

Assessment of Regional Green Development Performance: Evidence from Tianshui City

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Abstract:

Green development has become a crucial global trend. This study evaluates Tianshui City's green development level by constructing an indicator system with 30 metrics across three dimensions: economic development, sustainability, and green development capacity. Using 2012–2022 statistical data and the CRITIC method, we assess performance trends and identify obstacles. Results show an overall upward trajectory, with sustainability exhibiting steady growth, while economic and green development capacities display fluctuations. Policy recommendations are proposed to enhance Tianshui's green transition.

Keywords:

Green Development Level, Indicator System, CRITIC Method, Tianshui City

1. Introduction

In recent years, rapid industrial and technological advancement has precipitated severe environmental challenges globally. Confronted with escalating ecological crises, nations worldwide recognize the necessity to transition from traditional heavy industry-dependent models toward green development pathways. This paradigm shift has spurred policy interventions aimed at fostering sustainable growth. China, like other nations, faces intensifying ecological constraints that increasingly influence urban development trajectories. The Chinese government prioritizes green development, as evidenced by the 19th National Congress of the Communist Party's emphasis on "lucid waters and lush mountains as invaluable assets," "adopting green development modes," and "building a beautiful China" [1]. Northwestern Chinese cities—often grappling with pollution and economic lag—exemplify regions where green transitions are critical for future prosperity. Globally, "green economy" and "green growth" encapsulate this concept. Pearce et al. [2] define green economy as an ecologically and economically viable model that avoids resource depletion and systemic collapse. Since the 21st century, China's green policies have gained international traction, underscoring a consensus on ecological sustainability [3]. Green

development harmonizes economic progress with environmental stewardship, advocating science-based, people-centric approaches.

Scholars have employed diverse methods to assess green development: Wang Jinnan et al. [4] evaluated regional disparities across China. Han Meili et al. [5] analyzed Shandong Province's performance. Zhang Yufang et al. [6] applied Super-SBM models to Shanxi's cities. Feng C et al. [9] used DEA to compute a Global Development Performance Index (GDPI) for 165 nations. Li W et al. [10] measured water resource efficiency via GTFPWR. Agnieszka W K et al. [14] synthesized six indices to create Poland's green development metric. These studies highlight methodological pluralism—from CRITIC weighting to DEA—in quantifying sustainability. Rodenburg et al. [15] further systematized green space frameworks for regional management.

The synthesis of global and Chinese research demonstrates green development's centrality to 21st-century progress, necessitating tailored policies for regions like Tianshui.

2. Study Area

Tianshui City is situated in the southeastern part of Gansu Province, located in the western segment of the Qinling Mountains and the middle reaches of the Wei River. It administers 2 districts and 5 counties, covering a total area of 14,300 square kilometers. Geographically, it is positioned between 104°56'E to 106°73'E and 34°07'N to 35°17'N. To the east, it borders Baoji City in Shaanxi Province, to the west it neighbors Dingxi City, to the south it connects with Longnan City, and to the north it adjoins Pingliang City. The northwestern part of the city is characterized by loess ridges and gullies, while the southeastern part, encompassing the Qinling and Guan Mountains, is a forested area. The city's terrain generally slopes from high in the west to low in the east, and it has historically been a crucial passageway on the ancient "Silk Road".

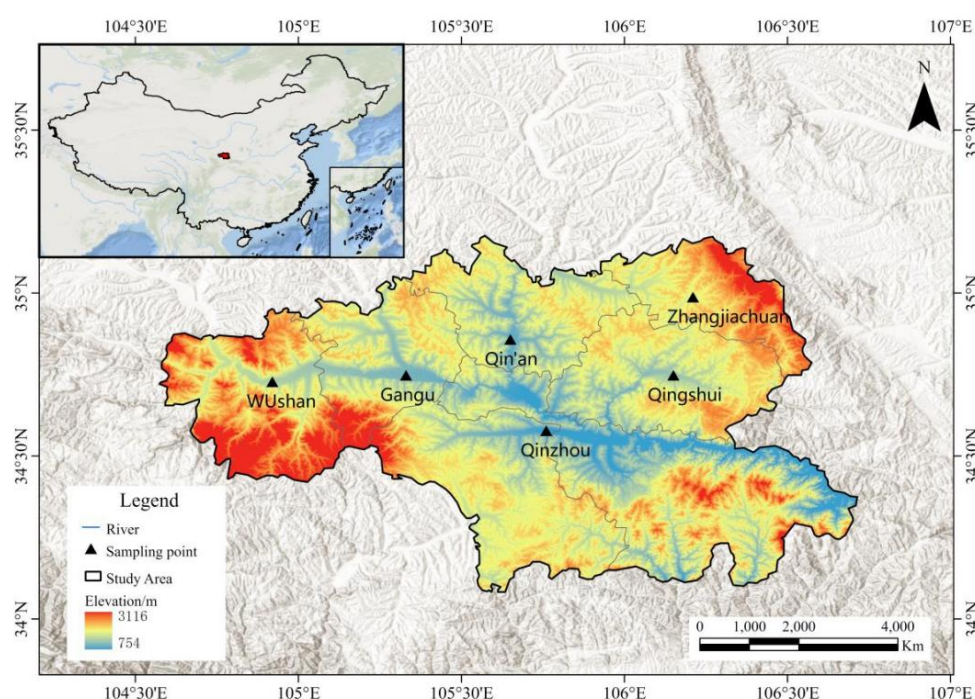


Figure 1. Overview Map of the Study Area.

3. Data and Methods

3.1. Statistical Data Sources

The statistical data were obtained from the following official publications: Tianshui Statistical Yearbook (2012-2022), Gansu Development Yearbook (2012-2022), China City Statistical Yearbook (2012-2022), Tianshui Environmental Status Bulletin (2012-2022). The majority of raw data were collected directly from these sources, while some indicators were calculated based on the original datasets.

3.2. CRITIC Method

The CRITIC method (Criteria Importance Through Intercriteria Correlation) is a relatively objective evaluation approach that has gained widespread application. The specific procedures are as follows:

(1) Data Standardization: To eliminate dimensional influences among different indicators, the deviation method is applied to standardize the raw indicator data:

$$d_{ij} = \frac{x_{ij} - (x_j)_{\max}}{(x_j)_{\max} - (x_j)_{\min}} \text{ (Positive indicator)} \quad (1)$$

$$d_{ij} = \frac{(x_j)_{\max} - x_{ij}}{(x_j)_{\max} - (x_j)_{\min}} \text{ (Negative Indicator)} \quad (2)$$

Here, x_{ij} represents the original value of the j -th evaluation indicator in the i -th year, d_{ij} denotes the standardized data after processing, and $(x_j)_{\max/\min}$ indicates the maximum or minimum value of the j -th evaluation indicator.

(2) Calculate the information measure of the j -th evaluation indicator.

$$C_j = \sigma_j \sum_{i=1}^p (1 - r_{ij}) \quad (i = 1, 2, 3, 4, \dots, x; j = 1, 2, 3, 4, \dots, y) \quad (3)$$

Here, C_j represents the information measure contained in the j -th evaluation indicator, σ_j denotes the standard deviation of the j -th indicator, and r_{ij} represents the correlation coefficient between evaluation indicators i and j .

(3) Calculate the weights for each indicator.

$$W_j = \frac{C_j}{\sum_{j=1}^y C_j} \quad (j = 1, 2, 3, 4, \dots, y) \quad (4)$$

Where W_j represents the weight of the j -th indicator.

(4) Calculate the total green development score for Tianshui City.

$$V_j = \sum_{j=1}^y W_j d_{ij} \quad (i = 1, 2, 3, 4, \dots, x; j = 1, 2, 3, 4, \dots, y) \quad (5)$$

4. Results

4.1. Construction of Green Development Evaluation Indicator System for Tianshui City

In green development indicator system research, China has established an evaluation framework comprising three primary indices: economic growth greening degree, resource-environment carrying capacity, and government policy support, including nine secondary and fifty tertiary indicators [2]. Huang Yi et al. [16] developed a comprehensive regional evaluation system for Guangzhou, while Liu Xiaojie et al. [17] constructed a 39-indicator system for socio-economic assessment.

Other sector-specific systems include coal industry [19] and paper manufacturing [20] evaluations, as well as Yang Guohua's demand-resource-environment-future framework [21].

Based on the conceptual framework of green development and Tianshui's current conditions, this study establishes a tailored evaluation indicator system following scientific and rational principles. The system comprises three criterion layers (economic development, sustainability, and green development capacity) with 30 tertiary indicators, as detailed in Table 1.

Table 1. CRITIC method evaluation scores of the level of green development in Tianshui from 2012 to 2022.

Target Layer	Criterion Layer	Indicator Code	Indicator Laye	Directionality
Urban Green Development Level	A. Economic Development	A1	Per capita GDP	+
		A2	Disposable income per capita	+
		A3	Savings balance per capita	+
		A4	Total retail sales of consumer goods	+
		A5	Agglomeration economy (Urban economic density)	+
		A6	Tertiary industry share	+
		A7	General public budget revenue	+
		A8	Urban registered unemployment rate	-
		A9	Urban Engel coefficient	+
		A10	Urban-rural income ratio	+
		A11	Social insurance coverage rate	+
	B. Sustainability	B1	Annual average PM2.5 concentration	-
		B2	Percentage of days with air quality (+)	+
		B3	Harmless treatment rate of domestic waste	+
		B4	SO2 emissions per unit area (-)	+
		B5	NOx emissions per unit area (-)	+
		B6	Energy consumption per unit GDP	-
		B7	Water consumption per unit GDP	-
		B8	Electricity consumption per unit GDP	-
	C. Green Development Capacity	C1	Water supply pipeline density (+)	+
		C2	Drainage pipeline density (+)	+
		C3	Green coverage rate in built-up areas (+)	+
		C4	Per capita public green space area	+
		C5	Per capita road area	+
		C6	Number of higher education institutions (+)	+
		C7	Science/education expenditure as % of GDP	+
		C8	Number of doctors per 10,000 people	+
		C9	Number of hospital beds per 10,000 people	+
		C10	Number of operational public buses/trolleys	+
		C11	Urban wastewater treatment rate	+

4.2. Determination of Indicator Weights

The statistical data were processed according to Equations (1) and (2) to obtain standardized values, followed by further computation using Equations (3) and (4) to derive the indicator weights, as presented in Table 2.

Table 2. Comprehensive evaluation index weight of Tianshui's green development level.

Criterion Layer	Indicator Code	Indicator weights	Total
A. Economic Development	A1	0.0251	0.3389
	A2	0.0256	
	A3	0.0243	
	A4	0.0257	
	A5	0.0247	
	A6	0.0284	
	A7	0.0289	
	A8	0.0485	
	A9	0.0481	
	A10	0.0340	
	A11	0.0256	
B. Sustainability	B1	0.0470	0.3268
	B2	0.0334	
	B3	0.0418	
	B4	0.0439	
	B5	0.0421	
	B6	0.0380	
	B7	0.0421	
	B8	0.0385	
C. Green Development Capacity	C1	0.0300	0.3282
	C2	0.0336	
	C3	0.0314	
	C4	0.0303	
	C5	0.0259	
	C6	0.0361	
	C7	0.0321	
	C8	0.0249	
	C9	0.0286	
	C10	0.0268	
	C11	0.0285	

4.3. CRITIC Method Evaluation Results

The total evaluation scores of Tianshui's green development level from 2012 to 2022 were calculated using Equation (5), as visually presented in Figure 2.

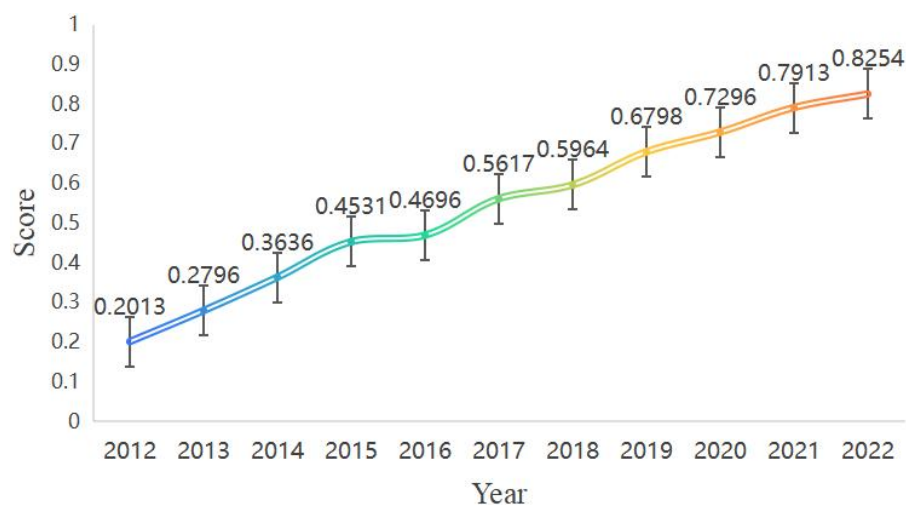


Figure 2. CRITIC evaluation results of the level of green development in Tianshui from 2012 to 2022.

5. Discussion

5.1. Target Layer Discussion

Analysis of Figure 1 reveals that Tianshui City's green development level demonstrated a consistent upward trend from 2012 to 2022, with satisfactory progress characterized by annual incremental improvements. The composite evaluation score increased from 0.201364125 in 2012 to 0.825469806 in 2020, representing an approximate threefold growth over this eight-year period.

5.2. Criterion Layer Discussion

According to the CRITIC method, the calculated results were multiplied by 100% for comparative purposes, yielding the evaluation scores of each criterion layer for Tianshui City's green development level from 2012 to 2022 as presented in Table 3. The temporal trends of these criterion layer scores are visualized in Figure 3.

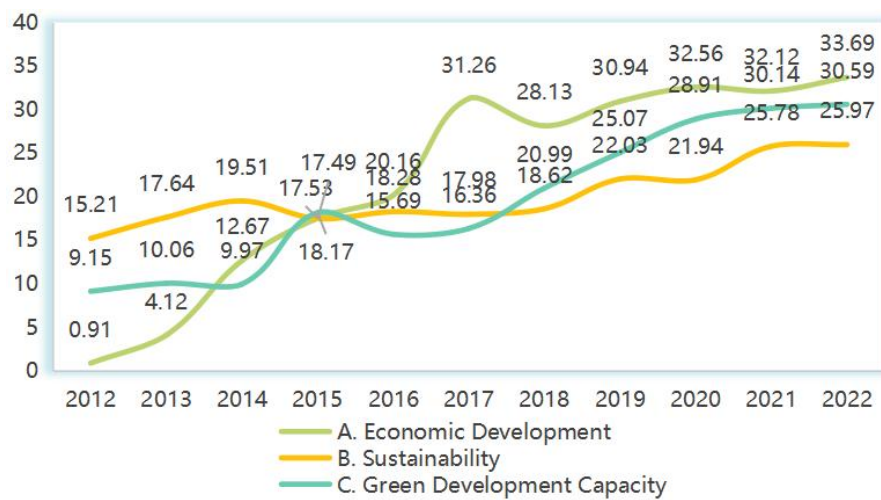


Figure 3. Evaluation scores of each criterion level of Tianshui's green development level from 2012 to 2022.

Table 3. CRITIC method evaluation scores of the level of green development in Tianshui from 2012 to 2022.

Criterion Layer	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
A. Economic Development	0.91	4.12	12.67	17.53	20.16	31.26	28.13	30.94	32.56	32.12	33.69
B. Sustainability	15.21	17.64	19.51	17.49	18.28	17.98	18.62	22.03	21.94	25.78	25.97
C. Green Development Capacity	9.15	10.06	9.97	18.17	15.69	16.36	20.99	25.07	28.91	30.14	30.59

Figure 3 demonstrates an overall upward trend in Tianshui City's economic development level, sustainable development level, and green development capacity from 2012 to 2022. During 2012-2016, the sustainable development level maintained relatively higher scores, while the economic development level showed more pronounced growth during 2016-2022. The economic development level experienced minor declines in 2018 and 2020. The sustainable development level exhibited

moderate fluctuations from 2015 to 2018 with a noticeable decrease in 2020. For green development capacity, downward trends occurred in 2014 and 2016, followed by steady growth after 2016.

5.3. Indicator-Level Discussion

Based on the CRITIC method, the calculated results were scaled by 100% for comparative analysis, yielding the temporal trend of economic development criterion layer scores for Tianshui City (2012-2022) as shown in Figure 4.

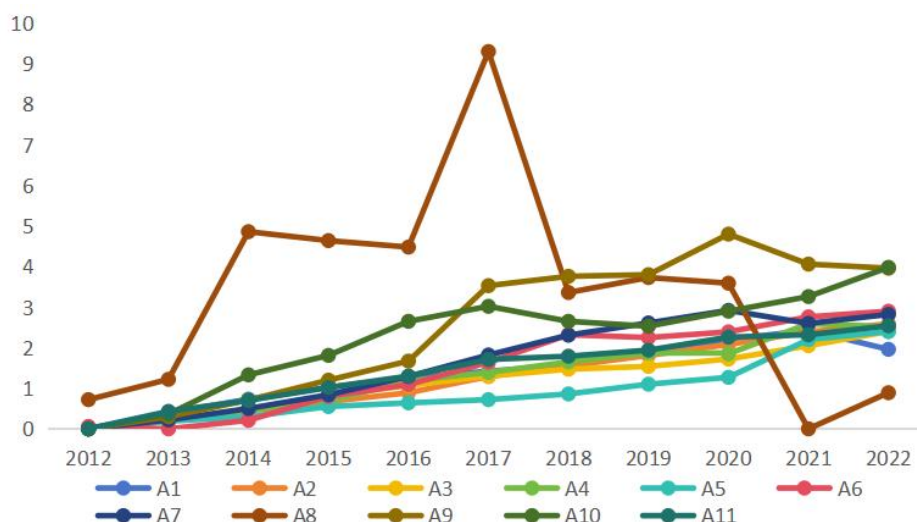


Figure 4. Economic Development Dimension: Indicator-Specific Scores for Tianshui City (2012-2022).

As the second-largest economic center in Gansu Province, Tianshui has consistently maintained leading economic performance within the province, with its heavy industry sector significantly contributing to regional economic development. Analysis of Figure 4 demonstrates that per capita GDP exhibited steady growth from 2012 to 2021, followed by a slight decline in 2022. According to provincial yearbooks, Tianshui's per capita GDP ranked either second or third in Gansu throughout this period, indicating stable economic expansion that provides strong momentum for enhancing urban green development. The tertiary sector has shown continuous growth since 2015, and cross-referencing with Figure 1 and Figure 2 reveals that accelerated industrial restructuring effectively promotes urban economic development. Furthermore, the registered urban unemployment rate has decreased annually since 2017, demonstrating successful industrial transformation alongside green development initiatives. This integrated analysis, supported by statistical yearbooks and visualized data trends, confirms Tianshui's balanced progress in economic growth and sustainable transition. The observed economic patterns - including the temporary 2022 GDP dip within an overall upward trajectory, sustained service sector expansion, and improving employment indicators - collectively validate the effectiveness of the city's development strategy that harmonizes industrial advancement with environmental considerations.

Following the CRITIC methodology, the computed results were scaled by 100% to facilitate comparative analysis, yielding the temporal trend of sustainability criterion layer scores for Tianshui City (2012-2022) as presented in Figure 5.

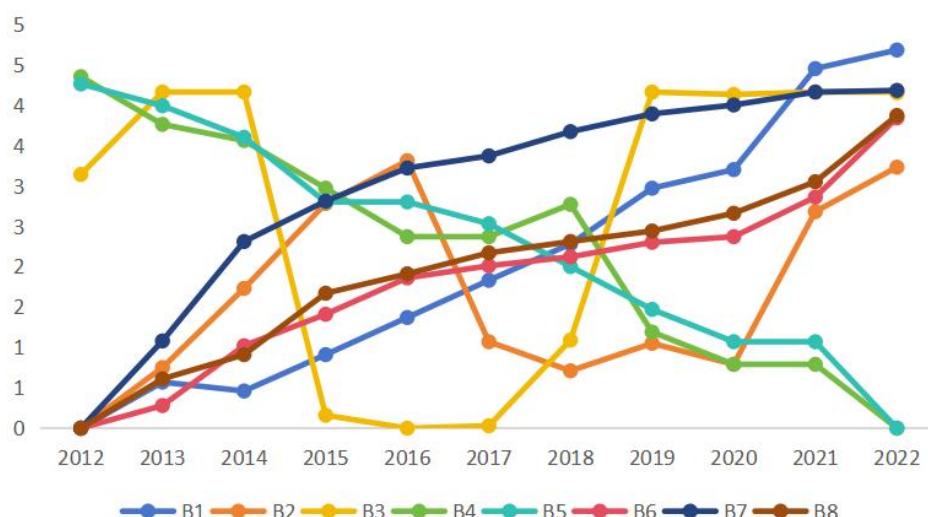


Figure 5. Indicator-Specific Scores of Sustainability Criterion Dimension for Tianshui City (2012-2022).

Analysis of Figure 5 reveals three distinct phases in Tianshui's air quality compliance: an initial improvement (2012-2017) demonstrating effective pollution control, followed by a decline (2017-2020) potentially linked to heavy industrial expansion, and subsequent recovery (2020-2022) with parallel PM_{2.5} reduction, indicating enhanced environmental governance. Concurrently, stable decreases in SO₂ and NO_x emissions per unit area reflect successful pollution mitigation alongside economic growth. While municipal waste treatment temporarily dipped in 2015, it resumed growth after 2018. Notably, energy efficiency metrics (energy/water/electricity consumption per GDP) showed consistent improvement, underscoring progress in resource conservation.

The CRITIC-derived results were scaled by 100% for standardized comparison, presenting the temporal evolution (2012-2022) of green development capacity criterion scores for Tianshui City in Figure 6.

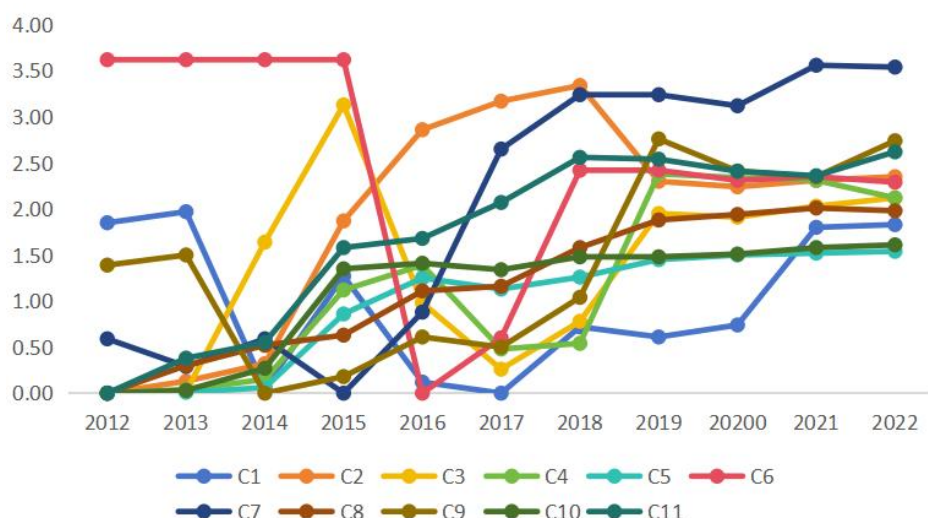


Figure 6. Green Development Capacity Dimension: Indicator-Specific Scores for Tianshui City (2012-2022).

Analysis of Figure 6 reveals that water supply pipeline density showed a brief decline during 2012-2014 before stabilizing into a steady upward trend, while

drainage pipeline density, urban wastewater treatment rate, and operational public transport vehicles maintained overall growth throughout 2012-2022, demonstrating Tianshui's parallel commitment to infrastructure development alongside urban expansion. Notably, the number of higher education institutions decreased in 2016 - cross-referencing with Figures 1-2 confirms this as a key factor affecting that year's green development performance. Subsequent annual increases in science/education expenditure as a percentage of GDP reflect the city's strategic integration of technological advancement with sustainable development goals.

6. Conclusions

Based on Tianshui's developmental context, this study establishes a tailored evaluation index system for assessing urban green development capacity, employing the CRITIC method to objectively determine weights for 30 tertiary indicators. The analysis reveals Tianshui's green development trajectory from 2012 to 2022 demonstrates overall positive progression with sustained upward momentum, though experiencing moderated growth during 2015-2018 primarily due to constraints in the green development capacity dimension.

Comprehensive evaluation suggests three strategic recommendations: First, economically, maintaining steady growth while accelerating tertiary sector development to facilitate industrial transformation. Second, environmentally, sustaining atmospheric pollution control and energy efficiency initiatives. Third, institutionally, strengthening science-technology-education investments to harness innovation-driven green development, particularly through enhanced STEM funding and policy integration. The findings underscore the necessity of balanced advancement across economic, environmental and institutional dimensions for sustainable urban transition.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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