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Harmony between Humanity and Nature in the Beijing-Tianjin-Hebei Urban Agglomeration during Decadal Development

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ABSTRACT: Building harmony between humanity and nature (HHN) migrates the conflict between social-economic development and eco-environmental conservation, promoting the coordination and balance between economic development and ecological protection, and then achieving the state of harmonious coexistence between humanity and nature. Here, taking advantage of the Beijing-Tianjin-Hebei urban agglomeration as the research region, this study aimed to evaluate the changes in comprehensive level of economic, social, and ecological development, as well as the coupling coordination degree of HHN from 2014 to 2021, and to identify their spatio-temporal evolution patterns. The findings reveal that from 2014 to 2021, the comprehensive development level of HHN in the Beijing-Tianjin-Hebei urban agglomeration exhibits a linearly increasing pattern, with significant differences in time and space. The comprehensive development level of HHN in the northern region of the Beijing-Tianjin-Hebei urban agglomeration has always been higher than that in the southern region. By 2021, all the cities had basically reached a middle development level. And the coordination degree of the comprehensive development of HHN showed a healthy development trend. In 2021, the coordination degree of HHN in the Beijing-Tianjin-Hebei urban agglomeration was at transitional development, with an average annual increase of 3%. In the future, the Beijing-Tianjin-Hebei urban agglomeration should prioritize coordinated development of HHN, enhance eco-environment protection and management, promote industrial transformation and upgrading, explore new development modes and ecological resource transformation strategies, and establish a modern capital region characterized by high-level ecological civilization development.

Keywords: Beijing-Tianjin-Hebei urban agglomeration; Ecological civilization; Harmony between humanity and nature; Coordination; Spatio-temporal evolution

1. Introduction

The concept of the harmony between humanity and nature (HHN) offers a novel approach to sustainable development (United Nations Development Programme, 2016) [1], compared with previously mainly based on economic construction. Since the 1990s, research has been conducted on a combination of ecological, economic, social, resource, energy and environmental topics, including environment and society [2], human environment and economy [3], economic society and environment [4], and so on. Human beings are increasingly recognizing their dependence on the natural environment and ecosystem services, and the importance of ecological environment for sustainable development [5]. Eco-cities such as Berkeley (USA), Curitiba (Brazil) and Freiburg (Germany) were the explorations made by western countries in building HHN, which proved the realizability of sustainable development [6]. The construction of HHN represents a significant undertaking for China, offering an effective means of achieving sustainable development while simultaneously balancing economic growth with ecological protection. The 18th Party Congress established the strategic decision of "vigorously promoting the construction of ecological civilization". In 2017, Xi Jinping emphasized that the primary objectives of ecological civilization construction in the new era are to promote green development, address existing environmental challenges, reinforce ecological protection and enhance the ecological and environmental regulatory system [7]. A mutually reinforcing relationship between economic

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development and HHN construction has been observed [8]. Some scholars even believe that HHN can promote a workable vision of international cooperation to solve ecological and social crises arising from the global climate emergency. And finally achieve active ecological peace based on a clear vision for long-term socio-ecological sustainability [9]. Consequently, the establishment of HHN has significant implications to assist China in enhancing environmental legislation and policies, technological innovation, and cultural and ethical frameworks [10,11].

The evaluation of the comprehensive development level of HHN serves as an effective approach for analyzing the efficacy of HHN development in a city or region. In recent years, cities became intimately associated in terms of eco-environment and social- economy and the concept of HHN has emerged as a foundational principle in the government's formulation of novel and rigorous environmental policies and legislation [12], and exerted significant ramifications on Chinese society, Chinese citizens, and international policy making [13,14]. For a region, the analysis and study of the evolution pattern and regional differences of the comprehensive development level of regional HHN in time and space can facilitate the identification of development shortcomings and promote comprehensive, coordinated and sustainable development. Currently, there are increasing interests in the construction of an evaluation index system from the perspective of sustainable development, including the ecological carrying capacity obtained through the ecological footprint method [15,16] and quantitative analysis to evaluate the degree of impact of human activities on the ecological environment through pressure-state-response (PSR) and drive-state-response (DSR) models [14,17,18]. To assess HHN level comprehensively and systematically, indicator systems were performed from multiple dimensions and had been conducted at the national, provincial, municipal and economic belt levels [19–22]. Li et al. (2015) studied the national and provincial levels of HHN and found that the overall level in China steadily improved from 1990 to 2000 [23]. By using the double benchmark progressive method, Zhang et al. (2019) reported that ecological environment quality was neglected in the HHN development process [24], based on the HHN development of 337 cities in China. Deng studied the uniform and coordinated development relationship between HHN construction and new urbanization in the Yangtze River Economic Belt using models such as comprehensive evaluation and coupled coordination degree [25]. Yang assessed HHN development level of three urban agglomerations, Beijing-Tianjin-Hebei, Yangtze River Delta and Pearl River Delta, and concluded that the development shortcomings of all three urban agglomerations are in the field of green environment [26]. In the new era, China's economic development should change from regional differentiation to regional balance and promote the construction and development of key regions on a large scale [27]. As an important driver of high-quality development and balanced regional development [28], urban agglomerations are representative of studies on the level of integrated development and coordination of HHN in urban agglomerations.

The Beijing-Tianjin-Hebei region is the most significant area of regional integration in northern China [29]. The region has experienced significant challenges in maintaining a balance between rapid economic development and ecological benefits, and the challenges have been further compounded by the presence of "urban agglomeration diseases", such as cross-regional environmental pollution, frequent smog, resource shortages, and land constraints, which have contributed to the region's overloaded state [30]. In the background of HHN construction, President Xi Jinping (2014) pointed out that the Beijing-Tianjin-Hebei collaborative development was necessary to explore an effective path for HHN construction and to promote the coordination of population, economy, resources and environment. The coordinated development of Beijing-Tianjin-Hebei is an effective way to explore the construction of HHN, as well as an important carrier to promote the coordination of population, economy, resources and environment. To date, there are relatively few studies on the evaluation of the comprehensive development level of HHN in the Beijing-Tianjin-Hebei urban agglomeration and the coordination among various dimensions. Based on the existing research on HHN construction, compared with the social, economic and human factors, this study paid more attention to ecological factors. And constructed an HHN comprehensive evaluation index system for the Beijing-Tianjin-Hebei urban agglomeration, analyzed the changes in the comprehensive development level of HHN, the spatio-temporal differences and the change rules of the coordination degree from 2014 to 2021. Meanwhile, this study analyzed the development process, mode and status quo of each city in the Beijing-Tianjin-Hebei urban agglomeration in recent years, as well as the problems encountered, and then provided references for the future construction and development of China's HHN (Figure 1).

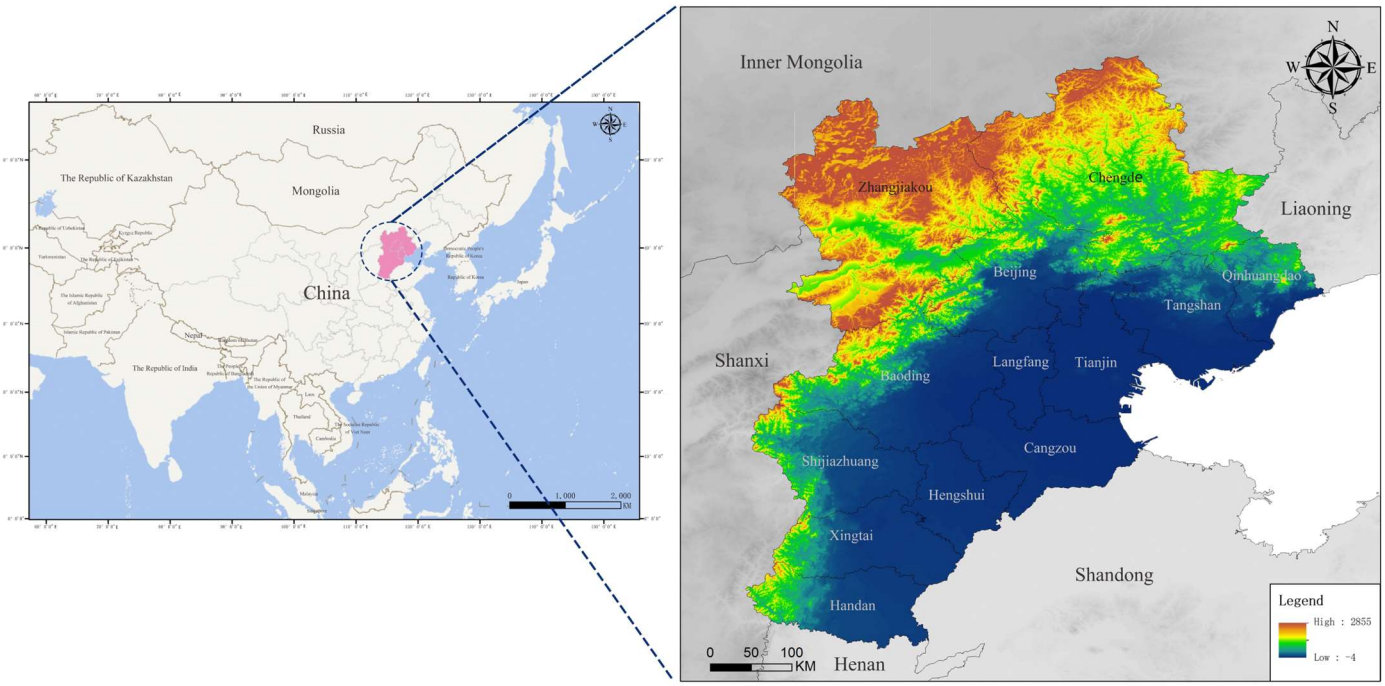

Figure 1. Geographical location and elevation of the Beijing-Tianjin-Hebei urban agglomeration.

2. Materials and Methods

2.1. Study Area

The study used Beijing-Tianjin-Hebei urban agglomeration as study system, which is a core of China's economy and an important region reflecting the country's competitiveness. The Beijing-Tianjin-Hebei region is composed of three central core functional areas (*i.e.*, Beijing, Tianjin, and Shijiazhuang) and ten prefectural cities (*i.e.*, Tangshan, Qinhuangdao, Handan, Xingtai, Baoding, Zhangjiakou, Chengde, Cangzhou, Langfang, and Hengshui). In recent decades, the Beijing-Tianjin-Hebei region has taken the lead in interconnected development, with a total population of 110 million and a GDP of 9.6 trillion Chinese yuan in 2021. With the rapid concentration of population, industry and the continuous increase of urban society and economic scale, the ecological and environmental problems in the Beijing-Tianjin-Hebei region were increasingly intensified [31]. Therefore, this paper studied the level of comprehensive development and coordination of the harmony between humanity and nature (HHN) in the region.

2.2. Data Collection and Standardization

The ecological and social data of the Beijing-Tianjin-Hebei region from 2015 to 2022 were extracted from the China City Statistical Yearbook, Beijing Statistical Yearbook, Tianjin Statistical Yearbook, Hebei Economic Yearbook, the official website of the National Bureau of Statistics, the Statistical Bulletin of National Economic and Society Development and Statistical Yearbook of the corresponding year on the website of each prefecture-level city government, Columbia University Center for Socioeconomic Data and Application, and China Air Quality Online monitoring and analysis platform. A few missing data of some individual indicators were updated by using the Kriging method based on data from the adjacent years.

To standardize the treatment of the metrics:

Positive indicators: $x'_{ij} = (x_{ij} - x_{min})/(x_{max} - x_{min})$.

Negative indicators: $x'_{ij} = (x_{max} - x_{ij})/(x_{max} - x_{min})$.

2.3. Coordination Degree of Nature-Human-Harmony

Similar to the concept of multi-dimensional and multi-indicator comprehensive evaluations in previous research [32–34], meanwhile, this study referenced the latest index system construction, more environmental considerations were taken into account [35]. Based on the common indicators and considering the scientific, accurate, accessible, and quantifiable principles, finally, this study employed an evaluation system that includes the index of the ecological

environment (EE), economic development (ED) and social life (SL) dimensions to determine the degree of development in the Beijing-Tianjin-Hebei region. The evaluation system was composed of 18 indexes (Table 1), referring to the international sustainability evaluation index systems [36] and HHN evaluation [37,38].

Table 1. HHN comprehensive evaluation index system. +, positive indicator; −, negative indicator.

Dimension	Indicator	Unit	Direction
Ecological environment (EE)	Proportion of good air quality (AQI)	%	+
	$PM_{2.5}$ concentration	$\mu g/m^3$	−
	LAI	m^2/m^2	+
	NDVI	-	+
	Npp	g C/m^2	+
	Green space per capita	Ha/pers	+
	Green coverage rate of built-up areas	%	+
	Industrial wastewater emissions	Million tons	−
	Industrial SO_2 emissions	Tons	−
	Industrial smoke(dust) emissions	Tons	−
	Amount of agricultural fertilizer applied per capita	Tons/pers	−
Economic development (ED)	GDP Per Capita	Yuan	+
	Proportion of tertiary industry	%	+
	Local general public budget revenue per capita	Yuan/pers	+
	Science and education expenditure/local general public budget expenditure	%	+
Social life (SL)	Population density	$Person/km^2$	+
	Difference in disposable income between urban and rural residents	-	+
	Total power of agricultural machines per capita	KW/pers	−

The weights of the 18 indexes were determined by using an entropy method, which provides relatively objective and comprehensive results [39]. The degree of equilibrium of the system structure could also be judged according to the amount of entropy value, with high entropy value indicating balanced the system structure. The main steps are as follows:

$$P_{ij} = x'_{ij} / \sum_{i=1}^{n} x'_{ij}$$

$$e_j = -\frac{1}{\ln(n)} \sum_{i=1}^{n} P_{ij} \ln P_{ij}$$

$$w_j = \frac{1 - e_j}{\sum_{j=1}^{m} (1 - e_j)}$$

$$R_i = \sum w_j * x'_{ij}$$

where, x'_{ij} is the value of the indicators after standardization; x_{ij} is the value of each indicator for each city each year; x_{min} is the minimum value of the indicator; x_{max} is the maximum value of the indicator; n is the number of years; m is the number of indicators, P_{ij} is the proportion of the first indicator in the first year; e_j is the information entropy of the first indicator; w_j is the weight of the indicator, R_i is the comprehensive evaluation level of HHN. Referring to the existing studies [40,41], the results of the comprehensive development level of HHN in the Beijing-Tianjin-Hebei urban agglomeration were classified into four levels, *i.e.*, Low level of development 0.0–0.4, middle development level 0.4–0.6, Higher development level 0.6–0.8, and High development level 0.8–1.0 (Table 2).

Table 2. Comprehensive development level of HHN.

Stage	Score Interval
Low level of development	0.0–0.4
Middle development level	0.4–0.6
Higher development level	0.6–0.8
High development level	0.8–1.0

The coupling theory suggests that coordination is the healthy interaction between the dimensions within a system, and the coordinated development meant that the system dimensions and the relationships between them developed in a coherent way [42,43]. Similar to previous studies that employed the degree of interaction and coordination between systems in determining coordination [44], this study used the coupled coordination degree model to measure the level of comprehensive development of HHN in the Beijing-Tianjin-Hebei region (*i.e.*, coordination of the eco-environment, social life, and economic development). The coupled coordination degree model among the three dimensions in this paper was constructed as:

$$C = 3 * \left[\frac{R_1 * R_2 * R_3}{(R_1 + R_2) * (R_1 + R_3) * (R_2 + R_3)}\right]^{1/k}$$

$$T = \alpha R_1 + \beta R_2 + \gamma R_3$$

$$D = \sqrt{CT}$$

where, C is the coupling degree; R_1, R_2, and R_3 are the three dimensional development indices, respectively; K is the adjustment coefficient, make $K \geq 2$; T is the integrated coordination index of the three dimensions α, β, and γ are parameters to be determined. In this study, the values are taken according to the combined weights of the three dimensions; D is the degree of coordinated development. Referring to the existing coupled coordination research results [45,46], HHN coordination development degrees are classified as shown in Table 3.

Table 3. Coordinated development criteria of HHN.

Type	Range of *D*	Breakdown Type
Dysfunctional decline	0.00–0.09	Extreme dysregulation recession
	0.10–0.19	Severe dysregulation decline
	0.20–0.29	Moderate dysregulation decline
	0.30–0.39	Mild dysregulation recession
Transitional development	0.40–0.49	Near dysfunctional development
	0.50–0.59	Barely coherent development
Coordinated development	0.60–0.69	Primary coordinated development
	0.70–0.79	Intermediate coordinated development
	0.80–0.89	Well-coordinated development
	0.90–1.00	High quality coordinated development

3. Results

3.1. Basic Characteristics of the Urban Agglomeration

The research method employed in this paper involves the calculation of the HHN comprehensive development index of the Beijing-Tianjin-Hebei urban agglomeration from 2014 to 2021. The index was calculated in three dimensions: Ecological environment (EE), economic development (ED) and social life (SL). As illustrated in Figure 2, from 2014 to 2021, the EE index had always been at a high level, both above 0.1, while the ED and SL indexes have been at a low level, hovering between 0.06 and 0.09. In 2014, the values of EE, ED and SL index were 0.27, 0.06 and 0.08, respectively. Among which, the EE index of Qinhuangdao, Chengde, Beijing and Zhangjiakou was relatively high in the whole Beijing-Tianjin-Hebei urban agglomeration, while those of Tangshan, Shijiazhuang and other cities were relatively low. The lowest SL was observed in Hengshui. After 2015, the EE index of most cities demonstrated an upward trend, while the ED and SL indexes exhibited minimal change. In 2021, the EE index of all cities had a value greater than 0.35, and the average value increased to 0.43. The EE index of Beijing and Chengde had reached 0.50 and 0.52, respectively, and the overall increase rate of the EE index was 59.26%. Of particular note, the increase rate of Tangshan, Shijiazhuang and Qinhuangdao was surpassing 100%.

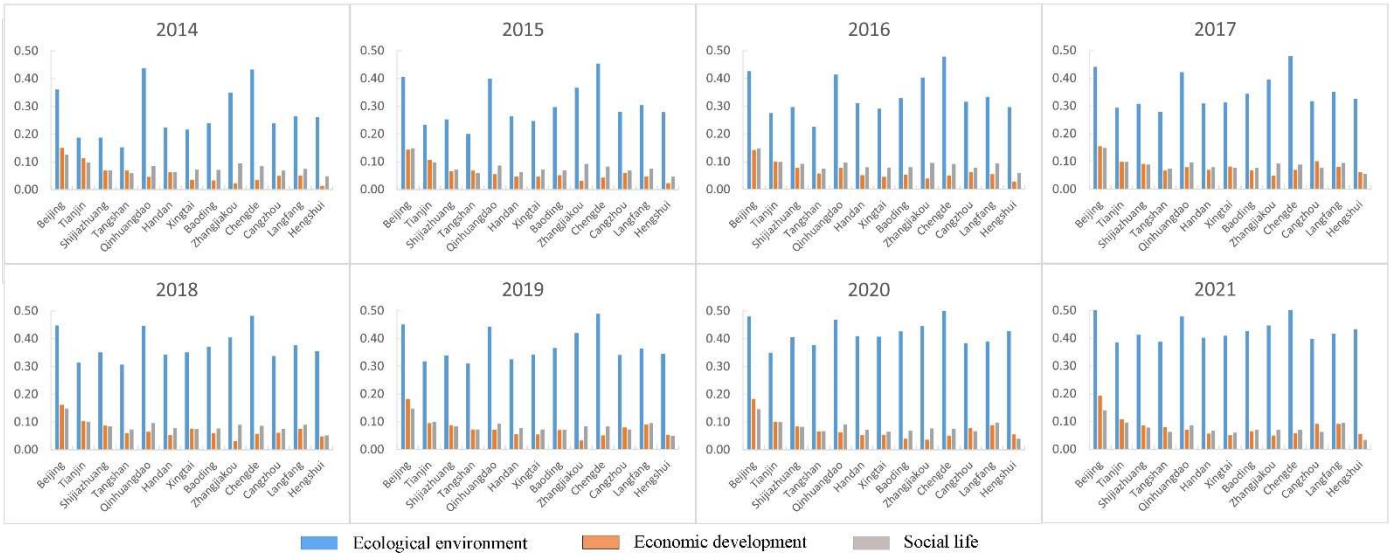

Figure 2. Changes of EE, ED and SL development indexes in the Beijing-Tianjin-Hebei urban agglomeration from 2014 to 2021.

3.2. Comprehensive Evaluation of the Harmony between Humanity and Nature in the Urban Agglomeration

The comprehensive development level of HHN in the Beijing-Tianjin-Hebei urban agglomeration exhibited a linear increase from 2014 to 2021, with an increase rate of 43.61% (Figure 3). The increase rate ranged from 11.32% (Qinhuangdao) to 87.99% (Tangshan) in the region in terms of the comprehensive development level of HHN. Among the cities examined, Tangshan, Shijiangzhuang, Baoding, Hengshui, Xingtai, Langfang and Cangzhou have a relatively higher increment (*i.e.*, ≥50%) compared to other cities, signifying noteworthy achievements in HHN construction over the past years. In other words, the comprehensive development level of HHN in the majority of cities in 2014 was at the middle or low development level, especially in Tangshan (score < 0.30). Beijing was the sole city to exhibit a higher development level. In 2021, the comprehensive development level of HHN of Beijing transitioned to a high development level with a score of 0.84. Cities Chengde, Qinhuangdao and Langfang attained higher development levels and other cities reached the middle development level.

Within the Beijing-Tianjin-Hebei region, the northern area exhibited a higher comprehensive development level of HHN than the southern area. And mainly distributed around Beijing (Figure 4). These findings indicate that despite the considerable increment, a significant discrepancy remains in the Beijing-Tianjin-Hebei region regarding the coordinated development of EE, ED and SL.

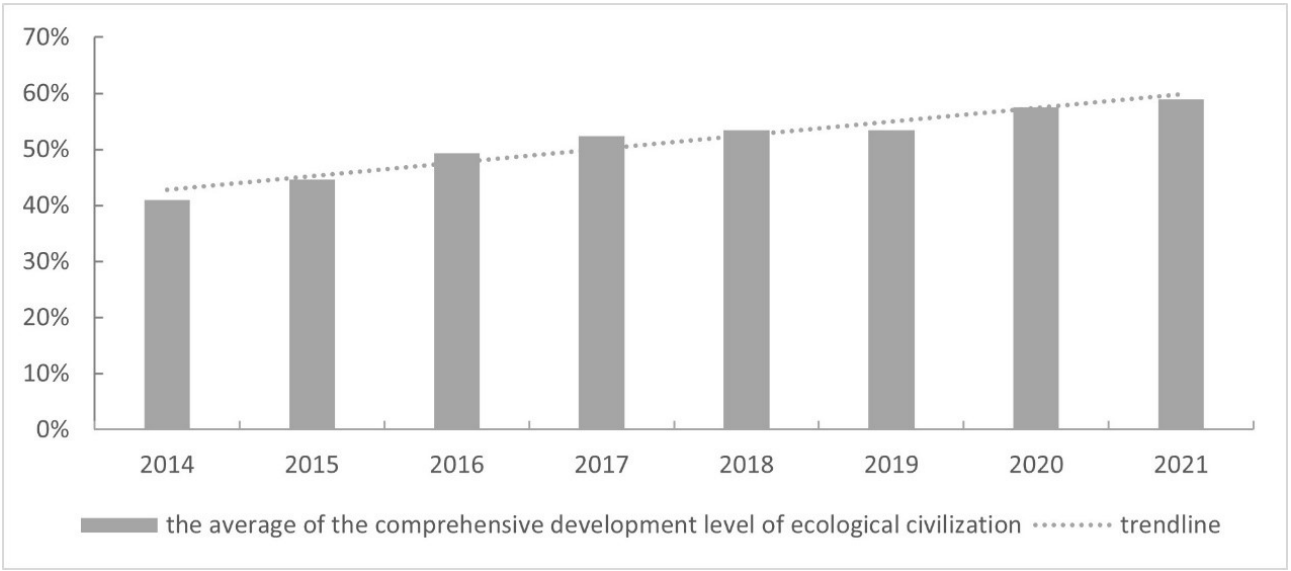

Figure 3. Comprehensive development level of HHN in Beijing-Tianjin-Hebei urban agglomeration from 2014 to 2021.

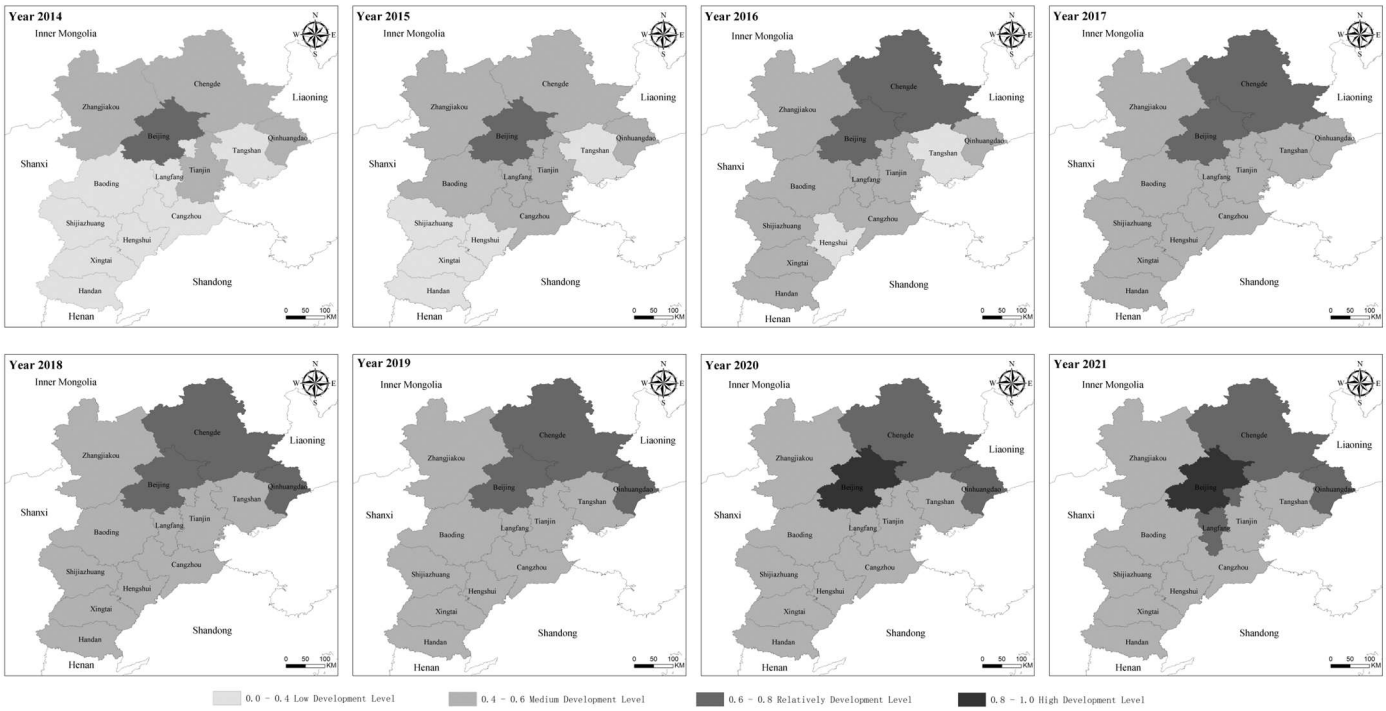

Figure 4. Spatial and temporal evolution of comprehensive development level of HHN within Beijing-Tianjin-Hebei urban agglomeration.

3.3. Coordination Degree of the Harmony between Humanity and Nature in Beijing-Tianjin-Hebei Urban Agglomeration

The results in Figure 5 revealed the coordinated evolution law of the comprehensive development of HHN from 2014 to 2021 based on the model calculation results. As shown in Figure 5, the coordination degree of the 13 cities exhibited quite different variations at the starting point in 2014. Specifically, Beijing was classified as a barely coherent development type, while Tangshan, Xingtai, Baoding, Shijiazhang, Cangzhou, Handan, Langfang and Hengshui were at mild dysregulation recession type. Despite these differences, the 13 cities in the Beijing-Tianjin-Hebei region had significant advancements in their comprehensive development of HHN from 2014 to 2021, indicating an upward trend. In 2021, Beijing achieved a primary coordinated development type, while Qinhuangdao, Chengde, Tianjin, Langfang, and Hengshui only attained barely coherent development types.

Across 13 cities, the average of the coordination degree increased from 0.39 to 0.49. Among them, Hengshui demonstrated a growth of over 70%, while Tangshan and Shijiazhuang exhibited an increase of more than 30%. Qinhuangdao, Chengde, Handan, Beijing and Zhangjiakou had increased rates of approximately 20% (Figure 5). The mean annual increment of the coordination degree of the comprehensive development of HHN in the Beijing-Tianjin-Hebei urban agglomeration was 3%.

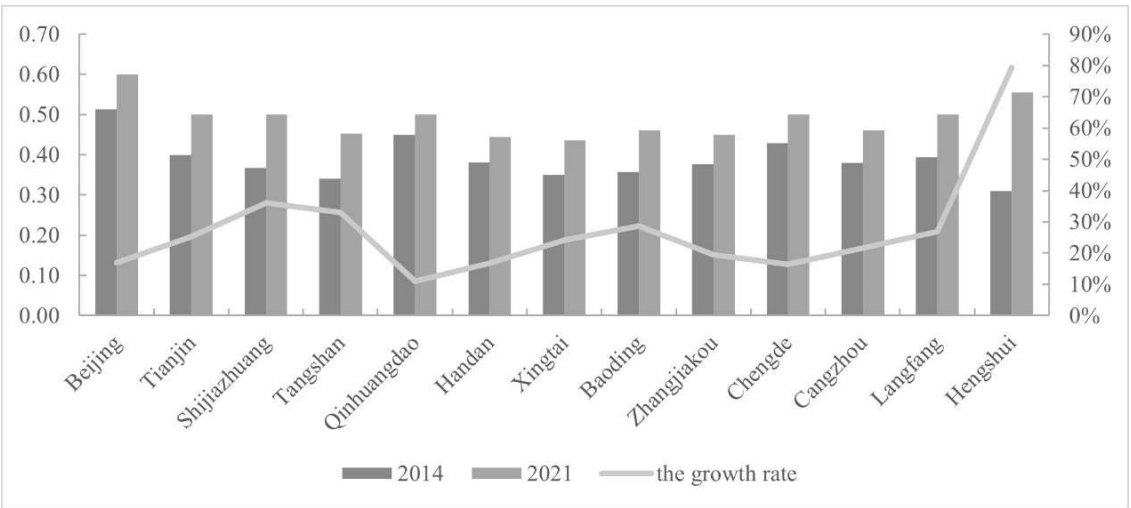

Figure 5. Coordination degree and growth rate of the comprehensive development of HHN in Beijing-Tianjin-Hebei urban agglomeration from 2014 to 2021.

4. Discussion

4.1. Analysis of Comprehensive Evaluation Results of the Harmony between Humanity and Nature

The study demonstrated that the comprehensive development level of the harmony between humanity and nature (HHN) in the Beijing-Tianjin-Hebei urban agglomeration had been continuously improved from 2014 to 2021. The Opinions on Accelerating the Construction of HHN were promulgated by the Chinese government in 2015 and thereby incorporating HHN construction into the national development plan for the five-year period and intensifying guidance and promotion of HHN construction nationwide. The comprehensive development of HHN in the Beijing-Tianjin-Hebei urban agglomeration has undergone significant growth and all cities had basically attained a middle development level by 2021.

From a spatial and temporal perspective, Beijing, Chengde and the northern cities of the Beijing-Tianjin-Hebei urban agglomeration consistently ranked top in the comprehensive development level of HHN. This could be attributed to the robust economic development and ecological environmental foundation in these cities. The northern cities focused on high-quality and comprehensive development and took the lead in responding to policies related to HHN construction. The northern cities also integrated the construction of HHN into the whole process of economic, political, cultural and social construction earlier, took the initiative to carry out ecological and environmental protection actions, and promoted the construction of HHN. In recent years, urban environmental self-purification capacity and the ecological environment capacity (*i.e.*, $PM_{2.5}$, AQI, green space per capita, green coverage rate and NPP) had obviously improved in these regions [47]. The northern areas of the Beijing-Tianjin-Hebei urban agglomeration, such as Zhangjiakou and Chengde, made great efforts to build an ecological barrier in the northwest of Beijing in the early stage, and concomitantly resulted in the curtailment of economic and social development. Due to the great efforts, the northern cities maintained an optional eco-environment and high urban forest coverage, thereby exerting as important water conservation places for the region. The northern cities, in anticipation of the 2022 Winter Olympic Games, primarily focused on consolidating the ecological barrier and advocating green and low-carbon development. Additionally, the northern cities could quickly carry out the construction of HHN by the significant development effect of urban clusters driven by the radiation of Beijing and other central cities. In contrast, the southern cities of the Beijing-Tianjin-Hebei urban agglomeration, including Xingtai, Baoding, and Hengshui, were industrial cities with relatively backward industrial structure and a slow industrial transformation speed. The adverse ramifications engendered by the development of the industrial economy proved challenging to completely resolve in a short period of time, exerting a discernible influence on the advancement of HHN.

With the development, expansion, and radiation of central cities, the internal connections of the Beijing-Tianjin-Hebei urban agglomeration were becoming closer. The concept of HHN gradually permeated into society and economic structures, offering an effective trajectory for the sustainable development of the Beijing-Tianjin-Hebei urban agglomeration.

4.2. Analysis on Coordination Degree of Comprehensive Development of the Harmony between Humanity and Nature

Our results showed that the coordination degree of the comprehensive development of HHN in the Beijing-Tianjin-Hebei urban agglomeration exhibited a sound development trend from 2014 to 2021, indicating a constantly sought coordination of the Beijing-Tianjin-Hebei urban agglomeration. In 2014, the Beijing-Tianjin-Hebei urban agglomeration began to pay more attention to and protect the ecological environment, promoting the coordinated economic, social and ecological development level of the whole region. The construction of HHN contributed to the balance in the three dimensions of ecological protection, economic development and social life, and gradually became a critical factor in promoting sustainable development. The Beijing-Tianjin-Hebei urban agglomeration had entered a phase of transitional development by 2021 in terms of the coordination degree.

The growth rate of each city in the Beijing-Tianjin-Hebei urban agglomeration was significantly different and varied from 2014 to 2021 in terms of the coordination degree of the comprehensive development of HHN. The lower growth rates observed in Beijing and Tianjin could be attributed to their high initial conditions. Beijing, China's capital, has steadfastly pursued green and low-carbon development in the new era. By prioritizing energy, construction, transportation and other fields, Beijing has advanced carbon emission reduction, strengthened ecological conservation, and accelerated the formation of green lifestyles. During the Winter Olympics, Beijing exemplified green development by integrating HHN principles into all aspects of socio-economic progress, advancing high-quality development in the capital and setting a national benchmark for sustainable development. Tianjin, the economic center of the Bohai Sea region, has embraced principles of HHN in its economic and social development. By optimizing the economic development structure, advancing green energy and high-tech industries, promoting the intensive and efficient use of

resources, Tianjin has strengthened ecological environmental governance, and improved the self-purification and carried capacity of the ecological environment, and fostered the coordinated development of ecology economic and society.

Langfang and Hengshui had a large increase primarily due to their low starting point, leaving ample room for coordinated development. Langfang, located between Beijing and Tianjin, serves as the "central core functional area" within the "Two Circles", "Two Wings", "Three Belts" and "Four Districts" spatial framework of Hebei Province, benefiting from distinct regional advantages [48]. Langfang has advanced the development of the "Plain Forest City" [49] and achieved sound and coordinated development of HHN by 2021, which integrated green industrial development, urban ecological construction, and social low-carbon life in recent years. Meanwhile, Hengshui, located in the south of Hebei Province and geographically far from Beijing, Tianjin, and the provincial capital Shijiazhuang, experienced relatively slower initial progress. In 2017, Hengshui City was designed as a key city in the Beijing-Tianjin-Hebei air pollution control corridor, promoting greater attention to the construction of HHN. Effective measures improved ecological environment problems, such as relatively poor air environment quality in winter. Hengshui also accelerated the speed of high-quality development, aligning with HHN efforts with the people's demand for better environmental quality and sustainable economic growth. By 2021, Hengshui achieved barely coherent development type.

It demonstrated that big cities took the lead in recognizing the complementary relationship between HHN construction and social-economy development. By integrating green development early into industrial planning, urban construction, and social life, the cities had great advantages in comprehensive and coordinated development and could play a good radiation driving role.

4.3. Countermeasures

Based on the research results, this study divides the Beijing-Tianjin-Hebei city cluster into three types of cities, and puts forward suggestions to promote comprehensive, coordinated and sustainable development.

(1) Cities with high HHN development and coordination levels, such as Beijing, Tianjin, Qinhuangdao, and Chengde, should continue prioritizing ecological environments, consolidating economic and social achievements, and fostering harmonious coexistence of humanity and nature. By adhering to green development principles, the cities should innovate HHN institutional frameworks, promote green-cycle economy and low-carbon lifestyle, and construct a new pattern of sustainable development. Leveraging the advanced HHN development, these cities should accelerate the coordinated progress of ecology, economy and society [50], maintaining their leadership role.

(2) Cities with stable HHN development and coordination levels, such as Shijiazhuang, Langfang, Zhangjiakou, Baoding, and Cangzhou, should further advance the balanced progress of ecology, economy, and society, promoting green transformation in economic development [51]. Simultaneously, these cities should also enhance environmental governance, pollution reduction, and carbon reduction in ecological protection, strengthen publicity and education in social life, and guide the public to practice green and low-carbon lifestyles. Constantly adjusting the development direction will ensure sustained progress of comprehensive development.

(3) Cities with relatively lagging HHN development and coordination levels, such as Handan, Hengshui, and Xingtai, should consolidate the background of the ecological environment, strengthen ecological protection, and explore a new model of transforming ecological resources into economic resources based on the advantages of regional ecological resources. By embracing the concept of "Lucid Waters and Lush Mountains Are Invaluable Assets", the cities can broaden the path of ecological resources transformation through ecological compensation, ecological product value accounting (GEP), ecological tourism, and carbon sequestration transactions. In the process of economic development, the cities should seek a green and low-carbon social life and a good ecological environment, provide the public with a better life and production space, and increase their happiness.

In the future, the Beijing-Tianjin-Hebei urban agglomeration should transcend administrative boundaries and focus on coordinated development as its core objective. Key priorities include strengthening the protection and management of ecological environment, promoting regional joint prevention and control, expanding the ecological environment capacity and ecological space, promoting the transfer or transformation and upgrading of polluting industries [52], which is an essential condition for achieving green development. And increasing investment in science and technology, consolidating the technical basis of green development, improving resource utilization efficiency, developing clean energy industry, exploring new development modes and ecological resource transformation modes are also crucial for fostering a green circular economy. Additionally, efforts should be made to mobilize the enthusiasm of social capital investment in ecological environment protection, accelerate the process of market integration, and build a diversified financing platform for environmental protection investment. Cultivating and promoting the concept of HHN, promoting

low-carbon lifestyles, and encouraging non-governmental organizations and volunteers to actively participate in environmental initiatives are vital. Developing better cities should establish co-construction and sharing mechanisms for HHN, aiming to create a new modern capital circle characterized by high-level HHN development. Ultimately, efforts should be made to form a new pattern of coordinated development of the Beijing-Tianjin-Hebei urban agglomeration with good ecology, green economy and social happiness, which plays an exemplary role nationwide.

5. Conclusions

During the construction of the harmony between humanity and nature (HHN), the Beijing-Tianjin-Hebei urban agglomeration encountered challenges such as uneven spatial development and uncoordinated comprehensive development. The rapid development of the social economy further exacerbated certain pressures on the ecological environment. The coordinated development of the Beijing-Tianjin-Hebei region is essential to adapt to the new normal of economic development, address mounting resources and environment constraints, mitigate regional, accelerate the transformation of economic development mode, foster new growth drivers, and optimize the regional development pattern. In this context, this study established an evaluation index system of the comprehensive level of HHN and an even-sum coordination model. Through mathematical model calculation, this study got the comprehensive evaluation and coordination degree of HHN for each city, then analyzed the reasons for the results combined with various data and information. Finally, provided references for promoting the social, economic and ecological coordination of the Beijing-Tianjin-Hebei urban agglomeration to improve the quality of the ecological environment and achieve sustainable development.

The study revealed that the comprehensive development level of HHN in the Beijing-Tianjin-Hebei urban agglomeration consistently improved from 2014 to 2021, with notable temporal and spatial variations. By 2021, the comprehensive development level of HHN in all cities had basically reached higher and higher levels. The comprehensive development level of HHN in Beijing, Chengde and northern cities had always ranked top in the Beijing-Tianjin-Hebei urban agglomeration. From 2014 to 2021, the coordination degree of the comprehensive development of HHN in the Beijing-Tianjin-Hebei urban agglomeration consistently improved, gradually shifting from mild dysregulation recession type and near dysfunctional development type to barely coherent development type and primary coordinated development type. This indicates that the Beijing-Tianjin-Hebei urban agglomeration has the potential to seek balanced development points in three dimensions of ecological protection, economic development and social life. The Beijing-Tianjin-Hebei coordinated development policy raised higher requirements for the economic development and ecological environment protection of the Beijing-Tianjin-Hebei urban agglomeration. Hebei, as the future ecological environment support area of the Beijing-Tianjin-Hebei region, should integrate the construction of HHN into its development strategy, ensuring that economic progress aligns with the people's aspirations for a fulfilling and sustainable quality of life.

From a methodological perspective, the coupling coordination degree model performed in this study holds significant potential for advancing research on the interplay among ecology, economy and society in the Beijing-Tianjin-Hebei urban agglomeration. This model served as an effective tool for analyzing the coupling relationship of various dimensions in the comprehensive development system of the harmony between humanity and nature (HHN).

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Author Contributions

Conceptualization, Y.L. and X.S.; Methodology, X.S.; Software, X.S.; Validation, C.Z., L.L. and S.L.; Formal Analysis, X.S.; Investigation, Y.L.; Resources, C.Z. and S.L.; Data Curation, X.S.; Writing—Original Draft Preparation, X.S.; Writing—Review & Editing, L.L., S.L. and X.S.; Visualization, X.S.; Supervision, Y.L.; Project Administration, C.Z.; Funding Acquisition, C.Z.

Ethics Statement

Not applicable.

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Not applicable.

Data Availability Statement

Data supporting these findings is available within the article or upon request.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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