifications, and spatial boundary definitions. Although the magnitude of the estimate varies across specifications, particularly when the low-priced observation C5 is excluded, the direction of the baseline finding remains unchanged. The results therefore indicate that the finding that residential property prices in the wetland-adjacent

area are higher than those in the surrounding control area is not dependent on a single observation, the use of the mean, or the 1.50 km treatment-zone boundary, demonstrating a degree of spatial robustness.

4.2.2. Results of the Land Proximity Premium Estimation

Based on the sensitivity analysis, three estimates are retained as reference values: the baseline estimate of (ΔP) = CNY 5,343.56/m², the median-based estimate of (ΔP_M) = CNY 4,539.68/m², and the leave-one-out estimate of (ΔP_{C-5}) = CNY 2,433.87/m². The baseline estimate is used as the primary result, the median-based estimate as a robustness estimate, and the leave-one-out estimate as a conservative lower-bound estimate that is not included in the main valuation results.

According to Equation (5):

Baseline premium: $baseV_{land}$= CNY 562.6791/m²

Robustness premium: $MiddleV_{land}$= CNY 478.0801/m²

4.3. Estimation of Enterprise Willingness-to-Pay Rate

For the control group, strategic emerging-industry parks with industrial characteristics similar to those of Tianhe Smart City, where the wetland is located, are selected as the rental benchmark. Because historical rental data are unavailable, publicly reported rental prices in 2026 are used as a reference for estimating enterprise willingness to pay.

According to data from property rental platforms, the average office rent in areas surrounding the wetland is ($\overline{R}_{eco}$) = CNY 55.05/m²/month, while the average rent in the control area is ($\overline{R}_{ctrl}$) = CNY 43.20/m²/month. According to Equation (6), the implied WTP_{rate} is approximately 27.43%. Based on this estimate, enterprises occupying office space with the ecological location advantage provided by the wetland exhibit an implicit rental premium of approximately 27.38%. In other words, to obtain the corresponding ecological location and environmental quality, enterprises are, on average, willing to pay approximately 27.38% more in rent than for office space of a similar level located away from the wetland.

4.4. Benefit–Cost Ratio Assessment

Based on the accounting results and Equation (7), the total cost of the wetland project is calculated as follows:

According to multiple government data sources, the total investment in the Daguan Wetland project was CNY 225.5441 million[26]. Based on the calculations above, the annual maintenance cost of the wetland is ($C_{operation}$) = CNY 1.22689 million. Therefore:C_{total} = CNY 23,781.3

The total benefits generated by the wetland are calculated according to Equation (8):

B_{total}= CNY 58,184.35

The benefit–cost ratio of the wetland is calculated according to Equation (9): BCR ≈2.45

Since (BCR > 1), the economic value generated by the project over its full operating period substantially exceeds its investment cost, indicating that the project is economically feasible.

5. Conclusions

This study takes Daguan Wetland Park in Tianhe District, Guangzhou, as a case study and uses the individual urban wetland as the basic accounting unit. From the perspective of "wetland investment–comprehensive returns," it monetizes the benefits generated by wetland construction, including rainwater reuse, annual runoff control, green-space maintenance cost savings, and surrounding real estate land value appreciation. Office property rents are further compared to provide market-based validation of the ecological location value associated with the wetland.

(1) Based on the monetary valuation methods and accounting framework established above, the benefits generated by the construction, operation, and maintenance of Daguan Wetland Park were estimated. Over the 10-year operating period following completion, the wetland generated a total

comprehensive benefit of CNY 581.8435 million, with a benefit–cost ratio (BCR) of 2.45. These results indicate the economic feasibility of investing in urban sponge infrastructure.

(2) Among the benefits generated by Daguan Wetland Park, direct ecological benefits amounted to CNY 19.1644 million, while spatial spillover benefits reached CNY 562.6791 million, accounting for approximately 98% of total benefits. The 27.38% implicit willingness-to-pay rate exhibited by enterprises for the wetland-related ecological location provides further market-based evidence, indicating substantial market potential and scope for value appreciation of the wetland's ecological value.

6. Limitations and Future Research

Given the limited empirical research on the investment returns of individual Sponge City facilities and the difficulty of quantifying many less visible benefits, this study attempts to establish a monetary accounting framework for the "investment–comprehensive returns" of an individual urban wetland. However, the analysis remains subject to limitations related to study scale, data availability, and valuation methods.

(1) This study mainly monetizes benefit components for which physical quantities, market prices, or cost-substitution bases can be clearly identified. Therefore, the estimated comprehensive benefits primarily reflect those benefits that can be identified and quantified under current research conditions and have relatively reliable monetary valuation bases. They should not be interpreted as representing the full value of the wetland's ecosystem services.

(2) Real estate prices are jointly determined by multiple factors beyond the ecological environment provided by the wetland. Although spatial grouping, buffer-zone comparisons, and comparable samples from areas with similar development levels were used to reduce the influence of non-wetland factors, it remains difficult to fully isolate all unobservable factors. Future research could employ more rigorous longitudinal econometric models to track changes in real estate prices before and after wetland construction, thereby improving the causal identification of wetland-induced land value appreciation.

(3) This study evaluates "investment–comprehensive returns" based on costs and benefits observed within a specific study period. However, both wetland ecosystem services and the spatial value of surrounding real estate exhibit pronounced long-term dynamics. Future research could therefore develop a full life-cycle assessment framework for urban wetlands and establish a more comprehensive long-term evaluation system for investment returns.

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