Chinese Industry and Technology of Eco-environment
2025, VOL. 6, NO. 5, 54-59
DOI: 10.47297/wspciateWSP2633-772X11.20250605

Ecological Design Strategies and Environmental Justice Research on Green Infrastructure in the Beijing-Tianjin-Hebei Region

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ABSTRACT
Driven by urbanization and technological development, problems such as carbon emissions and the urban heat island effect have intensified, leading to declining air quality, increased flood risk, and ecological degradation, impacting urban resilience and residents' quality of life. To address this, there is now a greater demand for green spaces in cities, and governments and communities have set mandatory requirements for the proportion of green space in urban areas. Basic green infrastructure such as green roofs, vertical greening, street trees, and urban parks can all be reduced. However, due to differences in economic development, management measures, and geographical factors among different cities, the allocation and mitigation effects of green infrastructure vary significantly. For example, first-tier cities and third-tier cities have different development goals. First-tier cities prioritize economic development while simultaneously carrying out environmental protection and restoration, while third-tier cities are still in the process of economic development. Furthermore, the effects and functions of green infrastructure differ in different areas of the same city, such as residential areas, commercial areas, and industrial areas. This paper analyzes the spatial distribution and ecological benefits of green infrastructure in the Beijing-Tianjin-Hebei region from the perspective of environmental justice, aiming to provide design strategy references for regional ecological equity and collaborative governance.

KEYWORDS
Beijing-Tianjin-Hebei region; Green infrastructure; Environmental justice; Ecology

1 Introduction

1.1 Research Background

In recent years, as a developing country, China has continued to prioritize economic development. However, with the intensification of the global ecological crisis and the international community's focus on sustainable issues, ecological civilization construction has become a key national strategy. As China proposed in 2005, "Lucid waters and lush mountains are mountains of gold and silver." emphasizing that economic growth and ecological protection should be carried out in unison [1]. This concept has promoted the institutionalization of China's ecological civilization construction and also reflects the strategic position of ecological protection in national development.

1.2 Research Significance and Objectives

Against the backdrop of rapid urbanization, Green Infrastructure (GSI) has become an important means of mitigating ecological degradation and climate risks. However, differences in economic level, land use structure, and population density among different cities lead to uneven distribution and benefits of GSI, resulting in environmental injustice. The Beijing-Tianjin-Hebei region, as a typical high-density urban agglomeration in China, faces particularly prominent ecological pressures and regional development disparities. This paper explores the spatiotemporal evolution of GSI and the differences in ecological and social benefits in the Beijing-Tianjin-Hebei region from the perspective of Environmental Justice (EJ), aiming to reveal the uneven distribution of ecological resources among different economic development areas. The research results can provide a reference for regional ecological design and collaborative governance, promoting the harmonious coexistence of economy and ecology.

To achieve the above research significance, this paper establishes the following three specific objectives:

(1) Systematically analyze the evolution of GSI construction and ecological design strategies in the Beijing-Tianjin-Hebei region since 2000, identifying the spatial distribution and design ideas of different types of GSI.

(2) Evaluate the ecological and social benefits of GSI from an EJ perspective, revealing the relationship between ecological resource distribution and socioeconomic differences.

(3) Propose targeted ecological design and regional governance strategies to achieve a dual improvement in ecological benefits and environmental equity.

1.3 Research Methods and Article Framework

This paper employs literature review and policy analysis as its primary research methods, combining spatial pattern

evolution and ecological policy documents, and adopts a comparative research approach to analyze the evolution and distribution characteristics of the GSI in the Beijing-Tianjin-Hebei region. First, it reviews the current state of relevant research in recent years, then explains the meaning of EJ. Second, it collects and analyzes comparative data on ecological data and GSI types in the Beijing-Tianjin-Hebei region from 2000 to the present. Finally, it summarizes the reasons for its unfairness and explores effective measures.

This paper consists of five parts: Part One is the introduction, outlining the research background, significance, and objectives; Part Two is the literature review, explaining relevant research, EJ, and the current ecological status and research in the Beijing-Tianjin-Hebei region; Part Three analyzes the spatiotemporal evolution and ecological benefits of GSI in the Beijing-Tianjin-Hebei region based on current research, and argues for its unfairness; Part Four proposes corresponding strategies; and Part Five is the conclusion.

2 Literature Review

2.1 Current Status of Domestic and International Research

In recent years, research on urban GSI and EJ has continued to deepen both domestically and internationally. Domestic scholars mainly focus on the evolution of urban ecological security patterns, the relationship between society and ecology, and ecological restoration pathways. Taking the Beijing-Tianjin-Hebei region as an example, Wang Zhenbo et al. used an ecological security pattern model to reveal the evolution characteristics of ecological spatial structure from 2000 to 2015, and pointed out that socio-economic drivers are an important factor in the change of ecological patterns [2]. Huang Yingli et al. analyzed the coordinated development relationship in the Beijing-Tianjin-Hebei region from the perspective of the coupling of socio-economic and ecological environment systems, and believed that economic expansion has a significant inhibitory effect on ecological restoration [3]. Meng Fandi et al. conducted a regional study on ecological restoration of national land space based on the ecosystem service supply and demand and ecological resilience model, and found that there are significant differences in ecological restoration potential among regions [4]. In addition, Li Mei et al. pointed out that although the coordinated governance of the Beijing-Tianjin-Hebei region has achieved certain results, there is still an imbalance in the sharing of ecological resources and governance mechanisms [5]. Regarding the ecological benefits of GSI, Hu Fengning and Zhou Liang reviewed the role of GSI in urban cooling and mitigating the heat island effect, and pointed out that its ecological benefits are significantly affected by vegetation type and spatial pattern [6]. Liu Yonghong et al. quantitatively assessed the urban heat island effect in the Beijing-Tianjin-Hebei region using remote sensing data, finding a close correlation between thermal environment distribution and green space structure [7]. Wang Jianting et al. conducted a comprehensive analysis of green space in the Beijing-Tianjin-Hebei region from a spatial evaluation perspective, providing a reference for regional ecological planning [8].

Foreign studies have focused on the Energy and EJ issue earlier. Bullard first proposed that environmental pollution and unequal resource allocation often concentrate in disadvantaged communities [9]; Mohai et al. further systematized the EJ theoretical framework, emphasizing that environmental benefits and risks should be fairly distributed [10]. In empirical studies, Song et al. revealed significant socioeconomic disparities in green space exposure in major Chinese cities, with high-income groups enjoying more ecological services [11].

In general, domestic and international research has yielded rich results in EJ theory and GSI spatial equity, but comprehensive research on different development levels and spatial structures in the Beijing-Tianjin-Hebei region is still insufficient, with most analyses focusing on ecological construction from a relatively macroscopic perspective. Most current studies tend to adopt a macro perspective when analyzing ecological construction. Building upon previous research, this study integrates the perspective of EJ to examine the spatial distribution and typological characteristics of GSI across regions with different economic development levels in the Beijing-Tianjin-Hebei region. Furthermore, it explores the ecological benefits of GSI and evaluates their environmental equity, aiming to identify how optimizing GSI can contribute to achieving environmental justice and, ultimately, enhancing ecological restoration outcomes.

2.2 Definition and Significance of Environmental Justice

The concept of Environmental Justice (EJ) originated in the American social movement of the 1970s, aiming to oppose the unequal distribution of pollution and environmental risks. Bullard's research points out that environmental pollution and ecological risks are often concentrated in low-income, vulnerable, and minority communities, revealing the social nature of environmental problems [9]. Yu et al., through research in major Chinese cities, found that although the overall greening rate has increased, high-quality green spaces are prominent in some areas, meaning that ecological improvement has actually exacerbated social inequality [12]. EJ aims to integrate the principle of social equity into the ecological governance process, achieving the dual goals of ecological restoration and social equity.

This definition constructs three core aspects of EJ:

(1) Distributive Justice: Focusing on whether the distribution of environmental benefits and risks is fair among different social groups and regions.

(2) Procedural Justice: Emphasizing the public's equal right to participate and speak in environmental decision-making and ecological governance.

(3) Recognition Justice: Focusing on respect and recognition for vulnerable groups, marginalized communities, or minority groups, avoiding their neglect in policy-making. Overall, this provides a theoretical basis for this paper to analyze the fairness of green infrastructure in the Beijing-Tianjin-Hebei region from the three dimensions of allocation, procedure and recognition.

2.3 Ecological Measures and Current Status of Green Infrastructure in the Beijing-Tianjin-Hebei Region

2.3.1 Ecological Mitigation Policies and Measures for Green Infrastructure in the Beijing-Tianjin-Hebei Region

In recent years, the national and local governments have successively introduced a number of ecological policies to promote the process of ecological restoration and improve the global climate crisis. The *"Opinions on promoting green development in urban and rural construction"* clearly proposes to strengthen the protection and restoration of urban ecological space and improve the green infrastructure system such as urban parks, green corridors, wetlands and ecological buffer zones [13]. In addition, the *"White Paper: Green Development in the New Era of China"* released in 2023 further emphasizes that under the 'Dual Carbon Goals' regional ecological security can be improved through green space optimization and ecological network reconstruction, while consolidating the natural ecological status and enhancing the climate resilience of cities and the carbon sink of cities [14].

As the most representative urban agglomeration in northern China, the Beijing-Tianjin-Hebei region is a key area for national ecological civilization construction and regional coordinated development, and actively responds to this policy. By building a system that breaks down local interest limitations, strengthens the unity of ecological protection, effectively enhances ecological connectivity, and improves climate resilience [15]. In addition, the introduction of green finance policies has also provided financial support for the construction of ecological infrastructure. Liu Lei pointed out that green finance plays a dual role of policy guidance and capital leverage in the ecological coordinated governance of Beijing-Tianjin-Hebei, which helps to achieve a long-term mechanism for green transformation and ecological restoration [16].

2.3.2 Ecological Status and Differences of Green Infrastructure in the Beijing-Tianjin-Hebei Region

Despite significant progress in ecological governance and green infrastructure construction in the Beijing-Tianjin-Hebei region, significant differences in development among regions remain. Research by Wang Zhenbo et al. indicates that the overall ecological security pattern of the Beijing-Tianjin-Hebei region tended to improve between 2000 and 2015, but there were still significant gradient differences between the core cities and the surrounding areas [2]. Liu Yonghong et al. found through remote sensing analysis that the green coverage rate and ecological cooling island effect in Beijing's urban area were significantly better than those in Tianjin and some cities in Hebei [7]. In terms of spatial distribution, Beijing's urban green space layout is relatively balanced, and its ecological corridor system is well-developed; Tianjin, however, is limited by industrial layout and coastal development, resulting in relatively insufficient green space connectivity; and the green space structure in some cities in Hebei, such as Langfang and Tangshan, is scattered, with limited ecological benefits [15]. This further points out that there are significant gaps in ecological resilience and the balance between supply and demand of ecological services among different cities, especially in small and medium-sized cities and industrial areas where the potential for ecological restoration is relatively low. Overall, the Beijing-Tianjin-Hebei region has formed a technical framework for ecological construction, but there are still shortcomings in the allocation and construction of GSI, resulting in environmental injustice in the region, and there is still room for improvement.

3 Analysis and Discussion

Based on the preceding analysis of policies and the current situation, the evolution of GSI in the Beijing-Tianjin-Hebei region can be divided into three main stages. This chapter analyzes and compares these stages from the perspectives of temporal evolution, functional benefits, and spatial equity.

3.1 Spatiotemporal Evolution of Green Infrastructure in the Beijing-Tianjin-Hebei Region (2000-2025)

Since 2000, the GSI in the Beijing-Tianjin-Hebei region has undergone a profound evolution from policy-driven to system-coordinated development under the guidance of national ecological policies. In response to the national call, the Green Infrastructure development in the Beijing-Tianjin-Hebei region from 2000 to 2025 can be divided into three stages:

the early policy proposal and ecological protection stage; the stage of coordinated development under economic development; and the stage of ecological quality improvement.

Before 2002, China's ecological construction was still in the conceptual advocacy stage. After in 2003 proposed the concept of a ‘resource-saving and environment-friendly society’ the institutionalization stage began [17]. In response to the national ecological restoration policy, ecological restoration projects, mainly based on the construction of protective forests, were launched in the Beijing-Tianjin-Hebei region, with policies focusing on protective forests, wetland restoration, and returning farmland to forest [18-20]. During this period, GSI construction mainly focused on quantitative growth, with a relatively scattered ecological spatial layout and ecological functions primarily focused on protection and restoration.

After entering the 2010s, regional coordination became the dominant direction. In 2015, reviewed and approved the *“Beijing-Tianjin-Hebei Coordinated Development Plan Outline”* promoting top-level alignment among the three regions in ecological governance and spatial planning [21]. The implementation of this outline has facilitated coordinated cooperation in ecological protection and spatial governance within the Beijing-Tianjin-Hebei region, shifting GSI construction from spontaneous urban restoration to cross-regional coordination and systematic layout, thus promoting overall connectivity and functional optimization of the ecological network.

After 2020, with the introduction of the ‘Dual Carbon Goals’ (the goals of carbon peaking in 2030 and carbon neutrality in 2060), GSI construction shifted from quantitative expansion to quality improvement [14]. The *"Opinions on promoting high-quality urban development"* issued in 2025, emphasizes green transformation and quality improvement from a top-level design perspective, providing strategic guidance for the optimization of green infrastructure in cities nationwide [22]. These policies mark a new stage in China's urban GSI development, centered on quality, coordination, and sustainability, achieving structural optimization from ‘patches’ to ‘networks’.

3.2 Ecological Benefit Assessment of Different Green Infrastructures

From a functional perspective, different types of GSI exhibit significant differences in ecosystem service provision. Forests, wetlands, and river ecological corridors constitute the core structure of the ecological security pattern of the Beijing-Tianjin-Hebei region. These infrastructures play a significant role in climate regulation, hydrological regulation, and air purification [2]. Quantitative studies by Liu Yonghong et al. show that urban heat island intensity is significantly negatively correlated with green space density. For every 10% increase in green space coverage, the average summer surface temperature can decrease by 0.7-1.0℃, indicating that GSI have important ecological benefits in regulating regional climate [7].

Studies indicate that the cooling mechanism of GSI mainly relies on processes such as shading, evapotranspiration, and cold air mass advection, and its effect is closely related to vegetation type, canopy structure, and spatial configuration. Wetland and forest ecosystems, due to their high vegetation coverage, strong evapotranspiration potential, and good air circulation, usually exhibit a more significant temperature mitigation effect in urban thermal environment regulation; in contrast, the cooling effect of street trees and small parks is limited by their spatial scale and surrounding building density, and can only play a role in a local area [6]. Therefore, GSI with basic ecological functions (such as wetland parks, protective forest belts, coastal wetlands, etc.) have significantly better comprehensive benefits in terms of cooling and maintaining ecosystem stability than landscape GSI (such as street trees, pocket parks, urban square green spaces) [4].

3.3 Spatial Equity Analysis from the Perspective of Environmental Justice

From EJ's perspective, the GSI in the Beijing-Tianjin-Hebei region exhibits imbalances in allocation, procedures, and recognition.

Regarding distributive justice, the uneven spatial pattern directly leads to unfair allocation of ecological resources. Ecological benefit evaluation results show that Beijing and Tianjin make significantly higher ecological contributions to urban green space, wetland systems, and ecological corridor construction than surrounding areas, forming a spatial pattern of ‘core concentration and peripheral sparseness’ [8]. This difference is reflected not only in the concentration of ecological functions but also in the varying accessibility of green spaces and ecological services to residents. Studies have consistently indicated that major Chinese cities generally exhibit a ‘central concentration and peripheral insufficiency’ characteristic in terms of green space exposure and accessibility, with high-income groups often enjoying more green resources and environmental welfare [12].

Regarding procedural justice, current ecological governance in the Beijing-Tianjin-Hebei region is still primarily based on a top-down administrative model, with limited local participation and public decision-making power. GSI planning largely relies on government-led special projects, and the public has insufficient say in the planning, design, and supervision process [5]. Furthermore, barriers remain between different cities in terms of ecological information disclosure, funding allocation, and policy implementation, resulting in policy integration but fragmented implementation, further

weakening institutional fairness [15]. Ecological policies and strategies in first-tier cities such as Beijing and Tianjin are significantly better than those in non-first-tier cities like Hebei.

Regarding recognition justice, the fundamental reason for this unequal distribution of GSI lies in the differences in economic foundation, fiscal investment, and planning orientation among regions. High-income groups and economic core areas typically enjoy higher-quality green spaces and ecological services, while the ecological needs of low- and middle-income groups and peripheral cities are often overlooked [16]. The high-quality parks and wetland systems in Beijing and Tianjin provide residents with abundant ecological benefits, while some small and medium-sized cities in Hebei suffer from insufficient ecological investment, resulting in inadequate access to green spaces and environmental quality, further exacerbating environmental injustice.

3.4 Reasons for and Implications of Disparities in Green Infrastructure

Overall, the development of GSI in the Beijing-Tianjin-Hebei region exhibits a pattern of quantitative growth followed by qualitative improvement, and then a lag in equity development. Over two decades of policy and construction efforts have promoted the overall optimization of the regional ecological network, but economic disparities and governance fragmentation have resulted in an uneven spatial and social distribution of ecological resources. This disparity not only weakens the overall resilience of the regional ecosystem but also exposes the limitations of current GSI development in terms of equity and inclusiveness, requiring further exploration and improvement.

4 Conclusions

4.1 Main Research Conclusions

This study analyzes the spatial-temporal evolution, ecological benefits, and equity of GSI in the Beijing-Tianjin-Hebei region from 2000 to the present. The results show that the overall GSI construction in the region has shown a continuous optimization trend, with gradual improvement in ecosystem functions and spatial structure. However, the uneven distribution of ecological resources due to regional development disparities remains a significant issue.

From the perspective of GSI construction in the Beijing-Tianjin-Hebei region, both spatial pattern and ecological function have shown optimization, with a significant improvement in the connectivity and comprehensive service capacity of the ecological network. However, due to differences in economic foundation, fiscal investment, and policy implementation capabilities, significant uneven distribution of ecological resources still exists within the region. Beijing and Tianjin, with their advantages in funding and policies, have significantly improved GSI coverage and functional integrity; while some cities in Hebei Province, limited by their economic structure and technological capabilities, have relatively lagging ecological restoration processes and lower levels of ecological service supply, forming a spatial gradient of 'core concentration and peripheral sparseness'.

From an EJ perspective, this study reveals the structural imbalances in the development of green infrastructure in the Beijing-Tianjin-Hebei region. This injustice is reflected not only in the spatial allocation of ecological resources but also in institutional processes and social identification. The concentration of ecological resources and the uneven economic development have resulted in core cities accumulating high-quality ecosystem services, while peripheral areas have long been marginalized in terms of ecological benefits, reflecting inequality in distribution. Meanwhile, the planning and governance of GSI remains primarily top-down, with insufficient public participation and social oversight, leading to procedural closedness and one-wayness in ecological governance. Furthermore, the 'invisibility' of vulnerable groups and ecologically fragile areas in policy priorities and resource allocation further exacerbates injustice at the identification level.

Overall, the development of GSI in the Beijing-Tianjin-Hebei region has shifted from policy-driven to systemic coordination, but the issue of environmental justice remains fundamentally unresolved. Future efforts should focus on further deepening regional coordination, financial support, and ecological compensation mechanisms to achieve a dual improvement in ecological benefits and social equity.

4.2 Recommendations for Optimizing Green Infrastructure

To address the injustices in the allocation, procedures, and identification of GSI in the Beijing-Tianjin-Hebei region, this study proposes a three-pronged approach: 'cross-regional collaboration', 'institutional and policy innovation' and 'financial support'.

Firstly, regarding distributive justice, 'cross-regional collaboration' should break down barriers between cities and strengthen ecological information sharing and spatial linkage mechanisms. Simultaneously, in the process of developing the economy and improving ecological quality, it is crucial to prevent core cities with good ecological benefits from

creating new environmental pressures on surrounding areas, and to establish ecological assistance mechanisms to support the restoration and management of ecologically vulnerable areas.

Secondly, regarding procedural justice, 'institutional and policy innovation' should promote openness and transparency in the governance process. Top-down management should be modified to build a multi-faceted management system with information disclosure and public participation, making the ecological governance process more transparent and inclusive, and enhancing the synergistic effect among local governments, social organizations, and residents.

Finally, regarding recognition justice, 'financial support' should narrow the ecological gap between regions and social groups. Economic and ecological technologies from high-economic development zones such as Beijing and Tianjin should be introduced to Hebei to improve the lack of funding for ecological projects.

In summary, the optimization of green infrastructure in the Beijing-Tianjin-Hebei region still suffers from limitations such as policy integration but fragmented implementation. Imbalances in institutional coordination and funding allocation mean that EJ goals have not been fully achieved. Future optimization of green infrastructure should continue to deepen cross-regional collaboration, institutional innovation, and financial support to improve the current unjust situation and achieve a dynamic balance between the ecological and social benefits of GSI in the Beijing-Tianjin-Hebei region.

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