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Research on Current Situation Evaluation and Demand Forecast of Water Resources Utilization in the Industrial Development of Beijing-Tianjin-Hebei Region

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ABSTRACT
Clarifying the changes in the utilization of water resources and future demand in the industrial development of the Beijing-Tianjin-Hebei region plays an important supporting role in realizing the optimal allocation of water resources for the industrial development of the Beijing-Tianjin-Hebei region. To this end, the researchers carry out research on the current situation evaluation and demand forecast of water resources utilization in the industrial development of Beijing-Tianjin-Hebei. First, the researchers use the industrial structure variation coefficient method to evaluate the industrial structure variation coefficient of the industrial development of Beijing-Tianjin-Hebei in different periods; secondly, the researchers evaluate the changes in the status quo of the industrial and agricultural water resources utilization and water resource utilization efficiency in different periods in the Beijing-Tianjin-Hebei region. On this basis, the researchers the water used for the development of the three industries in the Beijing-Tianjin-Hebei region in different periods is estimated. Then, the researchers use the trend extrapolation method to reasonably predict the industrial structure of the Beijing-Tianjin-Hebei region during the planning period, and determine the total industrial development production value of the Beijing-Tianjin-Hebei region during the planning period. At last, the researchers use the trend extrapolation method to predict the water efficiency of industrial development in the Beijing-Tianjin-Hebei region during the planning period, and finally determine the water demand for industrial development in the Beijing-Tianjin-Hebei region during the planning period.

Keywords: *Beijing-Tianjin-Hebei region, Industrial development, Water resources, Evaluation, Demand, Forecast.*

1. INTRODUCTION

Water resources are a strategic resource for the sustainable economic and social development of the Beijing-Tianjin-Hebei region and provide an important guarantee for economic and industrial development, residents' lives, and environmental protection. The "14th Five-Year Plan" of the Beijing-Tianjin-Hebei region clearly proposes to strengthen the strategic reserve of water resources, strengthen water pollution control and water resources protection, and improve the level of intensive and safe use of water resources. It points out the direction for accelerating the transformation and upgrading of the Beijing-Tianjin-Hebei industrial structure, effectively improving the efficiency of water resource utilization, and enhancing the coordination between industrial development and water resource utilization. At present, on the basis of analyzing the evolution of water resources characteristics such as the amount of water resources and the structure of water supply in the Beijing-Tianjin-Hebei region [1], [2], [3], [4], [5], [6], [7], scholars mainly forecast the water demand of the Beijing-Tianjin-Hebei region based on the trend of water consumption in the Beijing-Tianjin-Hebei region [8], [9], [10]. However, there are few documents that combine the structural optimization layout of the industrial development of Beijing-Tianjin-Hebei to scientifically predict

the demand for water resource utilization in the industrial development of the Beijing-Tianjin-Hebei region, and do not fully consider the correlation between the industrial development of the Beijing-Tianjin-Hebei region and the demand for water resource utilization. To this end, the development of water resources utilization status evaluation and demand forecast research for the development of the Beijing-Tianjin-Hebei industry is conducive to providing decision-making support for the optimal allocation of water resources for the development of the Beijing-Tianjin-Hebei industry and improving the coordination between the development of the industry and the utilization of water resources in the Beijing-Tianjin-Hebei region.

2. THE COEFFICIENT OF INDUSTRIAL STRUCTURE CHANGE IN THE INDUSTRIAL DEVELOPMENT OF BEIJING-TIANJIN-HEBEI REGION

During the "8th Five-Year Plan" period to the "13nth Five-Year Plan" period, with the acceleration of China's urbanization and industrialization process, the Beijing-Tianjin-Hebei region has accelerated the adjustment and transformation of industrial structure. The proportion of the primary and secondary industry structure has steadily declined, and the proportion of the tertiary industry structure has risen rapidly. Beijing's economic development has entered a post-industrial period, with the tertiary industry dominating. Among them, the average proportion of the primary industry and the secondary industry structure dropped from 6.28%, 46.57% to 0.41%, 17.74%, and the average proportion of the tertiary industry structure rose from 47.16% to 81.85%. The economic development of Tianjin has moved from the late industrialization period to the post-industrialization period. The tertiary industry has gradually become the leading industry, but the secondary industry structure still accounts for a relatively high proportion. Among them, the average proportion of the primary and secondary industrial structure dropped from 7.07% and 56.73% to 1.19% and 38.67%, respectively, and the average proportion of the tertiary industry structure continued to rise from 36.20% to 60.14%. Hebei's economic development has moved from the period of industrialization to the latter period of industrialization, with the secondary industry as the mainstay, and the secondary and tertiary industries have developed simultaneously. Among them, the average proportion of the primary industry structure continued to drop from 20.57% to 10.10%, and the average proportion of the secondary industry structure first continued to rise from 46.49% in the "8th Five-Year Plan" period to 53.01% in the "11th Five-Year Plan" period, and then fell to 43.15% of the 13th Five-Year Plan. The average proportion of the tertiary industry structure rose from 32.94% to 46.75%. By the "13th Five-Year Plan" period, the average proportion of the tertiary industry structure has exceeded that of the secondary industry. ("Figure 1")

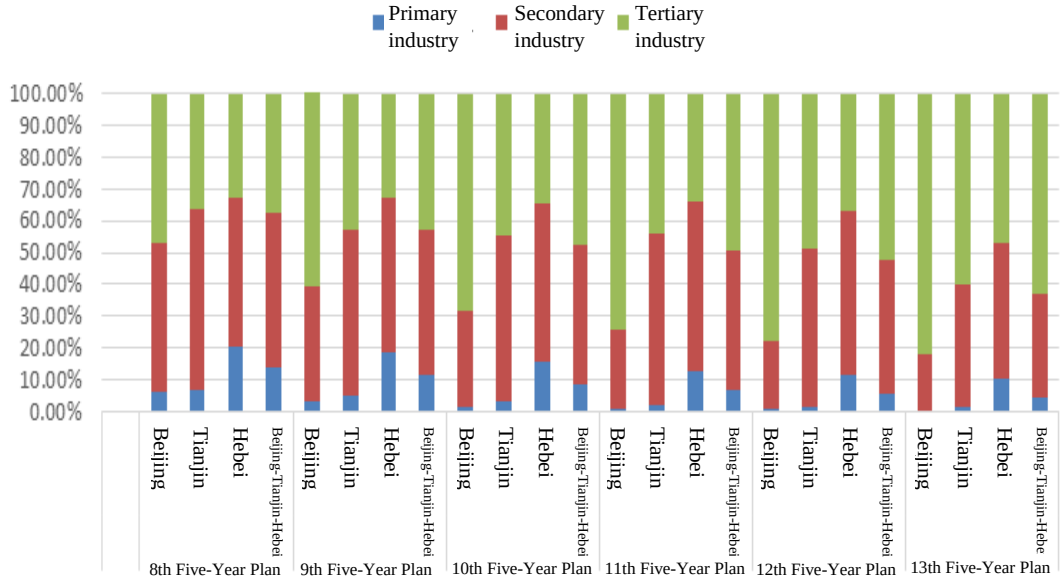

Figure 1 Changes in the industrial structure of the Beijing-Tianjin-Hebei region during the "8th Five-Year Plan" to "13th Five-Year Plan" period.

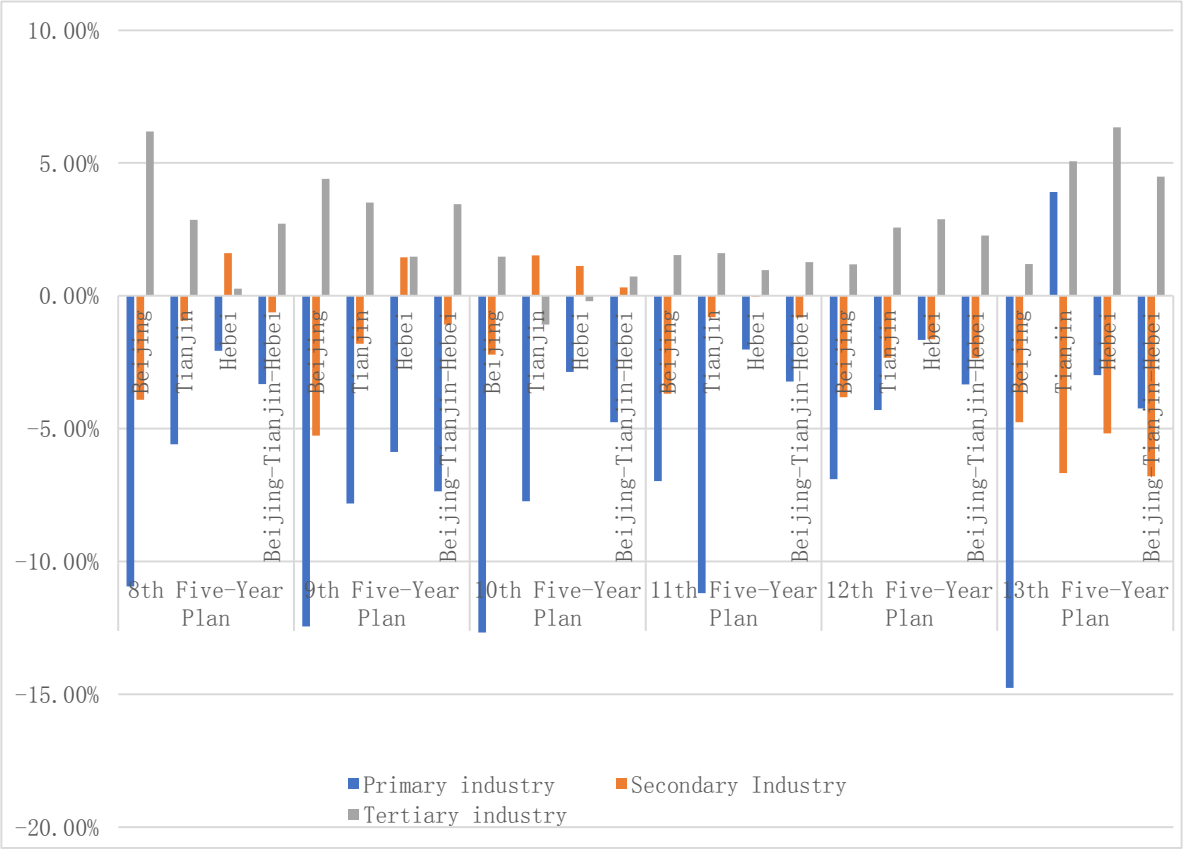

Figure 2 Variation coefficients of the three industrial structures in the Beijing-Tianjin-Hebei region in different planning periods.

a Note: The indicator data is calculated by the authors with reference to the "China Statistical Yearbook 1981-2019".

The coefficient of industrial structure change is mainly to reveal the direction of industrial structure change through the comparison of the proportion of the current output value of the three industries and the proportion of the base period output value. The industrial structure change coefficients of the Beijing-Tianjin-Hebei region in different planning periods are shown in "Figure 2".

It can be seen from "Figure 2" that during the "11th Five-Year Plan" period to the "13th Five-Year Plan" period, the average value of the change coefficient of the primary industry structure in the Beijing-Tianjin-Hebei region is always negative (only Tianjin during the "13th Five-Year" period is positive). This shows that the primary industry in the Beijing-Tianjin-Hebei region is in the trend of shrinking rapidly. Among them, the trend of contraction in Beijing is particularly obvious. During the period from the 8th Five-Year Plan to the 10th Five-Year Plan, the absolute value of the average coefficient of change of Beijing's primary industry reached more than 10%. During the "11th Five-Year Plan" to "12th Five-Year Plan" period, the absolute value of the mean value of the coefficient of change of Beijing's primary industry was close to 7%. By the "13th Five-Year Plan" period, the absolute value of the mean value of the coefficient of change of Beijing's primary industry was close to 15%. During the "8th Five-Year Plan" to "12th Five-Year Plan" period, the absolute value of the mean value of Tianjin's primary industry variation coefficient varied from 4% to 8%, and only exceeded 10% in the "11th Five-Year Plan" period. By the "13th Five-Year Plan" period, the average change coefficient of the primary industry was 3.19%. From the "8th Five-Year Plan" period to the "13th Five-Year Plan" period, the absolute value of the mean value of the coefficient of change of Hebei's primary industry mainly varied in the range of 2% to 3%, and it was only close to 6% during the "9th Five-Year Plan" period.

During the "8th Five-Year Plan" period and the "13th Five-Year Plan" period, the average value of the change coefficient of the secondary industry structure in the Beijing-Tianjin-Hebei region was generally negative, indicating that the secondary industry in the Beijing-Tianjin-Hebei region was gradually shrinking. During the period from the 8th Five-Year Plan to the 9th Five-Year Plan period, the average value of the change coefficient of the secondary industry structure in Beijing and Tianjin was negative, while the average value of the change coefficient of the secondary industry structure in Hebei was positive. By the "10th Five-Year Plan" period, the average value of the change coefficient of the secondary industry structure in the Beijing-Tianjin-Hebei region is positive. During the "11th Five-Year Plan" period-the "13th Five-Year Plan" period, the average value of the change coefficient of the secondary industry structure in the Beijing-Tianjin-Hebei region is always negative. On the whole, the secondary industry in Beijing has shrunk more obviously, and the absolute value of the mean coefficient of change of the secondary industry in Beijing is higher than that in Tianjin and Hebei.

During the "8th Five-Year Plan" period and the "13th Five-Year Plan" period, the average value of the coefficient of change in the tertiary industry structure in the Beijing-Tianjin-Hebei region was always positive (only the negative value in the Tianjin-Hebei region during the "10th Five-Year Plan" period), indicating that tertiary industry in the Beijing-Tianjin-Hebei region has shown a relatively stable expansion trend. Among them, the expansion of the tertiary industry in Beijing has changed from strong to weak, and the average coefficient of change in the structure of the tertiary industry in Beijing has continued to drop from 6.18% in the "8th Five-Year Plan" period to 1.20% in the "13th Five-Year Plan" period. The average values of the coefficients of change of the tertiary industry structure in Tianjin and Hebei are both in the volatility expansion stage, and have similar phase characteristics. They have expanded from 2.86% and 0.27% in the "8th Five-Year Plan" period to 5.06% and 6.34% in the "13th Five-Year Plan" period. During the "10th Five-Year Plan" period, the average value of the change coefficient of the tertiary industry structure in Tianjin and Hebei were both negative, which were -1.08% and -0.20%, respectively.

3. EVALUATION ON THE STATUS QUO OF WATER RESOURCES UTILIZATION IN THE INDUSTRIAL DEVELOPMENT OF BEIJING-TIANJIN-HEBEI REGION

3.1 Changes in the Utilization of Industrial and Agricultural Water Resources

The leading industries in the Beijing-Tianjin-Hebei region have undergone an evolution from "primary industry → secondary industry → tertiary industry". With the adjustment of industrial structure, water resources in Beijing-Tianjin-Hebei are re-allocated among different industries. The proportion of industrial and agricultural water used in the Beijing-Tianjin-Hebei region has declined, and the proportion of domestic and ecological water consumption has increased year by year (before 2003, the Beijing-Tianjin-Hebei region did not separately count the ecological water consumption data). From 1990 to 2019, the change in industrial water consumption in the Beijing-Tianjin-Hebei region is shown in "Figure 3".

During the "8th Five-Year Plan" period-the "13th Five-Year Plan" period, first of all, in terms of changes in total water consumption, the average value of Beijing's total water consumption fluctuated from 4.418 billion cubic meters to 3.983 billion cubic meters. The average value of total water consumption in Tianjin fluctuated from 2.206 billion cubic meters to 2.788 billion cubic meters. The average value of Hebei's total water consumption fluctuated from 20.172 billion cubic meters to 18.223 billion cubic meters. Secondly, from the perspective of changes in agricultural water consumption, the average value of Beijing's agricultural water consumption has dropped rapidly, from 2.087 billion cubic meters to 475 million cubic meters, a decrease of more than 75%. The average value of Tianjin's agricultural water consumption fluctuated, but stabilized at around 1.1 billion cubic meters. The average value of agricultural water consumption in Hebei has gradually declined, from 16.329 billion cubic meters to 12.237 billion cubic meters. Then, in terms of changes in industrial water consumption, the average industrial water consumption in Beijing dropped rapidly, from 1.377 billion cubic meters to 348 million cubic meters, a decrease of 75%. The average value of industrial water consumption in Tianjin fluctuated downward, from 701 million cubic meters to 548 million cubic meters, a decline

of 22%. The average industrial water consumption in Hebei fluctuated downward, from 2.625 billion cubic meters to 2.002 billion cubic meters, a decline of 24%. From the perspective of changes in domestic water consumption, the average domestic water consumption in Beijing has increased rapidly, from 955 million cubic meters to 1.830 billion cubic meters, an increase of nearly double. The average domestic water consumption in Tianjin has increased rapidly, from 430 million cubic meters to 665 million cubic meters, an increase of 55%. The average domestic water consumption in Hebei has increased rapidly, from 1.179 billion cubic meters to 2.691 billion cubic meters, an increase of nearly 1.3 times.

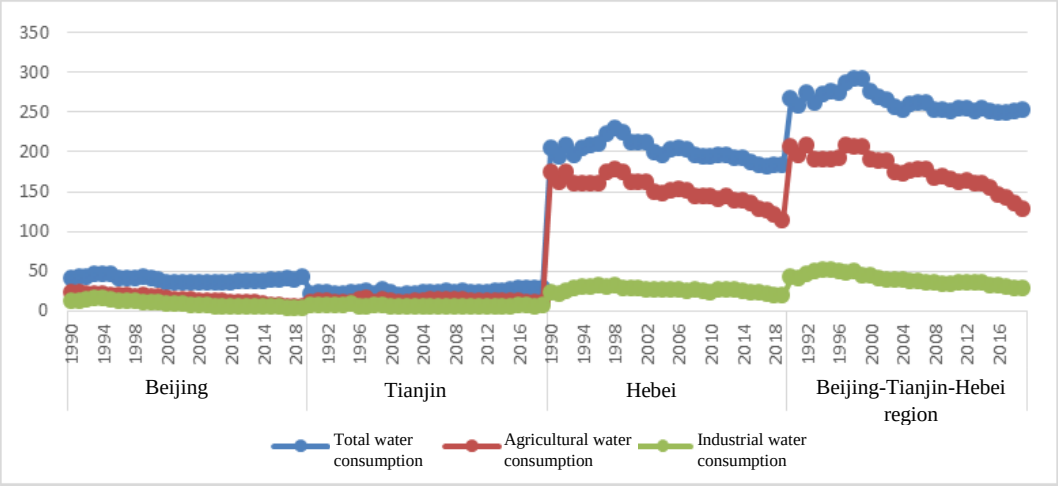

Figure 3 Changes in Water Resources Utilization in the Beijing-Tianjin-Hebei Region from 1990 to 2019.

3.2 Estimation of Water Consumption for Industrial Development

According to the "China Statistical Yearbook", only the four major categories of water consumption and total water consumption in the Beijing-Tianjin-Hebei region are calculated for agriculture, industry, life, and ecology. Among them, domestic water consumption includes household water consumption, tertiary industry and construction industry water consumption. Regarding the "Water Bulletin" of the Beijing-Tianjin-Hebei region over the years, Beijing and Hebei did not separately list the water consumption of the primary, secondary and tertiary industries. Among them, the primary industry only counts agricultural water consumption data, the industrial water consumption does not include the construction industry water consumption data in the secondary industry, and the tertiary industry water consumption data is included in the domestic water consumption data. Because only the "Tianjin Water Resources Bulletin" from 2003 to 2018 made statistics on the water consumption of the three industries, it is only possible to estimate the conversion coefficients of the primary industry and agricultural water consumption, the secondary industry and industrial water consumption, and the household and domestic water consumption based on the data of Tianjin's tertiary industry water consumption and residential water consumption, and to respectively derive and estimate the industrial water consumption and domestic water consumption of Beijing and Hebei, which can be expressed as

$$\begin{cases} FI_i(t) = FI_{12}(t)\cdot k_{1i} = FI_{12}(t)\cdot \dfrac{1}{T}\sum_{t=1}^{T}\dfrac{FI_{12}(t)}{A_{12}(t)}\cdot\dfrac{A_{1i}(t)}{A_{12}(t)} \\ SI_i(t) = SI_{22}(t)\cdot k_{2i} = SI_{22}(t)\cdot \dfrac{1}{T}\sum_{t=1}^{T}\dfrac{SI_{22}(t)}{I_{22}(t)}\cdot\dfrac{I_{2i}(t)}{I_{22}(t)} \\ PL_i(t) = L_i(t)\cdot k_i = L_i(t)\cdot \dfrac{1}{T}\sum_{t=1}^{T}\dfrac{PL_i(t)}{L_i(t)} \\ TI_i(t) = Total_i(t) - FI_i(t) - SI_i(t) - PL_i(t) - EI_i(t) \end{cases} \quad (1)$$

In formula (1), $FI_i(t)$, $SI_i(t)$, $PL_i(t)$, and $TI_i(t)$ are estimated value of the water consumption of the primary industry, the secondary industry, the domestic water consumption, and the tertiary industry, respectively, in the t period o i region; k_{1i}, k_{2i}, and k_i (i=1,2,3 are Beijing, Tianjin, Hebei respectively) are the conversion coefficients for the water consumption of the primary industry, the water consumption of the secondary industry, and the domestic water

consumption in the region of i; $\frac{FI_{12}(t)}{A_{12}(t)}$ is the ratio of the water consumption of Tianjin's primary industry to the water consumption of Tianjin's agriculture in the period of t; $\frac{A_{1i}(t)}{A_{12}(t)}$ is the ratio of the agricultural water consumption in the area of i in the period of t to the agricultural water consumption in Tianjin; $\frac{SI_{22}(t)}{I_{22}(t)}$ is the ratio of the industrial water consumption in the area of i in the period of t to the industrial water consumption in Tianjin; $\frac{PL_i(t)}{L_i(t)}$ is the ratio of the residential water consumption to the domestic water consumption in the area of i during the period of t; $Total_i(t)$ is the total water consumption of the area i in the period of t; $EI_i(t)$ is the ecological water consumption in the area i in the period of t.

According to formula (1), the water consumption for industrial development in the Beijing-Tianjin-Hebei region during the "8th Five-Year Plan" to "13th Five-Year Plan" period can be determined, as shown in "Figure 4".

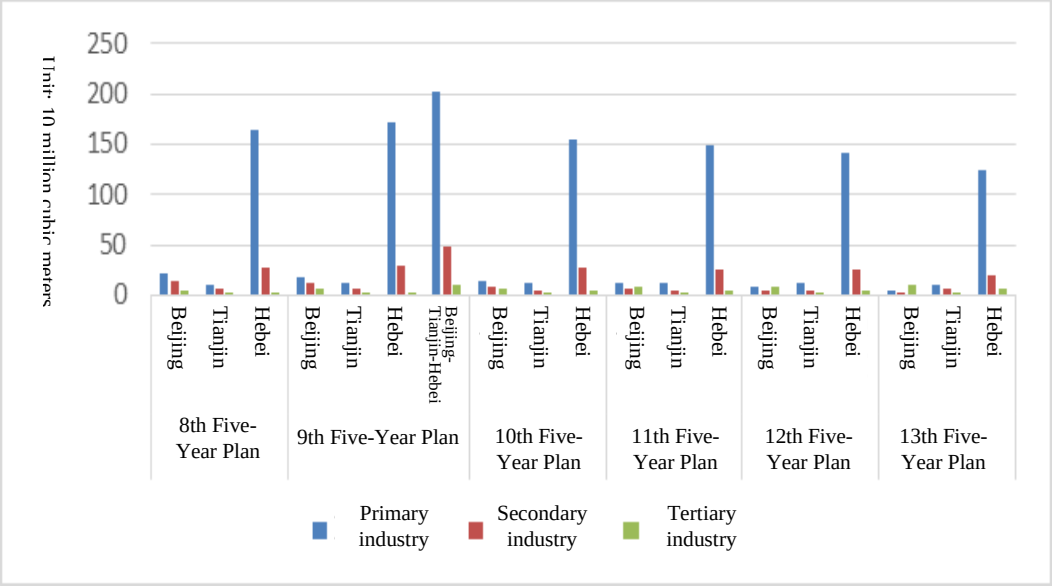

Figure 4 Changes of industrial water consumption in Beijing, Tianjin and Hebei in different planning periods.

4. FORECAST OF WATER RESOURCES UTILIZATION DEMAND IN THE INDUSTRIAL DEVELOPMENT OF BEIJING-TIANJIN-HEBEI REGION

4.1 Industry Development Forecast

4.1.1 Regional GDP Forecast

According to the GDP of each region of Beijing-Tianjin-Hebei from 1990 to 2019, the total GDP of Beijing-Tianjin-Hebei can be obtained. Based on the total GDP of the Beijing-Tianjin-Hebei region and the GDP of each region, the proportion of GDP in the Beijing-Tianjin-Hebei region from 1990 to 2019 is determined, as shown in "Figure 5".

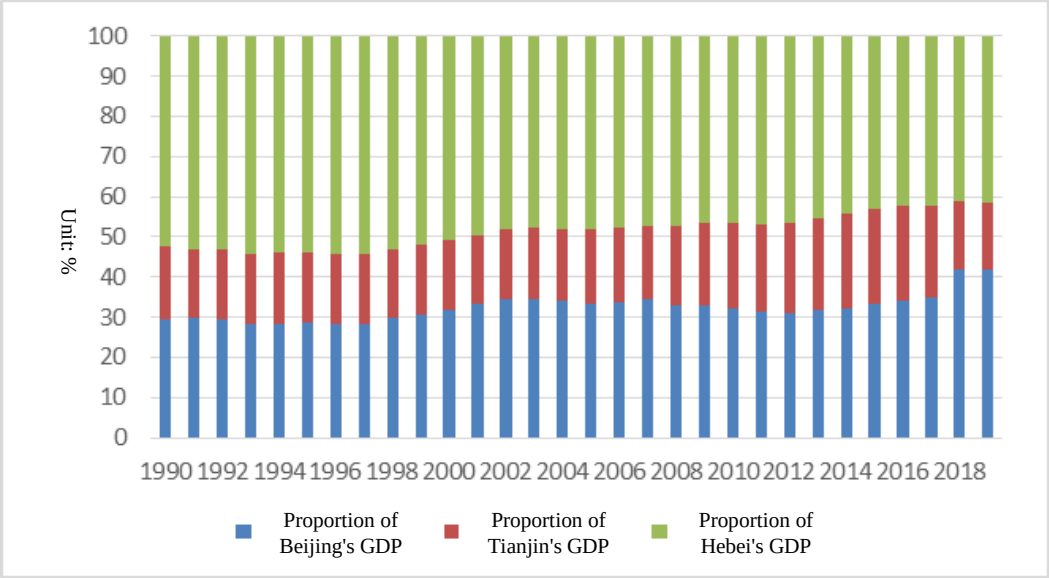

Figure 5 The proportion of GDP in the Beijing-Tianjin-Hebei region from 1990 to 2019.

According to "Figure 5", the trend extrapolation method is used to predict the proportion of GDP in the Beijing-Tianjin-Hebei region from 2025 to 2035, as shown in "Table 1".

Table 1. Proportion of GDP in the Beijing-Tianjin-Hebei region in 2025-2035 (Unit: %)

Year	Proportion of Beijing's GDP	Proportion of Tianjin's GDP	Proportion of Hebei's GDP
2025	43.95	17.11	38.94
2030	45.35	17.24	37.41
2035	46.75	17.36	35.90

In 1990, the total GDP of Beijing-Tianjin-Hebei was only 170.81 billion yuan. In 2019, it exceeded 8 trillion yuan, reaching 8458.01 billion yuan. However, its GDP growth rate continued to decline. Through data simulation and using trend extrapolation, it is estimated that the total GDP of Beijing-Tianjin-Hebei region in 2025, 2030, and 2035 will reach 10,0920.6 billion, 1,33,756, and 15,845 billion respectively. According to "Table 1", the GDP of the Beijing-Tianjin-Hebei region from 2025 to 2035 can be determined, as shown in "Table 2".

Table 2. GDP of Beijing-Tianjin-Hebei region in 2025-2035 (Unit: 100 million yuan)

Year	GDP of Beijing	GDP of Tianjin	GDP of Hebei
2025	51611.73	20092.89	45723.18
2030	69068.14	26260.60	56979.40
2035	90269.29	33515.93	69324.15

4.1.2 Forecast of Regional Industrial Structure

Based on the GDP data of the industrial development of the Beijing-Tianjin-Hebei region from 1990 to 2019, determine the proportion of the industrial structure of the Beijing-Tianjin-Hebei region from 1990 to 2019. The trend extrapolation method is used to predict the proportion of the industrial structure of the Beijing-Tianjin-Hebei region from 2025 to 2035, as shown in "Figure 6".

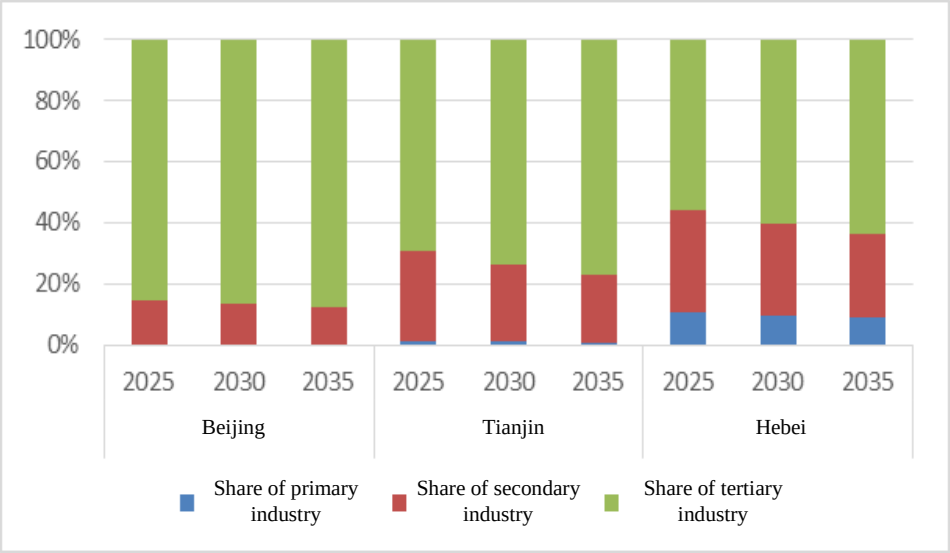

Figure 6 The proportion of the industrial structure of the Beijing-Tianjin-Hebei region from 2025 to 2035.

4.2 Forecast of Water Demand for Industrial Development

Based on the water efficiency of industrial development in the Beijing-Tianjin-Hebei region, the researchers use trend extrapolation method to predict the water efficiency of industrial development in the Beijing-Tianjin-Hebei region from 2025 to 2035, as shown in "Table 3".

Table 3. Water efficiency for industrial development in the Beijing-Tianjin-Hebei region from 2025 to 2035 (Unit: m^3/10,000 yuan)

Region	Year	Water consumption per ten thousand yuan of added value in the primary industry	Water consumption per ten thousand yuan of added value in the secondary industry	Water consumption per ten thousand yuan of added value in the tertiary industry
Beijing	2025	192.28	4.00	2.53
	2030	125.20	2.84	2.02
	2035	81.52	2.02	1.65
Tianjin	2025	412.27	9.36	1.61
	2030	341.66	7.83	1.29
	2035	283.15	6.55	1.07
Hebei	2025	221.35	12.43	3.28
	2030	168.49	11.15	2.76
	2035	128.25	10.01	2.44

According to "Table 3" and "Figure 6", on the basis of determining the GDP of the industrial development of the Beijing-Tianjin-Hebei region, and according to the GDP and water efficiency of the industrial development of the Beijing-Tianjin-Hebei region, the final forecast of the water demand for industrial development in the Beijing-Tianjin-Hebei region from 2025 to 2035 can be obtained. At the same time, for the forecast of water demand for the primary industry (agriculture) in the Beijing-Tianjin-Hebei region, first, according to Beijing's agricultural high-efficiency water-saving plan and the city's overall plan, Beijing's agriculture should optimize the planting structure, strictly manage water quotas, and negatively increase agricultural water consumption. Second, according to relevant reports such as the allocation of water resources in Tianjin, the effective irrigation area of Tianjin's farmland will be in a relatively stable situation for a long period of time in the future. At the same time,

the crop planting structure will be appropriately adjusted to develop water-saving irrigation agriculture. The third is to consider that non-capital function deconstruction will be deconstructed to Hebei Province in terms of agriculture and water-consuming industries. With reference to Hebei Province's water conservation and development plan, the area of arable land in Hebei remains basically unchanged. Taking into account the improvement of agricultural water-saving irrigation technology, the adjustment of the planting structure under groundwater pressure, and the stable changes in the water demand of forestry, animal husbandry and fishery in recent years, and the overall trend of increasing, the agricultural water demand can be determined. Therefore, the maximum water demand and current level of the primary industry (agriculture) in the Beijing-Tianjin-Hebei region remain unchanged year after year.

Aiming at the forecast of water demand for the secondary industry (industrial) in the Beijing-Tianjin-Hebei region, first, based on Beijing's "13th Five-Year Plan" and urban comprehensive planning, there would be zero growth in Beijing's industrial water and new water, it can be estimated that from 2025 to 2035, the highest water demand and current status of the secondary industry (industry) in Beijing will remain unchanged. Second, for Tianjin and Hebei, while maintaining the existing industrial structure, the industrial production scale and water-saving level have been increased simultaneously, and the maximum water demand of the secondary industry (industrial engineering) and the current level are basically the same each year. For this reason, the water consumption of the primary and secondary industries in the Beijing-Tianjin-Hebei region in 2019 at the current level is set as the upper limit of the water demand for the primary and secondary industries in the Beijing-Tianjin-Hebei region from 2025 to 2035, as shown in "Table 4".

Table 4. Industrial water demand in the Beijing-Tianjin-Hebei region from 2025 to 2035 (Unit: 100 million cubic meters)

Region	Year	Primary industry	Secondary industry	Tertiary industry
Beijing	2025	[1.99 , 3.74]	[2.90 , 3.45]	[11.14 , 11.57]
	2030	[1.25 , 3.74]	[2.44 , 3.45]	[12.10 , 12.47]
	2035	[0.81 , 3.74]	[2.01 , 3.45]	[13.14 , 13.52]
Tianjin	2025	[7.97 , 9.30]	[5.55 , 5.76]	[2.25 , 2.35]
	2030	[7.31 , 9.30]	[5.26 , 5.76]	[2.49 , 2.57]
	2035	[6.74 , 9.30]	[4.85 , 5.76]	[2.49 , 2.57]
Hebei	2025	[98.09 , 115.50]	[19.13 , 19.24]	[8.39 , 9.36]
	2030	[86.78 , 115.50]	[19.03 , 19.24]	[9.51 , 10.40]
	2035	[77.19 , 115.50]	[18.94 , 19.24]	[10.78 , 11.78]

5. CONCLUSION

This paper has carried out the research on the current situation evaluation and demand forecast of water resources utilization in the industrial development of Beijing-Tianjin-Hebei. Research shows that during the period from the8th Five-Year Plan to the 13th Five-Year Plan, the leading industries in the Beijing-Tianjin-Hebei region have undergone an evolution from "primary industry → second industry → tertiary industry". With the adjustment of industrial structure, water resources in Beijing-Tianjin-Hebei are re-allocated among different industries. The total water consumption in the Beijing-Tianjin-Hebei region has shown a fluctuating downward trend. The industrial and agricultural water consumption has dropped rapidly, and the domestic water consumption has risen rapidly. From 2025 to 2035, the proportion of tertiary industry structure in Beijing, Tianjin, and Hebei will reach 85%-88%, 69%-78%, and 55%-64%, respectively. The optimization and upgrading of the industrial structure will be accelerated, and the level of advanced industrial structure will be improved. The direction of the optimization of water resources in the Beijing-Tianjin-Hebei region is to appropriately reduce the use of water resources in the primary and secondary industries and increase the use of water in the tertiary industry under the premise of ensuring the safety of food production. That is, through industrial and agricultural water-saving technologies and other measures, it can give priority to control the water consumption of the primary industry, strictly

control the water consumption of the secondary industry, and reasonably increase the water consumption of the tertiary industry, so as to realize the effective improvement of the comprehensive output of water resources in the Beijing-Tianjin-Hebei region.

AUTHORS' CONTRIBUTIONS

Dan Wu is responsible for experimental design and writing the manuscript, Xiaoqian Xiang responsible for analysed data and writing the manuscript.

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