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A Policy-Derived Multi-Tiered Analytical Framework for Assessing the Beautiful China Goals (BCGs) Implementation at the Urban Agglomeration Scale

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Abstract

To advance environmental sustainability, China proposed the Beautiful China Goals (BCGs) as its localized strategy, with urban agglomerations serving as the key implementation scale. To address the limitations of difficulty in identifying key tasks and insufficient regional applicability, this study develops a multi-goal evaluation system comprising 21 goals and 52 indicators rooted in the policy framework. Methodologically, a three-tiered assessment framework—goal, city, and region—is constructed for urban agglomerations, integrating spatial-temporal analysis, city-level two-dimensional diagnostics, and regional synergy quantification. The framework is applied to the Yangtze River Delta Urban Agglomeration (YRDUA), a national-level pilot area for the BCGs, over the period 2015–2023. Results indicate that: (1) progress toward the BCGs in the YRDUA increased by 5.7%, but full achievement by 2035 remains unlikely. Significant structural imbalances exist among the 21 goals, with infrastructure-related goals scoring higher than those related to institutional development, innovation, and carbon neutrality. Spatially, BCGs' performance follows a "high southeast, low northwest" pattern, although distribution varied by goal, and regional equity has improved. (2) Fewer than half of the 41 cities had achieved "double high" states in both development magnitude and evenness by 2023, with cities following four distinct development pathways that reflect differing priorities and strategies for goal attainment. (3) Intercity cooperation in advancing the BCGs remains limited. Synergistic effects are relatively stronger for green production goals but weaker for ecological, technological, and institutional goals, with Ningbo, Suzhou, and Shaoxing emerging as key contributors to regional synergy. This framework offers a replicable tool for regional environmental planning and provides evidence for BCGs implementation strategies in China and beyond.

Keywords: Beautiful China Goals; evaluation system design; adaptive strategy; intercity synergy; YRDUA

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1. Introduction

In 2015, the United Nations adopted the 2030 Agenda for Sustainable Development, establishing 17 Sustainable Development Goals (SDGs) to address global social, economic, and environmental challenges under a shared vision for the planet's future [1]. As a

global framework, the SDGs call for all countries to follow their guidance and assume corresponding responsibilities [2]. However, some scholars argue that countries should tailor policy measures to their unique conditions, challenges, and stages of development to achieve the SDGs better [3]. China proposed the Beautiful China Goals (BCGs) as a localized strategic framework aligned with the environmental dimensions of the SDG agenda [4,5]. The BCGs establish a composite system of goals encompassing environmental protection and ecological security, with 2035 as the main target year [5–8]. This horizon reflects the role of Beautiful China construction as an integral part of China's broader national development agenda, which aims to achieve, in essence, socialist modernization by 2035. Thus, although the BCGs and the SDGs are closely aligned on environmental sustainability, their timeframes are not identical: the SDGs are framed by the 2030 Agenda, whereas the BCGs follow China's 2035 modernization horizon. To further clarify their relationship, this study summarizes the correspondence between the 21 BCGs and the relevant SDGs in Table S1.

Since the BCGs were proposed, a growing body of research has sought to assess their implementation progress [7,9,10]. Existing evaluation system designs can be broadly grouped into two approaches. The first is efficiency-oriented, which assesses BCGs performance by constructing an input–output evaluation system [11]. Although straightforward to quantify, this approach often focuses on specific processes or single dimensions and therefore cannot fully capture the scope of the BCGs. Given the comprehensive and systematic nature of the BCGs, more studies have adopted a composite approach that evaluates implementation performance using a multidimensional indicator system. In the closely related field of SDG assessment, composite evaluation systems are further developed through two pathways: top-down and bottom-up [12]. The top-down pathway relies on unified frameworks and indicators developed by international organizations or national authorities [13]. In one study, researchers measured sustainability progress across 141 countries using the 72 SDG indicators specified in the UN 2024 Sustainable Development Report, covering the economic, environmental, and social domains [14]. This pathway is highly standardized but less responsive to local contexts and practical needs. In contrast, the bottom-up pathway builds evaluation systems from local conditions or research priorities, allowing greater flexibility in indicator selection. This flexibility is reflected in studies that used material footprint to track progress toward SDG 8 and 12 [15], or developed context-specific frameworks for community-scale sustainability [16] and the Middle East and North Africa region [17]. However, this pathway often relies more on researchers' judgment, which may limit standardization and transferability.

In BCG assessment practice, the top-down pathway is primarily reflected in official monitoring, where the government establishes an evaluation system and oversees its implementation. In 2020, the Chinese government issued the *Evaluating Indicator System and Implementation Plan for Beautiful China Construction*. The system established 22 indicators across five domains—fresh air, clean water, safe soil, sound ecosystems, and clean human settlements—and was used to organize national assessment work through third-party institutions. Although authoritative and useful for macro-level monitoring, this system relies on domains as evaluating units and provides limited coverage of some key and emerging fields, which may reduce its practical guidance. In contrast, most academic BCG evaluation systems are closer to the bottom-up pathway. Fang et al. developed their system based on the theories of harmonious coexistence between humans and nature and "Five-in-One" beauty [18]. At the same time, Guan et al. classified the BCGs into eight subsystems, including air, water, and soil, based on the connotations of ecological and environmental achievements [5]. Such studies rely largely on researchers' judgment in defining dimensions and selecting indicators, making it difficult to form a transferable assessment paradigm

that can set benchmarks and provide guidance. More importantly, using subsystems as evaluation units may obscure structural weaknesses and reduce practical guidance.

In 2024, the Chinese government issued the *Opinions of the CPC Central Committee and the State Council on Comprehensively Promoting the Development of a "Beautiful China"*, which explicitly specifies the tasks of the BCGs, each with its own independent connotations and monitoring requirements [18]. Compared with the 2020 evaluation system, the *Opinions* provide a more comprehensive, fine-grained, and implementation-oriented arrangement of Beautiful China construction tasks. Using these policy tasks as evaluation units can reduce subjective bias, preserve the benchmarking role of a top-down system, and reveal task-level weaknesses that broad domains may mask. However, few studies have adopted such a task-oriented design. Additionally, most existing indicators are derived from national-scale data [19–21], which often diverges from regional statistics and lacks localized screening and expert validation, thereby further limiting their applicability at the regional level. To address these gaps, this study introduces an improved top-down evaluation system model, constructs a multi-goal framework based on policy-defined tasks, and selects indicators that balance regional relevance with scientific rigor.

Urban agglomerations are spatial entities formed by interconnected cities with varying functions, types, and scales. They serve as key drivers of regional and national development, while also concentrating substantial ecological and environmental pressures [22]. As regional integration deepens, urban boundaries become increasingly blurred, and cross-city resource flows intensify, positioning urban agglomerations as the primary spatial carriers for BCGs implementation [23]. Compared with individual cities, environmental governance in urban agglomerations is considerably more complex due to inherent spatial heterogeneity: uneven resource distribution, disparities in governance capacity, and imbalanced economic development are intertwined, collectively constraining BCGs progress [24]. Therefore, a systematic analysis of the spatial characteristics of the BCGs, including hotspot distribution, gravity center evolution, and regional equity, is critical for achieving differentiated spatial governance and balanced regional development. Although previous studies have assessed environmental sustainability at the urban agglomeration level, exploration of inner spatial characteristics remains limited [25–27]. Moreover, such studies predominantly focus on single resources or environmental dimensions, such as climate, land use, and ecosystem [28–30], with limited attention to multi-goal systems such as the BCGs. This gap makes it difficult to support urban agglomerations in addressing complex and interrelated ecological and environmental challenges.

The construction of Beautiful China requires the simultaneous achievement of all goals; it is not a simple aggregation of individual goals, but rather the outcome of their complex interactions [18]. The advancement of one goal may facilitate or hinder others, creating disparities across them [31]. For example, emission control measures aimed at improving air quality may reduce resource-use efficiency [32]. Meeting the 2035 target, therefore, demands coordinated advancement across all goals. Existing studies mostly adopted an averaging strategy to quantify BCGs' performance [9,22], reflecting overall development magnitude using a mean goal score. This approach masks disparities among goals because poor performance in some dimensions can be offset by strong performance in others, thereby yielding overly optimistic assessments. Therefore, incorporating a measure of evenness alongside mean scores is necessary for a more accurate assessment. Moreover, existing studies typically capture only static BCGs levels at specific time points, offering little insight into their dynamic evolution. This limitation hinders understanding of BCGs' development patterns, which this study aims to address.

Effective implementation of BCGs requires regional collaboration. Environmental issues exhibit strong externalities, making unilateral governance prone to collective-action

problems [33]. As stated in China's National New-type Urbanization Plan (2014–2020), environmental problems should be addressed at the urban agglomeration scale, necessitating an inclusive, coordinated, and joint action to advance the BCGs [34]. In this context, assessing the effectiveness of multilateral collaboration among cities is essential for guiding regional environmental governance. However, quantitatively evaluating such collaboration is challenging. Traditional methods, such as gravity models [35] or spatial econometric models [36], rely on predefined geographic or socioeconomic data to measure pairwise interactions, failing to capture the cumulative effects of multilateral cooperation and thereby limiting their utility [37]. To address this gap, this study applies a synergy-based quantification method to the BCGs, directly measuring the net outcome of collective action. This method identifies the size and direction of "synergy" without relying on pre-set relationship matrices, and decomposes individual cities' contributions [38]. Compared to traditional methods, it shifts the focus from measuring relationships to evaluating the effectiveness of cooperation, providing reliable quantitative evidence for urban agglomeration governance in support of the BCGs.

This study develops an integrated framework to assess the implementation of the BCGs in urban agglomerations. For the evaluation system, we propose an improved top-down design model and developed 21 goals, along with 52 localized indicators, for BCGs assessment. Methodologically, we construct a "goal-city-region" composite evaluation framework tailored to urban agglomerations. At the goal tier, spatial-temporal analysis techniques are applied to explore regional disparities. At the city tier, a two-dimensional diagnostic model is developed by integrating the goals' development magnitude and evenness indices, enabling the identification of each city's BCG performance and development patterns from both static and dynamic perspectives. At the regional tier, a synergy-based quantification method is introduced to measure the collective action of urban agglomerations in advancing BCGs. Accordingly, this study extends BCGs assessment from a single composite score to a multi-level diagnosis across the goal, city, and regional tiers. These three tiers are designed as a linked diagnostic chain: the goal tier identifies task-specific weaknesses, the city tier examines how these weaknesses shape city-level performance and development pathways, and the regional tier evaluates whether intercity synergy can mitigate such disparities. Compared with conventional SDG assessment practices that emphasize macro-level progress monitoring and cross-regional comparability, this study examines how SDG-related environmental themes are translated into tasks within China's domestic policy system. This helps identify goal-level weaknesses, intercity development differences, and regional collaborative governance issues that require local policy responses. Table S2 further shows the added value of the proposed framework relative to conventional SDG assessment practices. This framework is applied to the Yangtze River Delta Urban Agglomeration (YRDUA) from 2015 to 2023, a region characterized by strong economic vitality and significant ecological challenges [39]. In January 2025, YRDUA was designated as a national-level pilot area for Beautiful China [40], making it an ideal case for testing the proposed evaluation framework. To our knowledge, this case represents the first empirical pilot application of the proposed framework for assessing BCGs implementation at the urban agglomeration scale.

This paper is structured as follows: Section 2 describes the study area, methods, and data sources; Section 3 presents the detailed results; Section 4 discusses the findings; and Section 5 provides the conclusion and a discussion of the study's limitations. The research framework is shown in Figure 1.

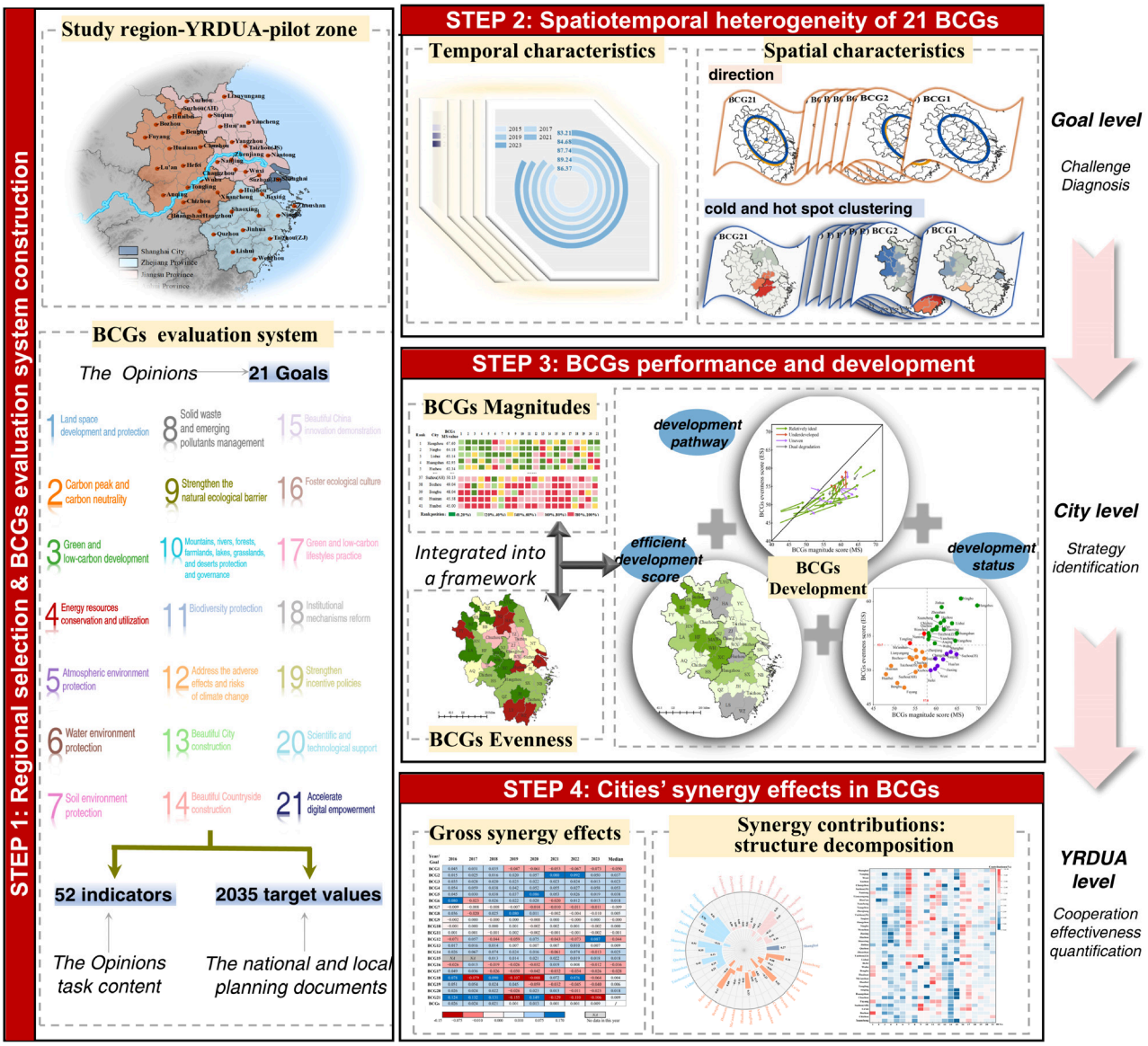


Figure 1. Research framework diagram.

2. Materials and Methods

2.1. Study Area

The Yangtze River Delta Urban Agglomeration (hereafter, YRDUA; 115.75–122.95° E, 27.04–34.49° N) was selected as the study area, covering 41 cities across Jiangsu, Zhejiang, Anhui, and Shanghai. Situated in eastern China along the lower reaches of the Yangtze River, YRDUA covers about 358,000 square kilometers, with a population of over 220 million in 2023 and contributing about a quarter of China's GDP. As the country's most developed urban agglomeration, YRDUA is strategically tasked with leading high-quality development nationally [41]. In January 2025, the region was officially designated as a national-level "Beautiful China Pilot Zone," tasked with deepening and broadening ecological and environmental protection efforts while serving as a demonstrative model. The implementation of this policy relies on the scientific monitoring and evaluation of YRDUA's progress toward the BCGs.

YRDUA has long faced conflicts between economic growth and environmental protection [42]. In this context, the BCGs are expected to provide a comprehensive governance framework to address pressing ecological challenges and promote sustainable regional

development [11]. The region also has notable advantages in intercity coordination and regional cooperation [43]. In 2018, the Yangtze River Delta integration strategy was elevated to a national strategy, followed in 2019 by the establishment of the Yangtze River Delta Ecological and Green Integrated Development Demonstration Zone at the junction of Shanghai, Jiangsu, and Zhejiang. This demonstration zone has promoted joint ecological conservation and cross-regional environmental governance. There is a pressing need to quantify the effects of these cross-regional practices to inform more effective policies and promote regional coordination. The spatial extent, administrative composition, and location of the YRDUA are shown in Figure 2.

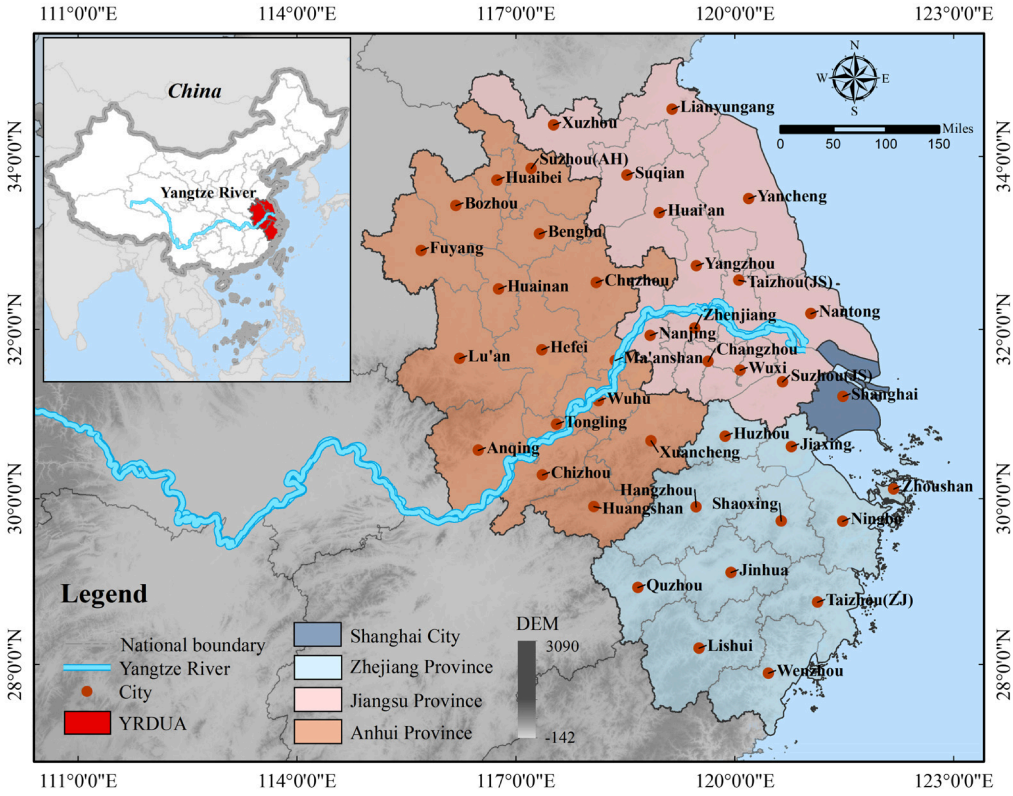


Figure 2. Geographic location and administrative composition of the Yangtze River Delta Urban Agglomeration (YRDUA).

2.2. Improved Top-Down BCGs Evaluation System Design Model

The BCGs evaluation system was developed with reference to official policies and technical guidelines, through the following four steps.

Step 1: Establishing the multi-goal framework guided by top-level planning. The *Opinions* divide the BCGs into several key tasks, covering different domains, which together form the overall development blueprint. Each task was translated into an explicit goal, serving as the basic unit for subsequent evaluation.

Step 2: Selecting and localizing candidate indicators. For each BCG goal defined in Step 1, candidate indicators were selected from the corresponding task descriptions in the *Opinions*. We first identified the governance object, action requirement, and expected outcome described in the policy text. Contents explicitly listed in the *Opinions* and measurable at the city scale were directly converted into candidate indicators. When no direct statistical indicators were available, proxy indicators were selected based on relevant technical guidelines, prior studies, and the availability of city-scale data. The candidate set was then localized to the YRDUA context. Sub-goals or indicators not applicable to the

YRDUA assessment were removed to improve regional applicability. The selection basis for each indicator is provided in Table S7.

Step 3: Expert validation and indicator finalization. A two-round Delphi method was used to validate the candidate indicators and finalize the indicator system. Six experts were selected through purposive sampling from universities, research institutes, and provincial or municipal departments of development and reform or ecology and environment within the YRDUA. All experts had over five years of relevant experience, appropriate professional or managerial qualifications, and prior involvement in related research or government projects. The six-member panel was considered appropriate because the indicator system is policy-oriented, interdisciplinary, and region-specific; therefore, expert selection prioritized professional relevance, judgment quality, and familiarity with the YRDUA governance context over statistical representativeness. The two rounds were conducted in June and August 2025, respectively, and each lasted 15 days. In the first round, experts scored the candidate indicators on a five-point scale for policy consistency, scientific rationality, data availability, and regional applicability, and provided revision suggestions. The indicators were then revised, and a second round was conducted until consensus was reached. Expert reliability was assessed using the response and authority coefficients, and consensus was tested using the mean importance score, coefficient of variation, and Kendall's W. The retained indicators showed significant second-round agreement (Kendall's W = 0.405, $p < 0.001$), indicating convergence and good content validity. Based on the Delphi results, the final indicator system included 52 indicators under 21 BCG goals. Details are provided in Supplementary Section S2.1.

Step 4: Setting the 2035 target value. After indicator finalization, target values for 2035 were set for all indicators to measure progress toward expected outcomes. Target values followed the principle of "policy thresholds first, regional benchmarks as supplements [14,44]." Explicit policy thresholds from national strategies and YRDUA provincial or municipal plans were adopted when available; otherwise, the BP10 benchmark was used. BP10 was calculated from all city-year observations of the 41 YRDUA cities during 2015–2023, using the 90th percentile for positive indicators and the 10th percentile for negative indicators. This benchmark represents leading yet attainable regional performance and reduces the influence of extreme values [18,37]. The target-setting basis for each indicator is provided in Table S7.

Ultimately, this study developed a BCGs evaluation system for YRDUA, comprising 21 goals, 52 indicators, and corresponding target values, as outlined in Table 1.

Table 1. BCGs evaluation system.

Area	Goal	Indicator	Target Value
Territorial Spatial Planning	BCG1 Land space development and protection	Retention rate of continental natural coastline (%)	35
		Proportion of cultivated land in the land requisition area (%)	50
		Proportion of construction land in urban area (%)	11.4
Green Production	BCG2 Carbon peak and carbon neutrality	Proportion of non-fossil energy consumption (%)	31
		Average of the annual change rate of CO^2 emissions in the past decade (%)	1
	BCG3 Green and low-carbon development	CO^2 emissions per unit GDP (t/1000 CNY)	0.6
		CO^2 emissions from transportation sources per unit road area (t/m^2)	BP10 benchmark
		The number of strategic emerging industry firms in the city (units)	BP10 benchmark
	BCG4 Energy resources conservation and utilization	Water use per unit GDP (t/1000 CNY)	35
		Water scarcity index (%)	25
		Reuse rate of industrial water above designated size (%)	97
		energy consumption per unit GDP (tce/10,000 CNY)	0.29
		urban construction land area per unit GDP (km^2/100,000,000 CNY)	0.05

Table 1. *Cont.*

Area	Goal	Indicator	Target Value
Environmental Governance	BCG5 Atmospheric environment protection	PM2.5 concentration (μg/m^3)	28
		Ozone concentration (μg/m^3)	120
		Emissions of major air pollutants per unit of GDP (-)	BP10 benchmark
		Proportion of excellent days (%)	BP10 benchmark
	BCG6 Water environment protection	Surface water quality index (/)	BP10 benchmark
		Water quality compliance rate of drinking water sources (%)	100
		Drainage network density in urban built-up area (km/km^2)	BP10 benchmark
		Centralized treatment rate of urban domestic sewage (%)	100
		Emissions of water pollutants per unit of GDP (t/100,000,000 CNY)	BP10 benchmark
	BCG7 Soil environment protection	Groundwater quality index (/)	BP10 benchmark
		Density of industrial enterprises in key soil pollution industries (enterprises/km^2)	BP10 benchmark
	BCG8 Solid waste and emerging pollutants management	Comprehensive utilization rate of general solid waste in key industrial enterprises (%)	80
		Utilization and disposal rate of hazardous wastes in key industrial enterprises (%)	100
Ecological Conservation	BCG9 Strengthen the natural ecological barrier	The proportion of the nature reserve area (%)	10
	BCG10 Protection and governance of mountains, rivers, forests, farmlands, lakes, grasslands, and deserts	Forest coverage (%)	30
		Soil and water conservation rate (%)	95
	BCG11 Biodiversity protection	Habitat Quality Index (HQI)	60
	BCG12 Address the adverse effects and risks of climate change	Impervious surface ratio in urban built-up area (%)	60
		Climate physical risk index	BP10 benchmark
Human settlement environment	BCG13 Beautiful City construction	Harmless treatment rate of urban domestic waste (%)	100
		Green coverage rate of built-up areas (%)	43
		Urban green space area per capita (m^2)	15
	BCG14 Beautiful Countryside construction	Fertilizer application per unit area of cultivated land (kg/hm^2)	220
		Rural sanitary toilet penetration rate (%)	100
		Proportion of towns treating rural domestic sewage (%)	90
		Harmless treatment rate of rural household waste (%)	100
	BCG15 Beautiful China innovation demonstration	Proportion of counties developing the Beautiful China demonstration projects (%)	100
		The number of Beautiful Villages built in each county (village/county)	1
	BCG16 Foster ecological culture	Public environmental attention (-)	BP10 benchmark
		Penetration rate of ecological protection knowledge and regulations (%)	BP10 benchmark
	BCG17 Practice green and low-carbon lifestyles	Penetration of 5A-level tourist attractions (%)	BP10 benchmark
		Public transport vehicles per 10,000 population (standard units)	20
		Daily domestic water consumption per capita (liters)	150
External Support	BCG18 Institutional mechanisms reform	Environmental regulation intensity (-)	BP10 benchmark
	BCG19 Strengthen incentive policies	Proportion of fiscal investment in environmental protection (%)	BP10 benchmark
		Green finance composite index (-)	BP10 benchmark
	BCG20 Scientific and technological support	Number of green patents (unit)	BP10 benchmark
		Proportion of fiscal investment in education and technology (%)	BP10 benchmark
	BCG21 Accelerate digital empowerment	Digital empowerment (-)	BP10 benchmark

2.3. Data Source

This study focuses on 41 cities within YRDUA. To ensure comparability with existing research, the evaluation period is set from 2015 to 2023. Data are primarily derived from the China Urban Statistical Yearbook, the China Urban Construction Statistical Yearbook, the statistical yearbooks and reports of the three provinces and one municipality, as well as other official publications and public datasets. Missing data are processed using mean imputation, substitution, and exponential trend extrapolation. Detailed data sources and processing methods for each indicator are summarized in Table S7.

2.4. Study Methods

2.4.1. Calculation of the 21 BCGs Scores

In line with the internationally recognized SDGs accounting method [45], this study applied a composite index method to calculate the scores for the 21 BCGs, ensuring comparability across them. The data was first normalized within the threshold range, followed by aggregation of indicators within each BCG. All calculations and data processing were performed using Python version [3.12.4] (Python Software Foundation, Wilmington, DE, USA).The formula is as follows:

$$\begin{cases} Positive\ attribute,\ Min(C_{ijk}^{n}/T_{k}^{n} \times 100,\ 100) \\ Negative\ attribute,\ Max\left\{ Min[(2 - C_{ijk}^{n}/T_{k}^{n}) \times 100,\ 100],\ 0 \right\} \end{cases} \quad (1)$$

$$X_{ij}^{n} = \sum_{k=1}^{K} S_{ijk}^{n}/K \quad (2)$$

where subscripts i and j refer to the specific year and city, respectively; C_{ijk}^{n} and T_{k}^{n} denote the raw value and the 2035 target value for the $k-$ th indicator under the BCG n. S_{ijk}^{n} represents the normalized value of the indicators, which have different positive and negative attributes, rescaled to a range of 0–100 using a modified normalization method. After aggregating all K indicators under each BCG with equal weights, a comparable final score is obtained, denoted as X_{ij}^{n}, $n = 1, 2, \ldots, 21$.

2.4.2. Evaluation of the BCGs Performance at the City Level: Integrating Magnitude and Evenness

1. Calculation BCGs magnitude score (MS) of cities

Given the equal importance of all BCG goals, each was assigned an equal weight when measuring overall achievements in the Beautiful China initiative. The city's BCGs overall magnitude score (MS_{ij}) was calculated using the arithmetic mean method, following standard practice in the field to ensure comparability with previous findings [46]. The formula is expressed as follows:

$$MS_{ij} = \sum_{n=1}^{N} X_{ij}^{n}/N \quad (3)$$

In the formula, X_{ij}^{n} denotes the score of city j in year i for goal n, and N represents the total number of goals.

Considering that the Beautiful China construction has a defined timeline, it is necessary to dynamically monitor the advancement sufficiency of BCGs in each city, to assess whether the targets will be achieved as planned by 2035. To this end, this study further calculated the relative compound annual growth rate ($CAGR_{j}^{O/D}$) of the BCGs based on the MS, which

serves as a quantitative basis for tracking the progress of Beautiful China construction [47]. The calculation formula is as follows:

$$CAGR_j^O = \left(\frac{MS_{j,2023}}{MS_{j,2015}}\right)^{\frac{1}{2023-2015}} - 1 \quad (4)$$

$$CAGR_j^D = \left(\frac{MS_{j,2035}}{MS_{j,2015}}\right)^{\frac{1}{2035-2015}} - 1 \quad (5)$$

$$CAGR_j^{O/D} = CAGR_j^O / CAGR_j^D \times 100\% \quad (6)$$

In this study, the initial, final, and target years for the BCGs are 2015, 2023, and 2035, respectively. $CAGR_j^O$ is the observed compound annual growth rate of the MS score for the city j from 2015 to 2023, reflecting the historical advancement pace of the BCGs; $CAGR_j^D$ is the required compound annual growth rate for the city j to increase from its 2015 MS score to the target score of 100 by 2035, representing the expected pace needed for the BCGs to be achieved on schedule. The ratio $CAGR_j^{O/D}$ to measure the progress sufficiency of city j. A value of 100% indicates that the city is precisely on track to achieve the BCGs by 2035, whereas values below/above 100% indicate insufficient or advanced progress, suggesting that the city may achieve the BCGs later or earlier than 2035 if the current trend continues. This approach could be applied to each of the 21 individual goals, thereby identifying the specific sources of delayed or accelerated progress.

2. Calculation BCGs evenness score (ES) of cities

High-level MS may mask significant developmental disparities across individual BCGs, thereby obscuring the actual development status of cities. In this study, an improved radar chart method was used to calculate the city's BCGs Evenness Score (ES_{ij}). The formula is as follows:

$$A_{ij} = \sum_{n=1}^{N} A_{ij}^n = \sum_{n=1}^{N} f^n \pi (r_{ij}^n)^2, n = 1, 2, \ldots, 21 \quad (7)$$

$$L_{ij} = \sum_{n=1}^{N} L_{ij}^n = 2\left|r_{ij}^{\max} - r_{ij}^{\min}\right| + \sum_{n=1}^{N} f^n 2\pi r_{ij}^n \quad (8)$$

$$ES_{ij} = S_{ij} / \left[\pi (L_{ij}/2\pi)^2\right] \times 100 = 400\pi S_{ij} / {L_{ij}}^2 \quad (9)$$

where i, j, n are defined according to the previous equations. A_{ij} represents the area of the improved radar chart, r_{ij}^n, f^n denote the city's score and weight for goal n (with equal weights set as 1/21). L_{ij} is the perimeter of the improved radar chart, with $r_{ij}^{\max}$ and $r_{ij}^{\min}$ indicating the maximum and minimum scores among the 21 BCGs for the city, respectively. ES_{ij} is derived from the ratio of the total area of the radar chart formed by the 21 BCGs to the area of a circle with the same perimeter, multiplied by 100 to produce a result comparable to the MS. A value of 100 indicates that a city achieved identical scores across all BCGs, reflecting perfect evenness. Additionally, this approach can also be applied to measure the evenness of a specific goal across cities.

3. Integrated MS–ES two-dimensional evaluation framework

Assessing BCGs effective progress at the city level requires simultaneous consideration of all goals' development scale (MS) and balance (ES). Drawing on the methodological approaches of Liu et al. [31], this study constructed a two-dimensional "MS–ES" evaluation framework comprising three aspects: development pathway (DP), effective development score (EDS), and development status (DS). This framework was used to assess the systematic

development patterns adopted, the actual progress achieved, and the developmental stage reached by cities in the YRDUA at the end of the study period during BCG implementation. The framework provides a diagnostic tool that tracks processes through to outcomes, enabling a comprehensive evaluation of the urban BCGs development quality, and offering clear, actionable insights for the precise formulation and dynamic adjustment of policies. Detailed methodology is provided in Supplementary Section S3.

4. Sensitivity analysis

Patrick Gasser noted that different weighting schemes may introduce uncertainty into composite index assessments [48]. Robust results should not be significantly affected by weight changes, whereas sensitive results are. Based on this idea, this study conducted a one-at-a-time (OAT) weight-perturbation sensitivity analysis to test the effect of the equal-weighting scheme on the evaluation results for urban BCGs. It adjusts the weights of key BCGs one at a time and compares perturbed results with the baseline results to evaluate weight sensitivity and thus robustness [49]. For continuous evaluation outputs, including MS and ES, sensitivity was measured using the sensitivity coefficient:

$$SC = \left| \frac{(X_s - X_0)/X_0}{(w_s - w_0)/w_0} \right| \tag{10}$$

where SC is the sensitivity coefficient. X_0 and X_s denote the evaluation results under the baseline equal-weighting scheme and the perturbed-weight scheme, respectively. w_S and w_0 denote the weight of the BCG goal before and after perturbation, respectively. $SC < 1$ indicates low sensitivity to weight perturbation and therefore robust results. Smaller SC values indicate greater robustness [50].

For categorical outputs, the DP and DS types before and after perturbation were compared, and the type-change rate was calculated to test the robustness of city development pathways and state.

2.4.3. Quantification of Synergy Effects in BCGs Implementation Within YRDUA

The term "synergy" originally refers to "working together." In the context of BCGs, it describes how different cities, through cooperation, strengthen one another, resulting in an overall improvement that exceeds the simple sum of their individual efforts. To quantitatively assess the level of synergy in BCGs implementation across the YRDUA, this study adapted the methodological framework proposed by Liu et al. in their examination of G7 cooperation in achieving the SDGs [38]. The core of this approach lies in quantifying intercity cooperation or competition by comparing internal changes in BCGs at the individual (city) level with the external changes at the group (urban agglomeration) level. The internal change in a goal is defined as the difference in scores between two consecutive years. For the city j, this variable is denoted as $D^n_{j,t}$, and is calculated as follows:

$$D^n_{j,t} = \sqrt{(X^n_{j,t+1} - X^n_{j,t})^2} \tag{11}$$

where $X^n_{j,t}$ represents the score of the city j in the year t for BCG n.

The external change D^n_t for BCG n needs to be calculated at the group level:

$$D^n_t = \sqrt{\sum_{j=1}^{J} (X^n_{j,t+1} - X^n_{j,t})^2} \tag{12}$$

S_t^n represents the gross synergy effect of all cities for BCG n, which is defined as the difference between the sum of internal changes and the external change, with a correction for the direction of the goal change. The specific calculation formula is as follows:

$$S_t^n = \frac{1}{100} \times \frac{1}{J} \times \left(\sum_{j=1}^{J} D_{j,t+1}^n - D_t^n \right) \times \mathrm{sgn} D_t^n \tag{13}$$

where $\mathrm{sgn} D_t^n$ represents the direction of collective action for the goal n in the year t, taking a value of either +1 or −1. A value of +1 reflects that progress was driven by cooperation among cities, whereas a value of −1 suggests that development deviated from expectations due to inter-city competition or conflict. The absolute value of S_t^n indicates the intensity of interaction within YRDUA, with a value approaching 0 implying a lack of effective cooperation.

We further measured the contribution of each city j to the overall synergy effect, denoted as $C_{j,t}^n$, which helps understand the functional role of individual cities within YRDUA. The formula is as follows:

$$C_{j,t}^n = \frac{D_{j,t}^n - D_t^n / J}{S_t^n \times J} \times 100\% \tag{14}$$

When $C_{j,t}^n > 0$, it indicates that city j contributes positively to the overall synergy effect; otherwise, it plays a hindering role.

3. Results

3.1. The Spatiotemporal Heterogeneity of 21 BCGs

3.1.1. Temporal Characteristics

The BCGs calculation results are shown in Figure 3. The overall BCG score for YRDUA increased from 55.67 in 2015 to 58.84 in 2023, an increase of approximately 5.7%. Minor fluctuations occurred after 2017 due to the inclusion of BCG15 (Beautiful China Innovation Demonstration), but the overall upward trend remained clear. Among the 21 BCGs, the YRDUA performed above its overall level in more than half of the goals, particularly BCG13 (Building Beautiful Cities), BCG1 (Optimizing Land Spatial Patterns), BCG11 (Biodiversity Conservation), and BCG8 (Solid Waste Management), indicating notable achievements in green urban space creation and living-environment improvement. However, BCG15 (Beautiful China Innovation Demonstration), BCG16 (Promoting Ecological Culture), BCG2 (Carbon Peak and Carbon Neutrality), and BCG3 (Green Low-Carbon Development) had relatively low scores, indicating challenges in building ecological awareness and in production-system decarbonization. Moreover, the 21 BCG scores differed considerably, but these differences narrowed over time. This indicates that the YRDUA shifted from single-goal breakthroughs toward more coordinated implementation of Beautiful China tasks.

Figure 4 shows the dynamics of the 21 BCG scores. During the study period, eight BCGs increased continuously, among which BCG2 (Carbon Peak and Carbon Neutrality) and BCG15 (Beautiful China Innovation Demonstration) had the largest increases, at 369.7% and 327.6%, respectively. These results were mainly due to the strong push of the national "dual carbon" strategy and the intensive implementation of local pilot projects. Continuous increases were also found in BCG3 (Green Low-Carbon Development), BCG5 (Atmospheric Environment Protection), BCG4 (Efficient Use of Energy), BCG6 (Water Environment Protection), BCG8 (Solid Waste Management), BCG13 (Building Beautiful Cities), and BCG15 (Beautiful China Innovation Demonstration). However, 10 goals fluctuated noticeably, especially BCG14 (Developing Beautiful Villages) and BCG21 (Accelerating

Digital Empowerment), suggesting greater sensitivity to external influences. Notably, the scores for BCG7 (Soil Environment Protection), BCG9 (Establishing Nature Reserves), and BCG10 (Ecological Protection) declined slightly, possibly due to urbanization-driven land-use pressure and weak enforcement of conservation policies. Addressing this requires stronger regional coordination and targeted investments in sustainable land management and ecological rehabilitation.

3.1.2. Spatial Characteristics

To reveal the spatial distribution characteristics of BCGs, this study used ArcGIS 10.7 tools to analyze cold- and hotspot clustering, central trajectories, and directionality, and to identify key regions for Beautiful China construction.

Figure 5 shows the spatial clustering of BCGs across the YRDUA. Overall BCGs score exhibited a significant "northwest-southeast" gradient pattern during the study period. All five high-confidence hot spots were located in Zhejiang Province, in the southeastern part of the YRDUA, whereas most cold spots were concentrated in Anhui Province, in the northwestern part of the region. Spatial aggregation varied considerably across BCGs.

BCG1 showed weak spatial correlation, with cold spots mainly clustered in central Anhui. This pattern reflects the "isolated island" phenomenon in territorial spatial optimization, suggesting a potential risk of contagious, destructive development in this region. Production-related goals (BCG2, BCG3, BCG4) exhibited a consistent "low-northwest, high-southeast" spatial structure. BCG2 and BCG4 showed particularly prominent spatial polarization, demonstrating the "Matthew effect" driven by disparities in economic foundations, industrial structures, and innovation capacities. For environmental goals, BCG5 followed a differentiation pattern, whereas cold spots dominated BCG6, BCG7, and BCG8. A notable cluster of soil-governance cold spots appeared in the Shanghai–Jiaxing–Suzhou region.

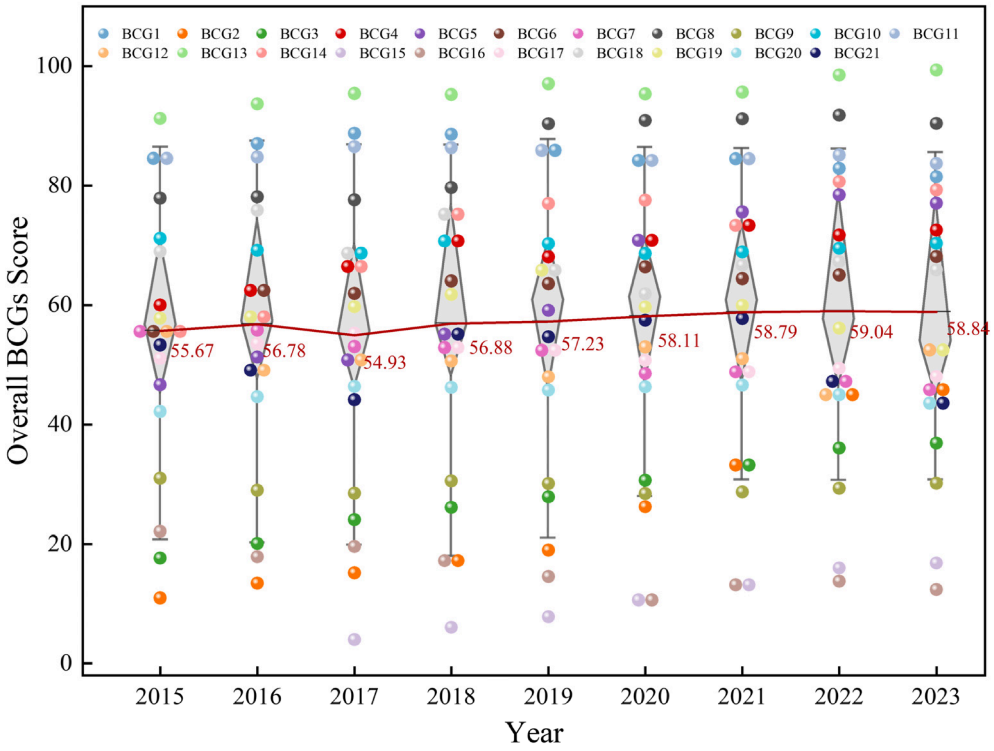


Figure 3. Changes in the overall BCGs score in YRDUA from 2015 to 2023.



Figure 4. The scores of individual BCG in YRDUA from 2015 to 2023.

In contrast, ecological goals generally showed low-value clustering in the northeast and high-value clustering in the southwest. BCG10 and BCG11 exhibited strong polarization and spatial dependence, whereas BCG9 and BCG12 lacked large-scale clustering, suggesting a stronger influence of localized factors. For living and support goals, high-confidence cold spots for BCG13 appeared in Shanghai, highlighting greening challenges in megacities. BCG14–17 formed clear clusters, with hot spots in developed cities such as Shanghai, southern Jiangsu, and northern Zhejiang, and cold spots in northern Anhui, southern Anhui, and southwestern Zhejiang. This suggests a close link between the construction of living environments and

economic development levels. Hot spots for BCG18 and BCG19 were located in central Jiangsu and border areas, while cold spots appeared in southeastern Zhejiang and northern Anhui. BCG20 and BCG21 formed high-value clusters centered on Shanghai and Hangzhou, highlighting the role of technological innovation in driving green development.

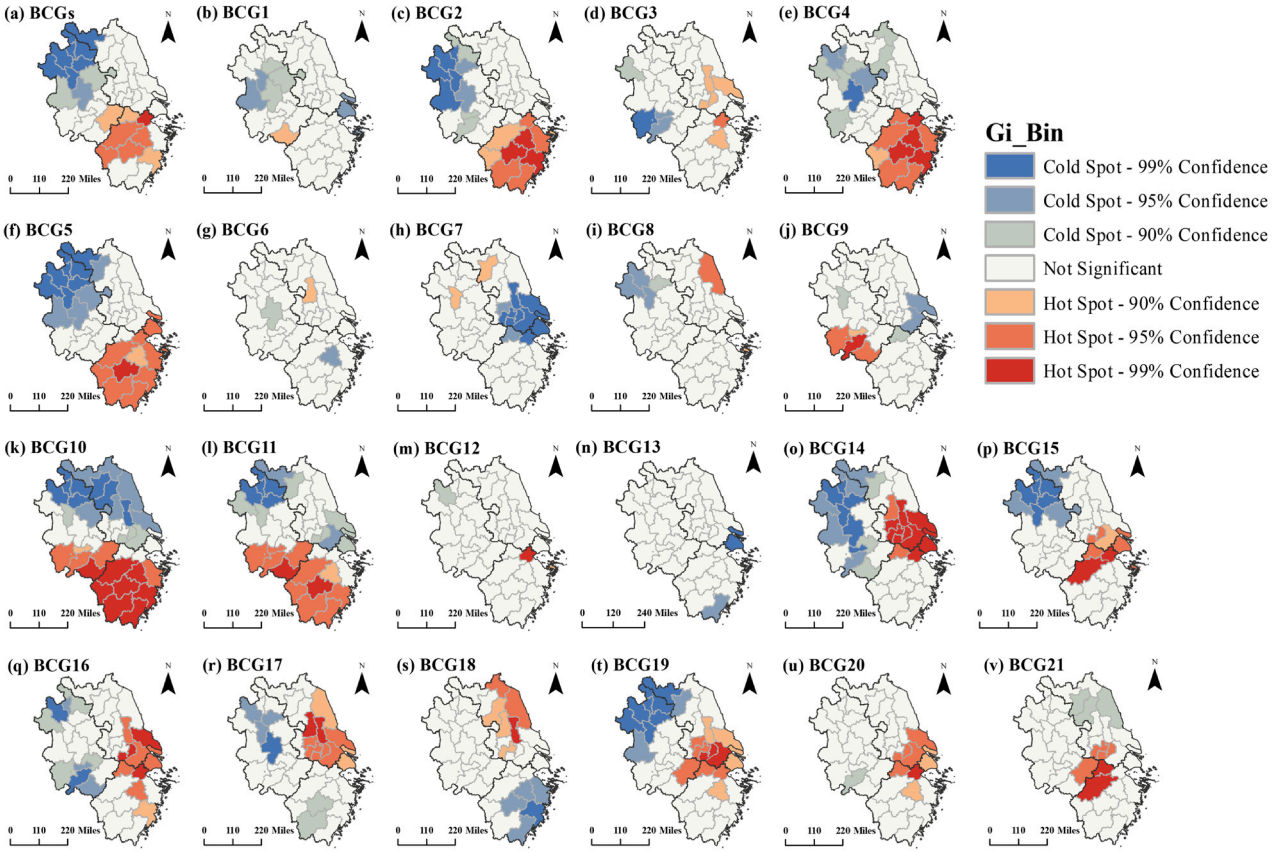


Figure 5. The spatial distribution of hot and cold spots of BCGs in YRDUA.

The center of gravity and standard deviation ellipse (SDE) analyses were used to examine further the spatial patterns and dynamics of the BCGs (Figure 6 and Table 2). Results showed that all BCGs exhibited consistent southeast-northwest orientation. Notably, BCG15 had an ellipticity of around 0.3, indicating a more balanced spatial distribution than other BCGs. The SDE azimuth of the overall BCGs decreased slightly from 147.52° to 147.38°, and the center migrated by only 1.49 km, indicating general spatial stability. The SDE major and minor axes decreased by 0.23 km and 0.39 km, respectively, indicating a slight contraction in spatial coverage.

Spatial evolution varied across BCGs. Land planning goals (BCG1) and ecological goals (BCG9–11) had minimal changes in SDE axes, azimuth, and migration distances, indicating spatial stability and strong institutional rigidity. In contrast, production goals (BCG2, BCG3), living goals (BCG14), and support goals (BCG21) exhibited clear spatial reconfiguration, with a consistent northeastward shift. Their SDE azimuths decreased by 2.25°, 4.56°, 1.42°, and 1.29°, respectively, with corresponding center migrations of 25.18 km, 18.72 km, 13.87 km, and 18.87 km. This shift suggests that the northeastern YRDUA is emerging as a new growth pole for the dual carbon agenda, green production, rural revitalization, and digital transformation. Notably, BCG4 remained spatially stable, although its center shifted 7.77 km northwest, indicating a shift in resource-management focus toward the resource-rich northwest. Similar SDE center movements were observed for environmental goals (BCG5–8), living goals (BCG16 and BCG17), and support goals

(BCG18 and BCG19), indicating ongoing spatial adjustments influenced by policy and market dynamics.

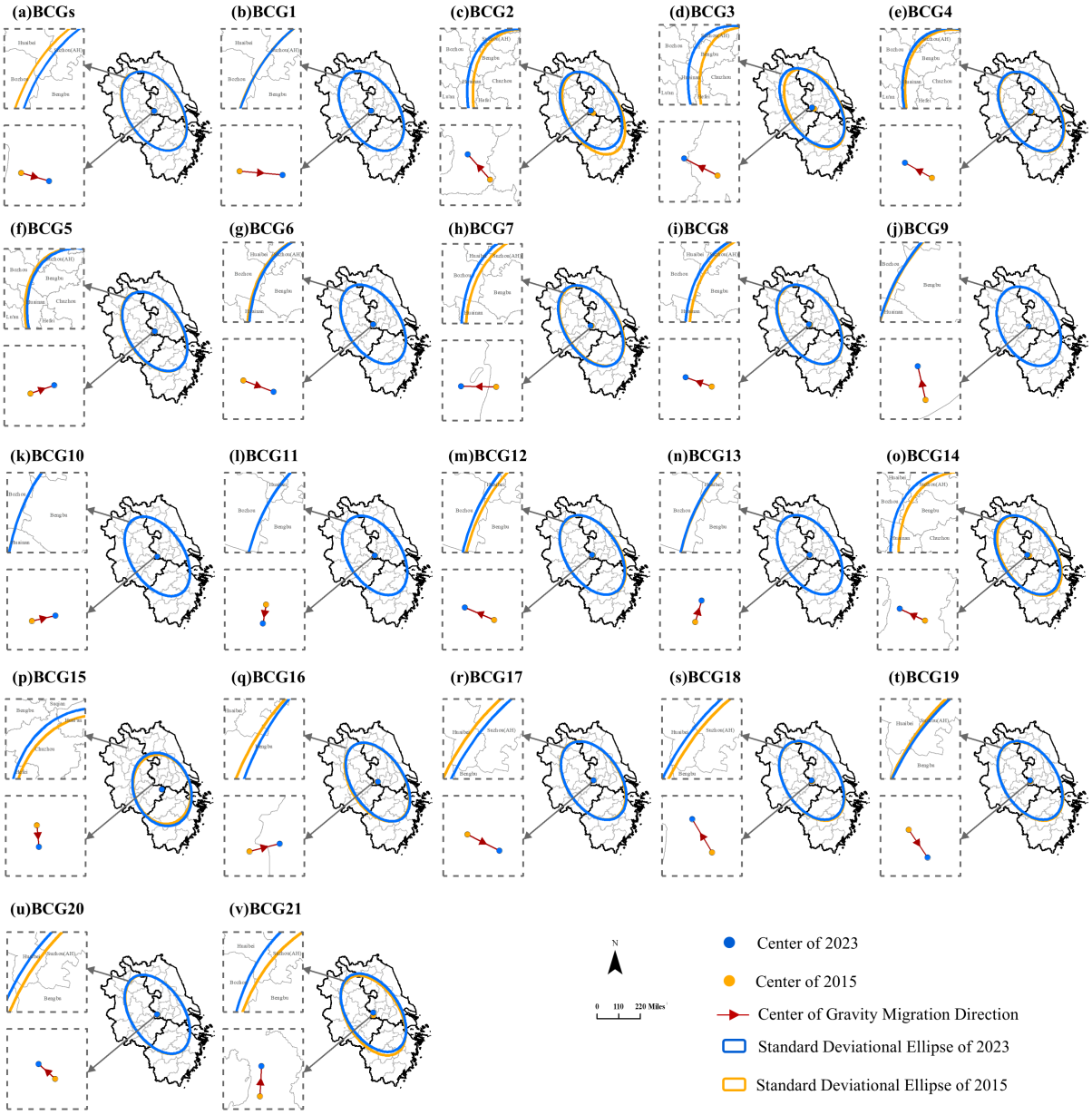


Figure 6. The spatial directional trend of BCGs in YRDUA.

Table 2. The Standard deviation ellipse (SDE) parameters of BCGs in 2015 and 2023.

SDE Parameter	Center Migration Distance (km)	Minor Axes (km)	Major Axes (km)	Azimuth (°)	Ellipticity (/)	Minor Axes (km)	Major Axes (km)	Azimuth (°)	Ellipticity (/)
Year		2015	2015	2015	2015	2023	2023	2023	2023
BCG1	1.08	179.82	293.71	148.02	0.63	180.31	294.66	148.06	0.63
BCG2	25.18	178.18	299.33	151.73	0.68	177.21	281.95	149.49	0.59
BCG3	18.72	168.68	291.54	150.65	0.73	171.64	295.01	146.09	0.72
BCG4	7.77	179.06	296.20	147.61	0.65	177.96	296.17	147.38	0.66
BCG5	3.97	180.76	295.51	147.29	0.64	180.07	293.10	147.54	0.63
BCG6	2.07	180.34	293.45	147.13	0.63	180.16	293.66	147.35	0.63
BCG7	6.63	178.70	295.90	147.72	0.66	178.50	299.68	148.45	0.68
BCG8	4.91	180.57	293.16	148.04	0.62	180.10	293.71	147.37	0.63
BCG9	0.54	190.06	283.97	151.37	0.49	190.24	284.34	151.33	0.50
BCG10	0.09	179.73	294.60	147.42	0.64	179.68	294.79	147.42	0.64

Table 2. *Cont.*

SDE Parameter	Center Migration Distance (km)	Minor Axes (km)	Major Axes (km)	Azimuth (°)	Ellipticity (/)	Minor Axes (km)	Major Axes (km)	Azimuth (°)	Ellipticity (/)
Year		**2015**	**2015**	**2015**	**2015**	**2023**	**2023**	**2023**	**2023**
BCG11	0.29	179.68	293.42	147.52	0.63	179.68	293.47	147.52	0.63
BCG12	0.02	180.94	294.01	146.80	0.63	180.58	294.73	147.31	0.61
BCG13	0.39	179.12	293.13	147.22	0.64	179.34	293.72	147.30	0.64
BCG14	13.88	179.05	294.64	148.35	0.65	179.58	293.18	146.92	0.63
BCG15	0.82	188.15	237.28	161.08	0.26	191.01	252.10	159.34	0.32
BCG16	5.86	177.45	291.60	147.22	0.64	173.73	293.58	147.07	0.69
BCG17	4.52	179.95	290.70	147.05	0.62	181.19	291.16	146.91	0.61
BCG18	4.85	180.95	292.03	147.65	0.61	180.82	290.13	147.54	0.61
BCG19	3.39	179.39	290.87	148.28	0.62	179.11	292.29	147.44	0.63
BCG20	0.22	178.08	292.82	147.30	0.64	177.32	293.85	146.59	0.66
BCG21	18.87	176.41	296.46	147.42	0.68	176.81	292.63	146.13	0.66
overall BCGs	1.49	179.92	293.30	147.53	0.63	179.53	293.07	147.39	0.63

3.1.3. Regional Evenness Characteristics

Figure 7 presents the evenness performance of BCGs across cities. From 2015 to 2023, the ES value of overall BCGs increased from 88.73 to 89.70, reflecting a gradual convergence in regional disparities and more equitable development in Beautiful China construction. At the individual goal level, BCG13 had the highest ES, averaging 93.90 annually. This suggests that Beautiful City construction performance has been relatively consistent across cities, likely due to effective infrastructure standardization and public service equalization policies. In contrast, BCG2 had the lowest ES, averaging 69.46 annually, underscoring pronounced regional imbalances in pursuing dual carbon goals. Regarding dynamic changes, nearly half of the BCGs improved in ES. BCG4 and BCG14 had the largest increases, at 11.12% and 9.55%, respectively. This reflects the effectiveness of resource allocation policies and the rural revitalization strategy in promoting regional equity. Conversely, BCG16 and BCG19 had the largest declines in ES, falling by 16.35% and 14.28%, respectively, highlighting the urgency of cross-regional cultural collaboration and policy coordination. Additionally, BCG2, BCG15, and BCG3 showed noticeable ES fluctuations, possibly due to external uncertainties affecting the dual carbon agenda and green transformation, such as policies, technologies, and market factors.

3.2. The Overall BCGs Performance and Development

3.2.1. The MS of BCGs Across Cities

Figure 8 displays the BCGs development magnitude of individual cities within YRDUA from 2015 to 2023. The MS values across the region ranged from 45.00 to 67.60. The top five cities were Hangzhou (67.60), Ningbo (64.18), Lishui (63.14), Huangshan (62.95), and Huzhou (62.24). The lowest scores were in Huaibei (45.00), Huainan (45.58), Bengbu (48.04), Bozhou (49.04), and Suzhou (50.96).

High-MS cities (top 20%) consistently scored above the regional average in BCG1, BCG3, BCG4, BCG5, BCG15, and BCG19, indicating strengths in territorial spatial optimization, green low-carbon development, resource efficiency, air quality, innovation demonstration, and green incentive policies. However, these leading cities had notable deficiencies in BCG6, BCG7, BCG13, BCG17, and BCG18, including gaps in environmental protection for water and soil, beautiful city construction, green lifestyle promotion, and institutional reform. In contrast, low-MS cities (bottom 20%) lagged in several foundational and long-term goals, including BCG1, BCG2, BCG4, BCG10, BCG11, BCG14, BCG16, and BCG20. Despite these challenges, some demonstrated comparative strengths in BCG6, BCG7, BCG9, and BCG18. This suggests that targeted efforts in water-soil gover-

nance, ecological conservation, and institutional reforms could help improve their overall BCGs performance.

The $CAGR^{O/D}$ indicator was employed to assess BCGs progress sufficiency in cities toward the 2035 targets (Figure 9). During the study period, Suzhou (AH) had the highest $CAGR^{O/D}$ at 78.10%, indicating that its BCGs' advancement closely aligned with the trajectory needed for the 2035 target, although a slight gap remained. Nine cities, mainly in Anhui, exhibited $CAGR^{O/D}$ between 40% and 60%, indicating moderate pressure for progress. Twenty-seven out of 41 cities scored below 40%, showing slow progress and a need for intensified efforts to meet the 2035 targets. Notably, Wenzhou, Lishui, Nantong, and Zhoushan displayed negative $CAGR^{O/D}$ values, indicating that their MS values in 2023 regressed relative to 2015. Except for Lishui, the other three ranked in the middle to lower tiers in BCGs magnitude. The coexistence of low achievement and negative progress underscores the particular challenges these cities face in BCGs implementation. Further analysis revealed a structural imbalance: while a substantial share of BCGs exceeded 100% $CAGR^{O/D}$, many others were below 0%. This imbalance was most evident in cities with delayed or regressive progress, such as Wenzhou, Lishui, Nantong, and Zhoushan, highlighting the need for regional policymakers to reallocate resources across goals and reduce development gaps.

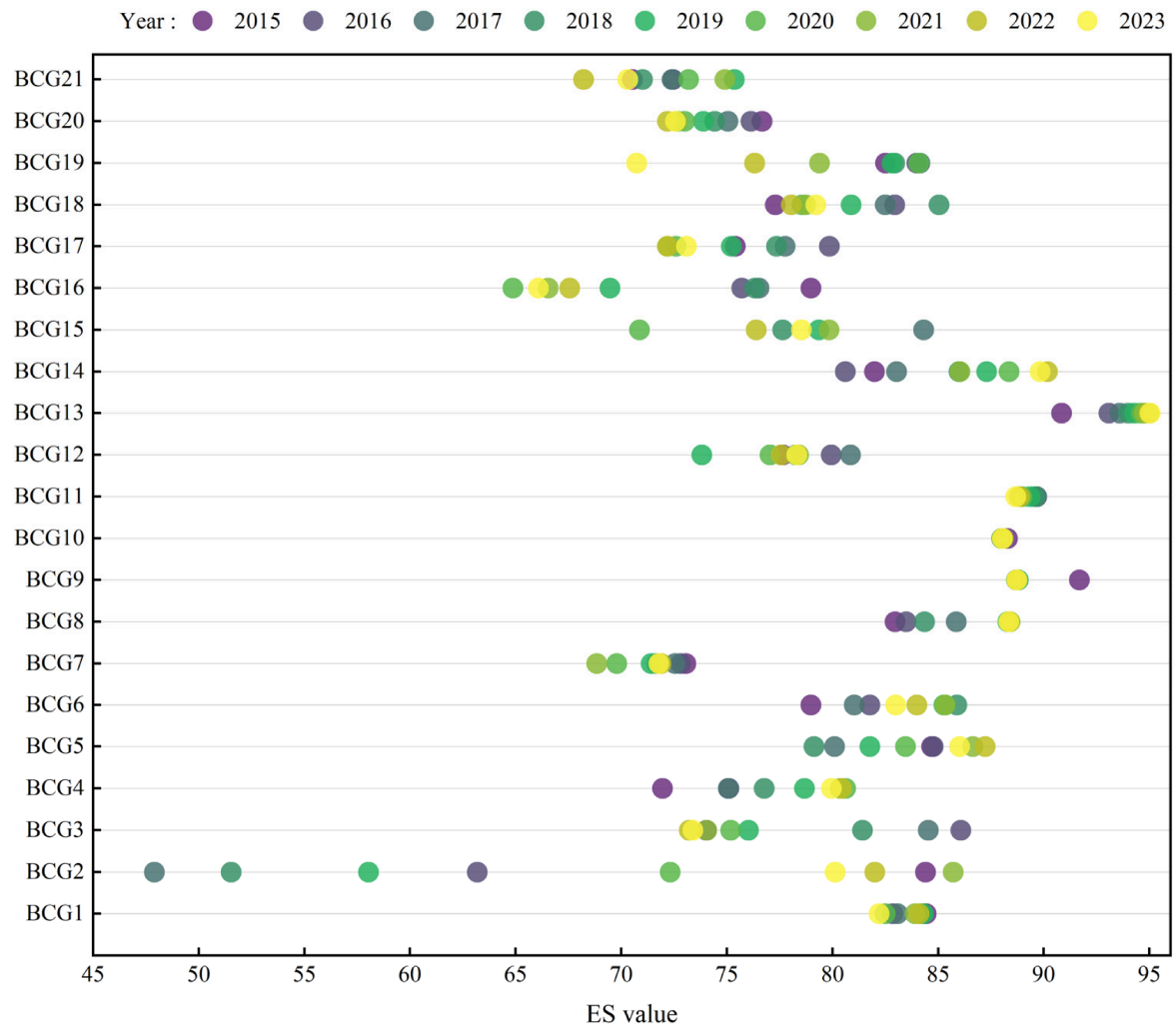


Figure 7. The evenness score (ES) of 21 BCGs between 2015 and 2023.

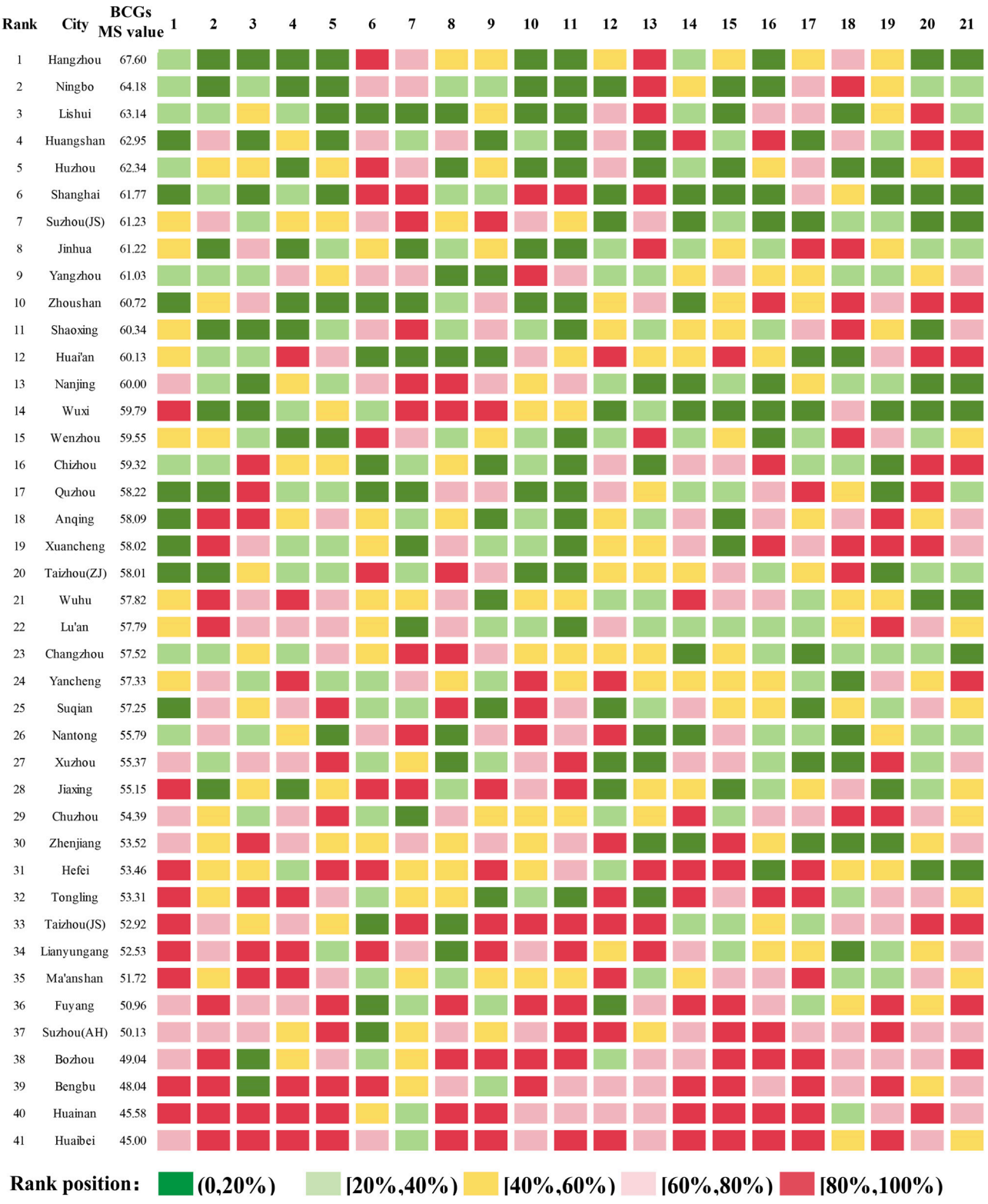


Figure 8. The BCGs' magnitude score (MS) and its structure for YRDUA's 41 cities.

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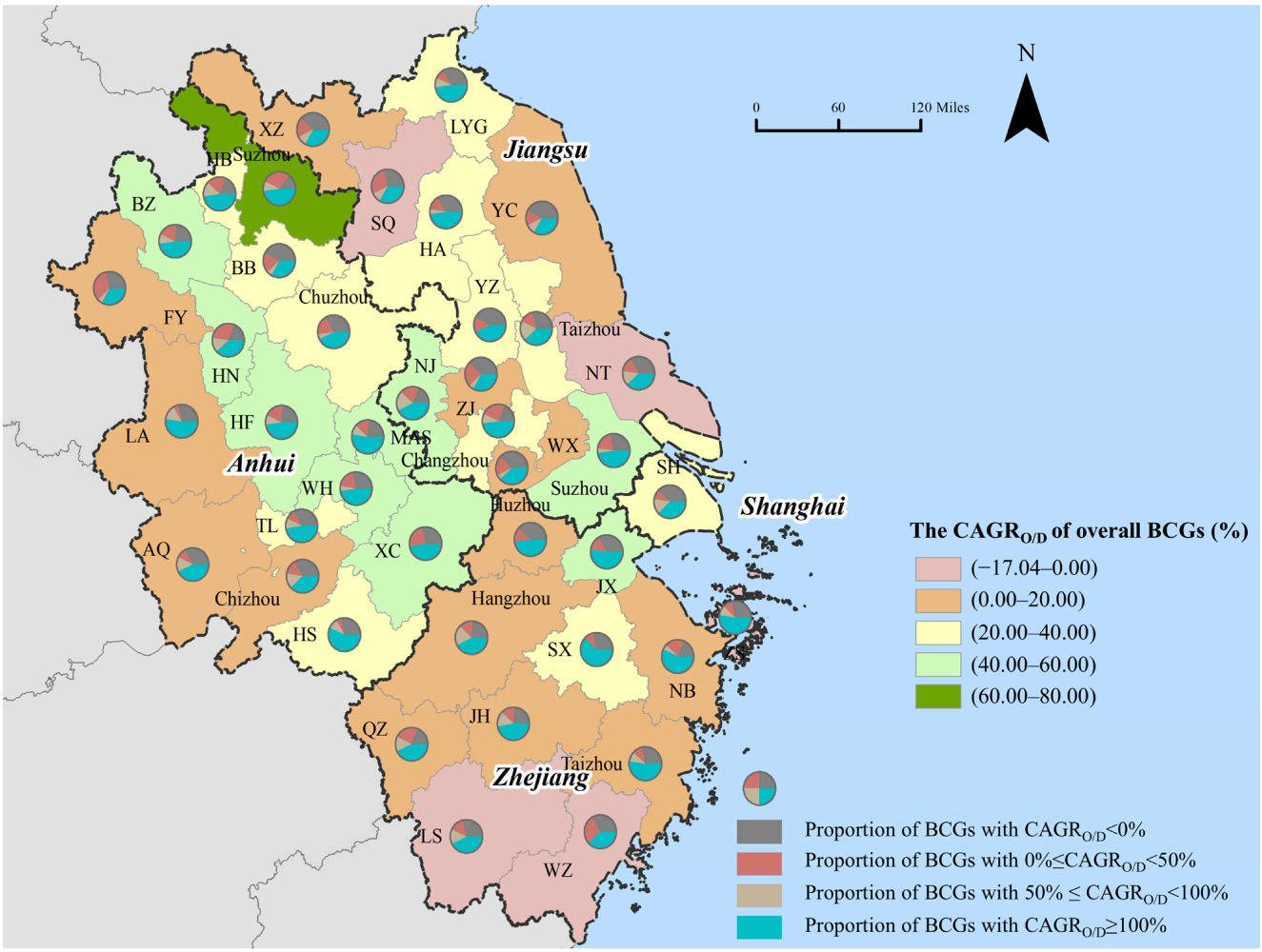


Figure 9. The BCGs' advancement sufficiency and its structure in YRDUA.

3.2.2. The ES of BCGs Across Cities

Balanced development among goals is crucial for the overall implementation of the Beautiful China initiative. Figure 10 shows the ES values and their changes across the 41 cities. Cities in Zhejiang, including Ningbo, Zhoushan, Huzhou, and Hangzhou, maintained high balance levels, with average annual ES values above 57.5, indicating effective policy coordination and resource allocation across multiple BCGs. Conversely, Bengbu and Fuyang in Anhui had relatively low average ES values of 48.01 and 48.74, respectively. This indicates a need for stronger coordination to reduce disparities in goal implementation. Overall, the YRDUA's ES values remained moderate to low, with a "higher in the south, lower in the north" spatial distribution.

Over time, YRDUA's ES values have improved. In 2015, most cities were in the medium ES range, with four cities below 48. By 2023, 41.46% of cities had reached the upper-medium or high ES tiers, and all cities except Fuyang exceeded 48, indicating improved inter-goal coordination. ES values increased in 28 cities, with the largest rise in Lu'an at 10.7%. However, ES values declined in 13 cities, with the largest decrease in Huai'an at 5.81%. For cities with declining ES values, policy attention should focus on inter-goal disparities, key shortcomings, and targeted measures to restore balance.

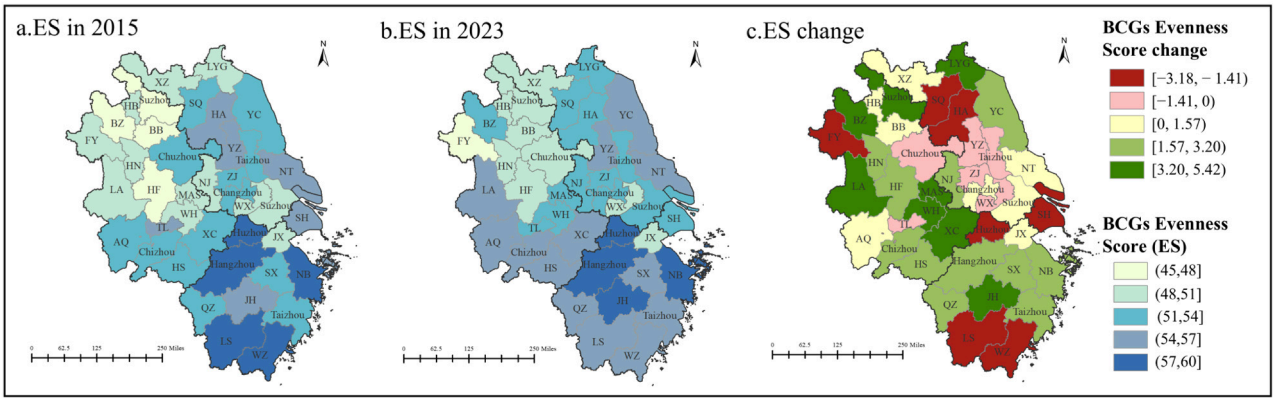


Figure 10. The BCGs' evenness score (ES) and its change in YRDUA. City abbreviations are defined as shown in the previous figure caption.

3.2.3. The Development of BCGs Across Cities: Integrating MS and ES

This study developed a two-dimensional framework integrating MS and ES to evaluate BCGs development across YRDUA cities from 2015 to 2023. The framework incorporated three metrics: development pathway (DP), effective development score (EDS), and development status (DS). As shown in Figure 11a, four distinct DPs were identified. Among the 41 cities, 24 followed a relatively ideal trajectory, improving in both MS and ES. A total of 13 cities advanced in only one dimension. A total of 9 followed an "uneven" pathway, where MS increased but ES declined, indicating higher overall achievement at the cost of coordination; 4 followed an "undeveloped" pathway, where ES increased but MS declined, indicating improved evenness at the expense of overall magnitude. The remaining 4 cities experienced "dual degradation," regressing in both dimensions. These results indicate considerable divergence in development pathways across the YRDUA. Nearly half of the cities still lacked a coordinated and sustainable development pattern.

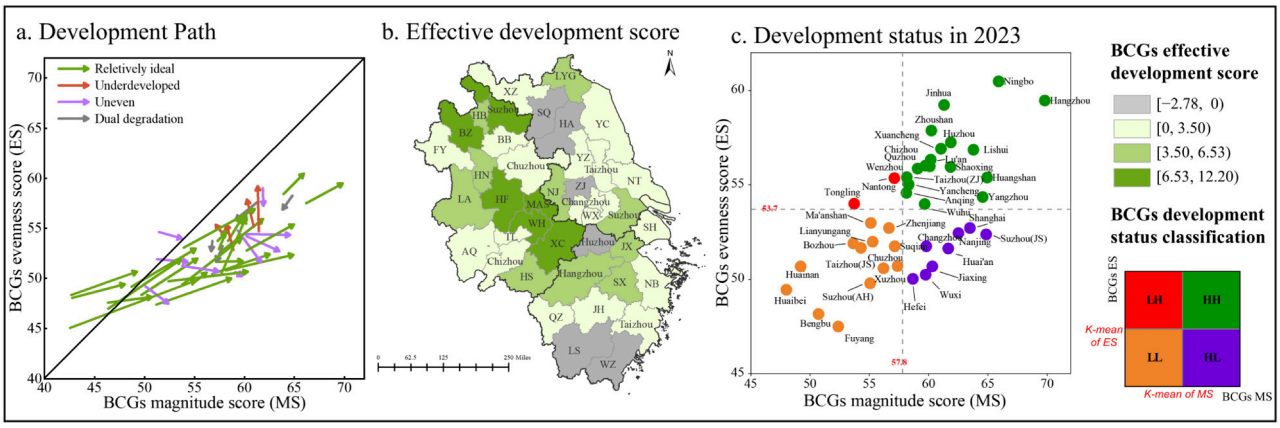


Figure 11. The development pathway (DP), effective development score (EDS), and development status (DS) in BCGs' implications for YRDUA.

EDS measures alignment with the ideal development trajectory and represents actual BCG progress. As shown in Figure 11b, 85.36% of cities achieved net progress when both MS and ES were considered. Suzhou (AH), Bozhou, Xuancheng, Wuhu, Ma'anshan, and Hefei recorded EDS values above 6.53, the highest among all cities. In contrast, six cities—Wenzhou, Lishui, Suqian, Huzhou, Zhenjiang, and Huai'an—had negative EDS values, in which declines in the other dimensions offset gains in one dimension. As a result, these cities showed no net improvement in BCG development during the study period.

Based on the two-dimensional framework, cities were classified into four DS types at the end of the study period (Figure 11c). A total of 18 cities were categorized as HH-type, with high performance in both magnitude and evenness of BCGs. The remaining 23 cities (56.1%) showed less balanced development states. A total of 10 were classified as LH or HL types, with below-average performance in either MS or ES. Another 13 were LL-type, lagging in both dimensions and facing dual challenges in magnitude and coordination. Overall, at this mid-term stage toward the 2035 targets, the YRDUA still faces insufficient and uncoordinated BCG development. Given the significant disparities across cities, tailored strategies are needed to support future improvements.

3.2.4. Weight-Sensitivity Analysis

To examine the effect of equal weighting on evaluation results, +5% and +10% OAT weight-perturbation tests were conducted for BCG2, BCG4, BCG5, BCG6, BCG7, and BCG8. The remaining BCG weights were proportionally rescaled to maintain the total at 1. These higher-weight scenarios reflect the key role and policy priority of pollution and carbon reduction tasks in urban Beautiful China construction [11,18], with results shown in Table 3.

Table 3. Weight-sensitivity result.

Perturbed Goal	Weight Perturbation	SC Mean Value of MS	SC Mean Value of ES	Change Rate of DP	Change Rate of DS
BCG2	5%	0.032	0.005	4.88%	0%
	10%	0.032	0.005	4.88%	0%
BCG4	5%	0.014	0.007	0%	0%
	10%	0.014	0.007	0%	0%
BCG5	5%	0.011	0.009	2.44%	0%
	10%	0.011	0.009	4.88%	2.44%
BCG6	5%	0.009	0.007	0%	0%
	10%	0.009	0.007	0%	0%
BCG7	5%	0.013	0.009	0%	0%
	10%	0.013	0.009	0%	0%
BCG8	5%	0.026	0.014	0%	0%
	10%	0.026	0.014	0%	0%

Overall, the mean sensitivity coefficients of MS and ES remained well below 1 under all perturbation scenarios, indicating that development magnitude and evenness were insensitive to changes in sub-goal weights. The DP and DS classifications were also stable. The maximum DP change rate was 4.88%, affecting at most two cities, while the maximum DS change rate was 2.44%, affecting at most one city. Most scenarios produced no changes in either DP or DS. These results indicate that increasing the weights of key BCGs did not materially affect city classifications. This confirms the robustness of the equal-weighting scheme and supports the main conclusions for the YRDUA.

3.3. The Synergy Effects in BCGs of YRDUA

3.3.1. Changes in Gross Synergy Effects

Synergy effects were used to assess the effectiveness of intercity collaboration in BCGs implementation within YRDUA. Figure 12 shows changes in the synergy effects of all BCGs during the study period. Overall, cities exhibited positive synergy in Beautiful China construction, but the level declined annually and remained near zero since 2019. This trend indicates weakening cooperative momentum in BCGs implementation and highlights the need for more resilient intercity mechanisms to reverse the decline. At the goal level, most BCGs showed positive synergy (14 out of 21). Green production goals (BCG2–BCG5) demonstrated strong, sustained synergy, suggesting a production cooperation model oriented toward green, low-carbon, and resource-efficient development. In contrast, BCG9, BCG10, and BCG11 had synergy levels close to zero, indicating that these

goals relied mainly on individual city efforts rather than collective action. This pattern may stem from the strong externalities of ecological conservation and the lack of effective compensation and responsibility-sharing mechanisms.

Year/ Goal	2016	2017	2018	2019	2020	2021	2022	2023	Median
BCG1	0.045	0.031	0.035	−0.047	−0.061	−0.053	−0.067	−0.073	−0.050
BCG2	0.015	0.025	0.016	0.020	0.057	0.080	0.092	0.050	0.037
BCG3	0.035	0.028	0.020	0.025	0.022	0.023	0.024	0.013	0.023
BCG4	0.054	0.059	0.038	0.042	0.052	0.055	0.027	0.058	0.053
BCG5	0.045	0.030	0.038	0.037	0.086	0.053	0.026	0.019	0.038
BCG6	0.080	−0.023	0.026	0.022	0.028	−0.020	0.012	0.013	0.018
BCG7	−0.009	−0.008	−0.008	−0.007	−0.014	−0.010	−0.011	−0.011	−0.009
BCG8	0.036	−0.020	0.025	0.080	0.011	−0.002	−0.004	−0.010	0.005
BCG9	−0.002	0.000	−0.000	0.000	−0.000	0.000	−0.000	0.000	−0.000
BCG10	−0.001	0.000	0.000	0.001	−0.002	0.002	0.001	−0.002	0.000
BCG11	0.001	0.001	−0.001	0.002	−0.002	−0.001	−0.001	−0.002	−0.001
BCG12	−0.071	0.057	−0.044	−0.059	0.075	−0.043	−0.073	0.087	−0.044
BCG13	0.017	0.016	0.014	0.007	0.007	0.007	0.010	0.007	0.009
BCG14	0.026	0.067	0.074	0.024	0.016	−0.061	0.074	−0.013	0.025
BCG15	*NA*	*NA*	0.013	0.014	0.021	0.022	0.019	0.018	0.018
BCG16	−0.026	0.013	−0.019	−0.026	−0.032	0.019	0.008	−0.012	−0.016
BCG17	0.049	0.036	−0.026	−0.030	−0.042	−0.032	−0.034	−0.026	−0.028
BCG18	0.078	−0.079	0.090	−0.107	−0.088	0.072	0.076	−0.064	0.004
BCG19	0.051	0.054	0.024	0.045	−0.059	−0.032	−0.045	−0.040	0.006
BCG20	0.026	0.024	0.022	−0.026	0.023	0.013	−0.011	−0.023	0.018
BCG21	0.124	0.132	0.131	−0.155	0.149	−0.129	−0.110	−0.106	0.009
BCGs	0.026	0.024	0.021	0.001	0.013	0.001	0.001	0.009	/

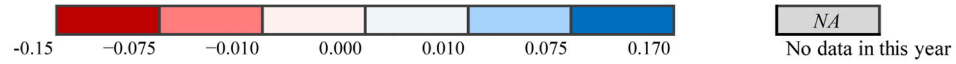


Figure 12. The YRDUA synergy effects for 21 BCGs between 2015 and 2023.

BCG7 showed growing negative synergy, while BCG8 showed weakening positive synergy. These results imply that the current collaborative framework is insufficient for the coordination demands of soil environmental protection and solid waste management. Furthermore, synergy shifted from positive to negative in BCG1 and BCG19, suggesting that initial cooperation in territorial spatial development and green incentive policies may have given way to regional competition. BCG12, BCG16, BCG18, BCG20, and BCG21 showed high interaction levels, but their synergies were unstable, alternating between co-operation and competition. This fluctuation highlights the fragility of existing collaboration mechanisms, which remain susceptible to external shocks and internal strategic behavior. For instance, BCG21 showed strong antagonism after 2021, reflecting intense intercity competition for digital empowerment resources. This competition ultimately hindered regional collective progress. Overall, the synergy mechanisms in BCGs are complex and goal-specific, requiring tailored governance approaches to overcome collaboration barriers and promote sustained regional cooperation.

3.3.2. Synergy Contributions from Individual Cities

This study further calculated each city's contribution to the gross synergy effect and identified its functional role in the cooperation pattern. Following conventional research practice, the median value was used to represent contributions over the study period, reducing the influence of outliers.

Figure 13 shows that city contribution rates ranged from −0.23% to 0.70%. Overall, 73.2% of cities made positive contributions, with the highest rates in Ningbo (0.70%),

Suzhou (0.53%), and Shaoxing (0.51%). Compared to core cities such as Shanghai, Hangzhou, and Nanjing, these three cities faced fewer institutional and interest-related barriers in BCG cooperation. They therefore acted as leaders in regional synergy. By contrast, Fuyang, with a contribution rate of −0.23%, was identified as a significant bottleneck. At the provincial level, nearly all cities in Zhejiang, except Huzhou, made positive contributions. Most cities in Jiangsu made only marginal contributions, while Anhui included both high contributors and major obstacles.

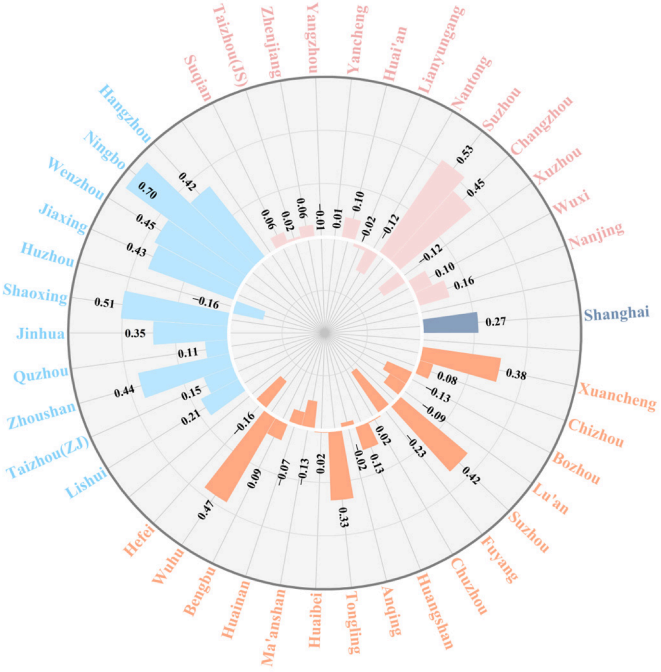


Figure 13. The synergy contribution rate of YRDUA's 41 cities.

City contributions varied across goals due to systematic differences in resource endowments, socioeconomic conditions, and policy implementation capacity (as shown in Figure 14). Positive contributors dominated 13 goals. This pattern was especially strong in BCG4, BCG5, BCG6, and BCG14, where more than 93% of cities made positive contributions. These results indicate strong regional collaboration in resource use and environmental protection within the YRDUA. For BCG14, the overall positive contribution was mainly driven by cities in Anhui, likely reflecting the province's policy emphasis on rural revitalization and eco-agriculture. However, negative contributors dominated eight goals. BCG7 was particularly problematic, as 34 cities hindered its implementation. Cities with BCG7 contribution rates below −1% were concentrated in Zhejiang and Jiangsu, where economic development, land-use intensity, and soil pollution were relatively high. These cities may intensify regional pressure for soil governance through cross-border pollution and other negative spillovers. Therefore, interprovincial coordination is needed to reduce adverse spillover effects and improve collaborative soil governance.

Key actors with decisive influence on specific BCGs were also identified. For example, core cities such as Nanjing, Hangzhou, and Hefei contributed substantially to BCG3, yet acted as clear impediments in BCG7. Even in goals with generally weak synergy, pivotal players could still be identified. Suzhou, Fuyang, and Taizhou were the main negative contributors to BCG9; Tongling served as a central driver of BCG10; and Lianyungang, Suqian, and Huaibei formed major collaborative barriers in BCG11. These findings clarify critical actors in regional BCGs synergy and provide a basis for differentiated policy design.

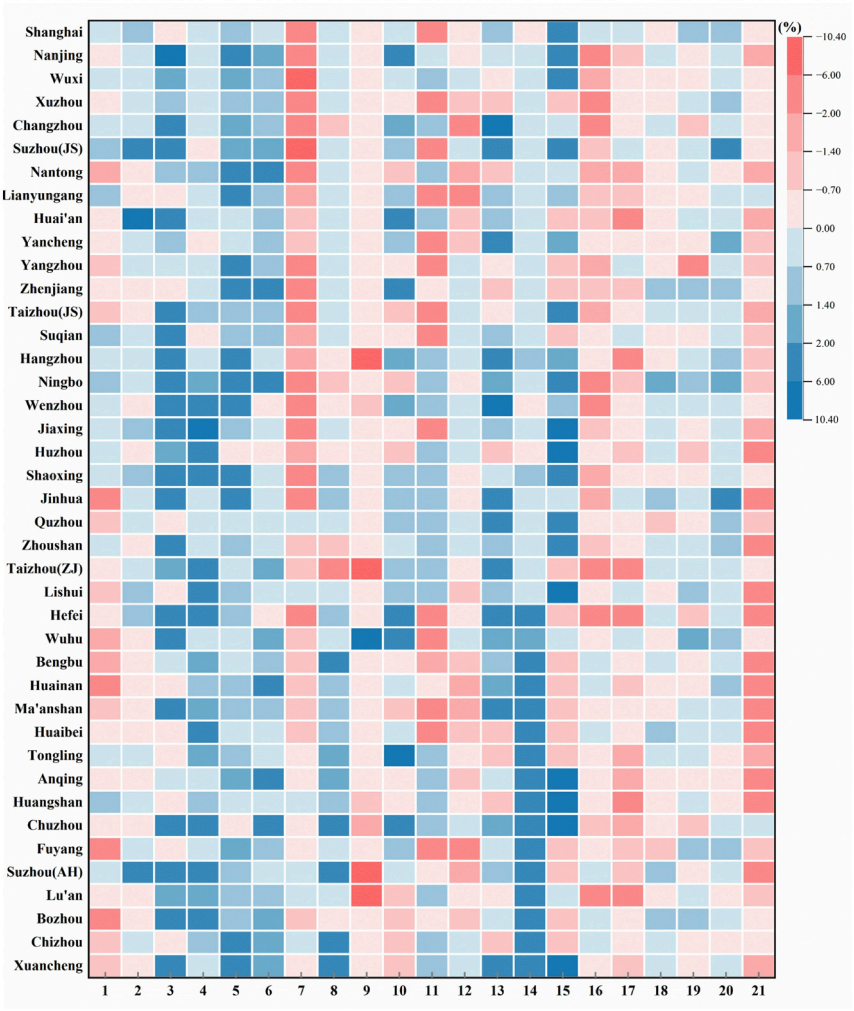


Figure 14. The synergy contribution structure of each BCG. The color scale is centered at zero. Blue indicates positive contributions, meaning that a city strengthens the regional synergy effect of a given BCG and acts as a facilitator of collective progress. Red indicates negative contributions, meaning that a city weakens the regional synergy effect and acts as a barrier or hindrance to that BCG. Near-white cells indicate weak or near-zero contributions, and darker colors represent larger absolute contribution values.

4. Discussion

This study constructs an integrated analytical framework that incorporates development scale, evenness, and synergy along a "goals–cities–region" logical pathway, which could enable a systematic diagnosis of Beautiful China construction within the YRDUA, overcoming the limitation of a single-dimensional focus in previous studies [4,5]. Findings of this study provide valuable insights for developing targeted local strategies and promoting coordinated regional governance.

4.1. Assessing Achievements and Challenges in Beautiful China Implementation at the Goal Level

The BCGs represent a localized implementation of the SDGs in China, offering a concrete blueprint for medium- to long-term ecological and environmental work [51,52]. This study decomposed the BCGs into 21 specific goals based on critical tasks, building on earlier macro and systemic research [5,11]. This enables a more refined identification of structural differences in BCG development, providing operational-level policy support for the construction of Beautiful China.

Findings indicate that from 2015 to 2023, YRDUA made progress in BCGs, with the overall score rising from 55.67 to 58.84. Nevertheless, absolute performance remained relatively low, and the current trajectory is insufficient to achieve all targets by 2035. This aligns with studies indicating that China's progress in sustainable development fell short of expectations by 2030, primarily due to environmental challenges [47,53,54]. Structurally, strengths were observed in urban spatial quality, living environments, and ecological conservation, whereas ongoing challenges persisted in institutional and cultural innovation and in carbon-neutrality–related goals. These results align with Ma et al.'s analysis of the ecological civilization status in the Yangtze River Economic Belt [55], suggesting that investments in visible projects have largely driven YRDUA's current BCGs' achievements, while systemic transformation in cognition, institutions, and technology remains a major barrier. Policymakers should therefore guard against path dependency and shift emphasis from basic infrastructure to synergistic efforts in green awareness, institutional innovation, and industrial restructuring.

Spatial analysis supports tailored, place-based governance strategies for BCGs. The study found that BCGs generally exhibited a "high in the southeast, low in the northwest" spatial pattern, with Zhejiang emerging as a frontrunner in Beautiful China construction and northern Anhui experiencing slower progress. Similar spatial trends have been identified in other YRDUA studies [56–58]. It is recommended to develop functional corridors along the southeast–northwest axis to facilitate cross-regional exchange, resource complementarity, and policy coordination. Moreover, governance priorities vary considerably across BCGs: in promoting green production goals, the "Matthew effect"—where regions with stronger economic and innovative foundations transition faster, while traditional industrial bases lag—should be addressed [59]. Environmental goals reveal cold-spot clusters around the Shanghai–Jiaxing–Suzhou region, indicating high composite pollution pressures in urbanized areas. A northeast shift in the spatial centers of BCG2, BCG3, BCG14, and BCG21 suggests that the northeast YRDUA is becoming a growth node for dual-carbon targets, rural revitalization, and the digital economy, warranting early investment in infrastructure and innovation. In summary, given the diversity of Beautiful China's tasks and development patterns, differentiated resource allocation is essential to improve outcomes [60].

Regional equity must also be considered alongside overall achievement [61]. Results indicate that regional disparities widened in nearly half of the goals, with the most pronounced inequality observed in the dual-carbon goal (BCG2), as confirmed by previous studies [62–64]. These findings highlight significant flaws in current resource allocation and policy interventions, which limit equal opportunities and balanced development. Future efforts should focus on establishing regionally coordinated decarbonization mechanisms grounded in complementary strengths and shared responsibility [65]. Concurrently, policy systems for ecological compensation, technology transfer, and green incentives must be improved to enhance the inclusiveness of Beautiful China construction.

4.2. Guiding Classification Governance for Cities Through Integrated BCGs Development Magnitude and Evenness

Recent studies on the SDGs have cautioned that trade-offs exist among the goals, with excessive investment in some potentially undermining overall achievement [31,47,66]. Scholars have called for continuous monitoring of inter-goal disparities and timely adjustments to resource allocation strategies to ensure the comprehensive realization of sustainable development [67]. Aligning with the SDGs, the BCGs also exhibit complex interlinkages [18]. Therefore, this study examined both the magnitude and evenness of all goals, analyzing BCGs' progress in different cities within a two-dimensional framework,

and explored adaptive strategies to inform policy for the efficient and comprehensive implementation of BCGs.

Findings in the MS dimension reveal that cities with larger BCGs development magnitudes, such as Hangzhou and Ningbo, often exhibit lower development efficiency, indicating diminishing marginal returns. In contrast, lower-performing cities, such as Suzhou (AH) and Bozhou, demonstrated greater efficiency. A similar phenomenon was observed in the BTHUA's progress toward the SDGs [37]. Further analysis revealed that leading MS cities were not "top performers" across all goals, with notable weaknesses in environmental protection, whereas some lower-MS cities displayed comparative advantages in these areas. These findings underscore the need for differentiated governance strategies: leading cities should focus on optimizing resource allocation and technological innovation to overcome efficiency bottlenecks, while lagging cities should concentrate resources to consolidate strengths in specific BCGs. Moreover, establishing a regional coordination mechanism based on comparative advantage would fully leverage intercity complementarity [68].

Regarding ES, all cities exhibited limited evenness across BCGs, indicating that achieving Beautiful China goals comprehensively remains a common challenge for the region. Unlike MS, changes in ES showed no significant correlation with their levels, underscoring the complex interactions among BCGs [18]. Promoting balanced BCGs requires creating virtuous interactions across goals [69]. It is therefore essential to systematically analyze inter-goal relationships in YRDUA, identify key leverage tasks under various developmental and external conditions, and design scientifically grounded implementation pathways to facilitate overall balance.

The ideal pathway for achieving BCGs needs simultaneous improvement in both MS and ES. In practice, however, cities often prioritize one over the other according to local conditions, leading to distinct development pathways [31]. Over half of the cities followed the ideal pathway, advancing together in BCGs 3, 5, 6, 8, 13, and 14. This development path benefits from positive feedback mechanisms: green industrial transformation (BCG3) provides resources for environmental governance (BCG5, 6, 8), and environmental improvements in turn underpin enhanced living environments (BCG13, 14), creating a virtuous cycle of growth and stability. These cities thus achieved higher EDS and were more likely to reach the desirable "HH" status. Such positive interactions have been consistently emphasized in prior research [18,70]. However, some cities still faced trade-offs between growth and stability. A total of 9 cities followed an "uneven" pathway, concentrating resources in environmental goals (BCG2, 5) with high policy priority and great scaling potential, which led to resource competition and a decline in evenness. Another 4 cities adopted an "undeveloped" path, reallocating resources from goals of strength (BCG12, 18, 21) to weaker ones, thereby enhancing coordination at the cost of overall magnitude.

Following different pathways, cities ultimately yielded four statuses: HH, HL, LH, and LL. Strategy adjustments should follow a "classified guidance" approach. Most HH-type cities achieved leading performance through the ideal pathway (e.g., Hangzhou, Ningbo). They should continue to play a demonstrative role, promoting their multi-goal synergistic governance experience. HL-type cities face sustainability risks even with high achievements, especially core cities like Shanghai, Nanjing, and Hefei, which adopted an "uneven" strategy at the cost of stability. These cities invested heavily in the dual-carbon goal (BCG2) but failed to spur progress in others, instead widening internal disparities due to policy and resource conflicts, reflecting a resource wave phenomenon under existing performance evaluation systems [18]. Thus, core cities should be cautious about the adverse effects of current priorities on overall achievement, promptly adjust their development priorities, and reallocate resources from saturated areas to lagging sectors, while promoting the transfer of advanced technologies and management models. For LH-type cities, the core

task is to improve the overall BCGs' performance; yet, their heterogeneous development logics call for targeted strategies. Nantong, which pursued an "undeveloped" pathway, allocated resources broadly without a clear strategic emphasis. It is therefore advisable to identify and cultivate key growth areas that align with local comparative advantages.

In contrast, Tongling adopted an "uneven" strategy, concentrating resources in green production without achieving significant breakthroughs. A recalibration of strategic focus toward areas such as ecological protection that better suited to local conditions is needed to strengthen competitiveness in pivotal domains. Over 60% of LL-type cities have adopted relatively ideal development strategies, but still face challenges in both the magnitude and evenness of BCGs, primarily due to weak regional foundations. Thus, provincial or national-level support and investment mechanisms are needed to provide targeted resources and remove development barriers.

In summary, with the 2035 target deadline approaching, this study rigorously assessed whether cities are in a good BCGs' status and warned that cities in similar development stages might employ substantially different strategies. These insights provide actionable guidance for categorized governance within YRDUA, helping cities navigate tailored pathways toward BCGs fulfillment.

4.3. Quantitative Assessments of YRDUA's Collaboration in the Beautiful China Initiative

Achieving the BCGs cannot be accomplished through the isolated efforts of any single administrative unit. Scholars such as Yin et al. argue that the connectivity of geographical boundaries, the integrity of ecosystems, and the interconnectedness of socioeconomic and environmental impacts make intercity collaboration essential for advancing Beautiful China construction in the YRDUA [71]. The YRDUA has undertaken substantial practices in ecological environmental collaborative governance [72], but the effectiveness of these collaborations has yet to be systematically evaluated. This study contributes by introducing a "synergy effect" methodology to quantitatively assess the level of intercity cooperation in advancing the BCGs across the region.

Results indicate that gross synergy for overall BCG implementation in YRDUA remained limited and declined. This pattern may reflect strategic prioritization of local interests when cities face competing pressures across production, ecological, and livelihood goals. Synergy varied notably across specific BCGs. In goals related to green production (BCG2, 3, 4), inter-city cooperation was stable and deep, with almost all cities contributing positively to the gross synergy effect. Core cities such as Nanjing, Hangzhou, and Hefei played leading roles. Previous studies also identified close intercity linkage in CO_2 emission reduction and green development within YRDUA [73,74]. These findings highlight the significant achievements of the YRD integration strategy, demonstrating that cities are more likely to form a cooperative consensus when economic and environmental benefits align and technological pathways are clear. In contrast, goals with strong externalities and ambiguous accountability (BCG7–BCG12) displayed intense trade-offs or non-cooperation. The absence of clear responsibility division and benefit coordination in these areas encourages cities' free-riding behavior, leading to collective action dilemmas [33]. Therefore, it is essential to establish sound cost-sharing and benefit-allocation mechanisms to incentivize more cities to shift from "passive participation" to "active contribution," thereby guiding inter-city relations toward positive-sum synergy [75]. Additionally, support goals in digital and technological domains (BCG18–BCG21) alternated between cooperation and competition, indicating fragile collaborative mechanisms that are susceptible to policy changes and interest-driven games. Future efforts should focus on building sustainable cooperation paradigms and standardizing institutions and rules to enhance the resilience of regional collaborative networks.

Theoretically, the gross synergy of BCGs arises from the equal contributions of cities. In practice, however, cities' contributions are significantly mediated by differences in their resource endowments, industrial structures, and policy implementation efficiency [38]. Initially, marked differences were observed across provinces: cities in Zhejiang generally provided high and stable synergy contributions, reflecting effective regional co-governance. Most cities in Jiangsu showed limited synergy capabilities, primarily hindered by manufacturing transformation pressures, north–south development gaps, and high industrial homogeneity. Moreover, Anhui exhibited a coexistence of high-contribution and high-barrier cities, revealing uneven resource allocation and complex interest coordination within the province, with significant urban development conflicts. These findings underscore the need for differentiated intra-provincial coordination mechanisms: Zhejiang's demonstration effect should be strengthened, Jiangsu's internal collaboration bottleneck should be addressed, and Anhui should be encouraged to build effective internal support and compensation mechanisms. Additionally, the study found that core cities such as Shanghai, Nanjing, Hangzhou, and Hefei did not play a leading role in regional synergy, contributing less than non-core cities like Ningbo, Suzhou, Shaoxing, and Wuhu. This phenomenon can be attributed to the "siphon effect" of core cities, which rapidly concentrate resources but compress the development space of surrounding areas, thereby undermining their synergistic capacity [37]. Non-core cities, on the other hand, leverage their precise positioning and flexible policy innovations to emerge as key enablers of synergy. Moving forward, efforts should focus on enhancing the radiating capabilities of core cities through knowledge spillovers, technological collaboration, and institutional supply, thereby increasing their regional influence. In contrast, non-core cities should be supported in deepening their specialized professional advantages, together fostering a polycentric, networked model of regional collaboration [76].

5. Conclusions and Limitations

The Beautiful China initiative represents a Chinese interpretation of environmental sustainability and a strategic task for the country's medium- to long-term development. Establishing pilot zones is a critical implementation measure, and while diverse regional practices have emerged, associated academic research remains underdeveloped [77]. To enhance the operational effectiveness of the Beautiful China initiative, this study established a localized evaluation system grounded in policy-defined key tasks, comprising 21 goals and 52 city-scale indicators. On this basis, a goal–city–region multi-tiered assessment framework was constructed by integrating spatiotemporal pattern analysis, MS–ES two-dimensional diagnosis, and synergy quantification, enabling a systematic evaluation of BCG implementation at the urban agglomeration scale. This framework not only tracks overall BCGs progress, but also provides a comprehensive diagnosis of goal-level structural weaknesses, city-level pathway divergence, and regional synergy effects, thereby translating assessment results into decision-making evidence for task-oriented policymaking, classified urban governance, and strengthened regional collaboration.

Using the YRDUA during 2015–2023 as a case, this study obtained the following main findings:

First, overall BCGs' scores in YRDUA have improved, though growth rates remain insufficient to achieve the 2035 targets. Notable achievements were observed in the construction of Beautiful City, territorial spatial optimization, and biodiversity conservation. Spatially, the overall BCGs exhibited a clear "high in the southeast, low in the northwest" gradient, though spatial patterns and evolution varied significantly across goals, underscoring the need for differentiated regional strategies. Second, at the city level, BCGs' development magnitude increased, and evenness remained generally low. Over half of the

cities followed an ideal development pathway, improving both magnitude and evenness, but 9 cities adhered to a growth-oriented "uneven" strategy, and 4 pursued a stability-centered "undeveloped" pathway. By the end of the evaluation period, fewer than half of the cities achieved high levels in both dimensions. Third, the synergy for overall BCGs was limited, yet considerable variation existed across goals. Green production-related goals exhibited strong, stable cooperation, whereas ecological conservation, technology, and institutional goals showed weak, fluctuating synergies. Ningbo, Suzhou, and Shaoxing played leading roles in regional cooperation, with notable differences in urban contribution structure across goals.

Taken together, the three-tier analyses are complementary. The goal level identifies task-specific gaps in progress, dynamics, and spatial patterns; the city level shows how these gaps translate into uneven MS–ES performance and divergent development pathways; and the regional level examines whether cross-city synergy can mitigate such disparities. This synthesis confirms that a single composite index cannot capture BCGs implementation, because overall improvement may coexist with structural goal imbalance, divergent city pathways, and insufficient regional synergy. The proposed multilevel framework, therefore, provides a more robust basis for identifying where implementation gaps occur, which cities require differentiated strategies, and how regional cooperation should be strengthened. Applied to the YRDUA, the framework highlights the need for both differentiated and collaborative governance. First, the YRDUA should further strengthen long-term tasks such as low-carbon transition, institutional mechanisms, technological innovation, and ecological culture, while consolidating gains in living-environment improvement, spatial governance, and pollution control. Second, Beautiful China construction should be advanced by city type based on each city's MS–ES status and development pathway: HH cities should promote experience in multi-goal coordination; HL cities should prevent high development magnitude from masking goal imbalance; LH cities should strengthen breakthroughs in key goals; and LL cities need stronger capacity building and policy support. Third, cross-city collaborative governance mechanisms should be improved by strengthening ecological compensation, technology transfer, joint law enforcement, green industrial cooperation, and public data sharing, thereby enhancing the urban agglomeration's overall capacity to advance the BCGs. Overall, the proposed three-tier analytical framework offers a broader perspective for Beautiful China construction and localized SDG assessment, and provides substantial practical guidance.

Nevertheless, this study has several limitations. First, due to data availability constraints, the current indicator system does not fully cover all tasks under the Beautiful China agenda, such as nuclear safety. It is therefore recommended that statistical authorities invest in BCGs data systems and monitoring networks, and future studies integrate diverse data sources, including remote sensing and big data, to improve assessment accuracy. Second, while this study identified four city development pathways and preliminarily attributed their divergence to interactions among goals and government strategic preferences, these inferences lack robust statistical support. Future research could employ structural equation modeling, system dynamics, or similar methods to elucidate the complex interactions among the 21 BCGs and external influencing factors, such as socioeconomic conditions and sudden disruptive events. This would support the development of more scientific, detailed, and dynamic pathways for cities to fully achieve the BCGs.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/ijgi15070337/s1. The supplementary file comprises Section S1, Supplementary Information for the Introduction; Section S2, Supplementary Information for the Evaluation System Construction, including Section S2.1, Delphi Validation Procedure, and Section S2.2, Supplementary Information for the Indicator System; and Section S3, Supplementary Information for the Research Methods, including Section S3.1, Integrated MS–ES Two-Dimensional Evaluation Framework. Table S1: Correspondence between the 21 BCGs and relevant SDGs; Table S2: Comparison between conventional SDG assessment frameworks and the BCG assessment framework proposed in this study; Table S3: Basic information of the experts; Table S4: Scoring of expert familiarity with the research content; Table S5: Scoring of the rigor of expert judgment basis; Table S6: Expert consensus results; Table S7: BCGs evaluation indicator system; Figure S1: Outline of BCGs development pathway (DP) and effective development score (EDS); Figure S2: Outline of BCGs development status (DS) classification. Additional references supporting the supplementary analyses are cited in Sections S1–S3 [18,31,37,44,67,78–100].

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Abbreviations

The following abbreviations are used in this manuscript:

BCGs	Beautiful China Goals
SDGs	Sustainable Development Goals
MS	BCGs magnitude score
ES	BCGs evenness score
DP	development pathway
EDS	effective development score
DS	development status

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