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Study and Evaluation of Dynamic Carrying Capacity of Groundwater Resources in Hebei Province from 2010 to 2017

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Abstract: There is a severe issue with groundwater overuse and water scarcity in the North China Plain. The capacity of groundwater resources to promote economic development is also diminished due to the overexploitation of resources to suit the industrial needs of diverse sectors. Therefore, it is crucial to research the regional groundwater resource carrying capacity from both a temporal and spatial perspective. The relationship between water usage efficiency and groundwater availability, which was built using regional data on water supply and consumption as well as gross domestic product, is used in this study to assess the carrying capacity of Hebei's groundwater resources through time and space. The results show that from the perspective of time, in the years when the groundwater resource exploitation degree is greater than one from 2010 to 2017, the contribution rate of the groundwater resource exploitation to economic development reaches 62.5%, indicating that the economic development of the study area is highly dependent on the groundwater resources. The exploitation degree of groundwater resources is less than one, but the degree of economic development value keeps increasing to nearly 80% and the overexploitation rate is 75% in the total time scale. In terms of spatial scale, only Hengshui City has no overexploitation index, and the overexploitation rate is 9.1%. The overload and severe overload areas account for 45.45%, respectively. Among them, the exploitation degree of groundwater has been in a state of over-saturation, and as economic development depends on groundwater resources, water efficiency needs to be improved through water saving. Optimizing and promoting industrial structures and water-saving technology to further improve water efficiency are key factors to improve the carrying capacity of groundwater resources.

Keywords: groundwater resources; degree of groundwater exploitation; water utilization efficiency; degree of social and economic development; Hebei

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1. Introduction

In recent years, under the dual influence of human activities and climate change, the available freshwater resources globally have been continuously decreasing and water shortage has become a global problem [1–3]. Limited water resources are no longer able to support the overload in human production and economic activities [4–6]. When the development and utilization of water resources exceed their load-bearing limits, a series of ecological, environmental, and social problems will arise, such as grain production reduction, biodiversity reduction, water disputes between countries, and water conflicts between cities and rural areas [7–9]. Groundwater resources are also affected by human activities and climate change. It is reported that a decrease in groundwater resources has occurred in major groundwater exploitation areas around the world [10–13]. The annual decrease rate of groundwater resources in the high plains of the United States, northwest India and the

North China Plain are all serious [14]. Therefore, reasonable exploitation and utilization of groundwater resources has become an important topic in regional groundwater resource management within the limit of groundwater resource carrying capacity [15–17].

At present, the classic definition of groundwater resource carrying capacity refers to the capacity of groundwater resources to supply water to industrial and agricultural production, people's livelihood and ecological environment protection at different time scales in the future, and under certain technical and economic levels and social production conditions [18]. Most previous studies [19–23] on the carrying capacity of groundwater resources are mostly based on the dependence of the ecosystem on groundwater resources to determine the minimum environmental discharge and water level of groundwater in order to meet the minimum survival conditions of the population and promote the stable development of the ecosystem cycle. Compared with current studies on groundwater resource carrying capacity [14,15,24], previous studies are more inclined to analyze practical problems, mostly from the perspective of economic development and water resource carrying limit, the stability of ecosystem evolution, and the maximum population. Current studies are more inclined to evaluate the status of groundwater resource carrying capacity using different methods [25,26]. The unified feature of calculation methods is that all of them need to construct various criteria layer indexes involving water resource systems, ecological environment systems, and social economic systems, and grade the index layer belonging to the criteria layer. Finally, according to different algorithm models, the comprehensive index of groundwater resource carrying capacity is calculated and evaluated comprehensively [27], so that the macro concept of groundwater resource carrying capacity can be quantified. In this paper, the carrying capacity of groundwater resources refers to "the supporting capacity of groundwater resources to regional social and economic development under certain conditions of social development, based on the existing level of economic and social development, based on the principle of sustainable development, based on the premise of groundwater availability, under the condition of a certain industrial water efficiency", and is expressed by the supported GDP (yuan) [28]. The natural and social attributes involved in the carrying capacity of groundwater resources are always changing [29]. On the one hand, under the joint action of climate change and human activities, regional groundwater resources are always in a state of dynamic fluctuation. On the other hand, with the progress of science and technology and the development of society, the methods and intensity of exploitation and utilization of groundwater resources in human society will also change [28–30]. Therefore, the carrying capacity of groundwater resources will also change with the change of natural and social attributes. The availability of groundwater resources and the degree of economic development in a region are always in dynamic change [31–33], which is not unchangeable. Therefore, it is necessary to evaluate the carrying capacity of groundwater resources from the perspective of time and space and put forward corresponding control methods and countermeasures for over-exploited areas. The evaluation of the carrying capacity of groundwater resources in the North China Plain is not only an important subject in the study of the water cycle and sustainable development of groundwater resources in North China, but also has urgent practical significance for the coordinated and sustainable development of water resources, ecological environment, social economy, and food security.

In this study, the maximum available amount of groundwater and the scale of socioeconomic development (GDP) were used to represent the carrying capacity of groundwater, so as to solve the problem of water shortage in Hebei Province [34–37]. (i) Based on the correlation coefficient between economic development degree and groundwater exploitation degree in Hebei Province from 2010 to 2017, the overexploitation ratio relationship was evaluated and suggestions on improving groundwater resource carrying capacity were put forward. (ii) Water saving is fundamental, water transfer is key, pollution control is the premise, management is the guarantee. (iii) We should comprehensively adopt measures to conserve water and control pollution, fully tap potential, improve and expand the Yellow River diversion project system, promote the construction of the south-to-north water diversion project, and reform the water price formation mechanism and water management system.

2. Materials and Methods

2.1. Description of Study Area

Hebei Province is located in the southeast of North China, surrounded by Beijing and Tianjin inside and the Bohai Sea outside. It is an important part of the national strategy for the coordinated development of Beijing, Tianjin, and Hebei. Hebei Province belongs to the mid-latitude temperate continental monsoon climate with 4 distinct seasons. According to the form of the river runoff cycle, it can be divided into 2 types: outflow river directly into the sea and inland river not connected with the sea. Haihe River, Luanhe River, and Liaohe River belong to the outflow river, while the Anguli River in Bashang area belongs to the inland river. The average annual precipitation in Hebei Province was 520.8mm (from 1956 to 2016) and the average annual evaporation was 996mm. The total land area of the province is 187,700 km^2. It has various landforms, including plateaus, mountains, hills, basins, plains, lakes, and beaches. The deep confined water in the study area is mainly composed of medium coarse sand, gravel, and pebble aquifers, which are distributed in the shape of a fan and generally have the distribution of a thick sub-clay layer. The vertical recharge condition is poor, and the permeability coefficient is small, so the natural water is not easy to recharge to the groundwater aquifer. According to the occurrence conditions of groundwater and pore characteristics of water-bearing medium in the study area, groundwater can be divided into 3 systems: a loose rock, pore water, water-bearing system; a carbonate rock, karst water, water-bearing system; and a bedrock, fissure water, water-bearing system. The terrain is high in the northwest and low in the southeast, showing typical half-ring step landform features (Figure 1).

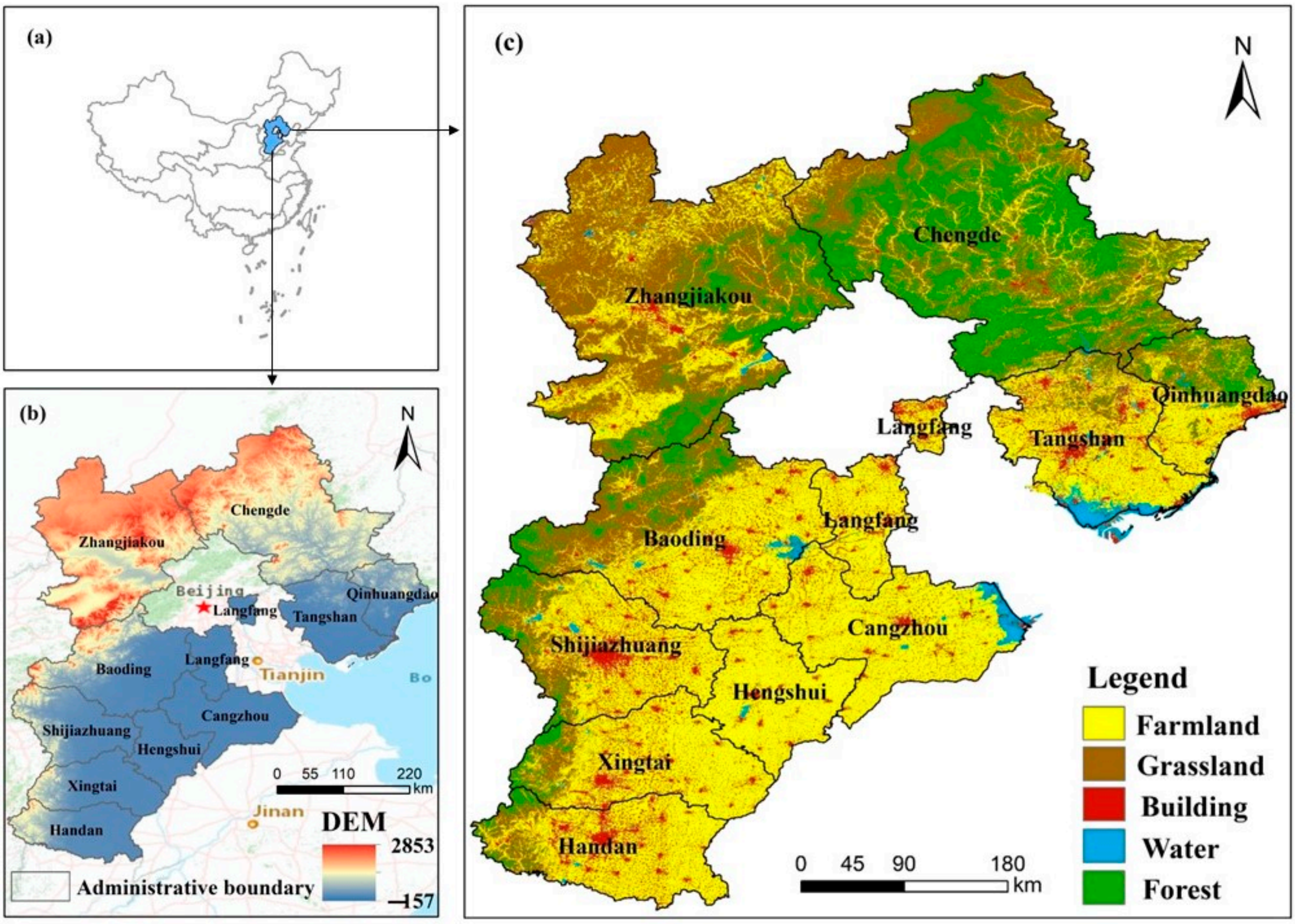

Figure 1. The map showing the location of study area (**a**), the elevation of Hebei (**b**), and land use types in Hebei (**c**).

2.2. Data Sources

The data sources of surface water resources, groundwater resources, groundwater supply, water consumption of various departments, and actual groundwater extraction involved in this study are all from the Hebei Water Resources Bulletin. The population and GDP data of Hebei Province are from the Hebei Statistical Yearbook.

2.3. Definition and Construction of Evaluation Model

At present, there is no unified standard for the concept of groundwater resource carrying capacity. Most of the concepts of groundwater resource carrying capacity are expanded based on the concept of water resource carrying capacity. It is believed that groundwater resource carrying capacity refers to the maximum capacity to meet the regional agricultural, industrial, and service production and the living water consumption of residents. In this paper, the bearing capacity of groundwater resources refers to "the supporting capacity of groundwater resources for regional social and economic development under certain conditions of social development, based on the existing level of economic and social development, taking sustainable development as the principle, taking groundwater availability as the premise, and under certain conditions of industrial water use efficiency", expressed in terms of the supported GDP (yuan).

In this paper, GDP is selected as the object of groundwater bearing capacity construction. The main reason is that GDP can reflect the bearing level of regional water resources to the overall economic activities and scale, which is a significant quantitative index. The research pays attention to the response degree of groundwater resources to the changes in the hydrological cycle process and economic development process, that is, the bearing object of the carrying capacity of groundwater resources is the scale of economic development.

According to the above definition, groundwater resource carrying capacity (C) is a function of water-use efficiency (θ) and availability of groundwater resources (A), the expression relationship between them is as follows:

$$C = A \times \theta \tag{1}$$

where C is the scale of social and economic development supported by groundwater expressed in GDP (yuan); θ is water efficiency, which includes various industries (yuan/m^3); and A refers to the amount of groundwater resources (m^3).

$$\theta = \frac{a\theta_{pri} + b\theta_{sec} + c\theta_{ter}}{a + b + c} \tag{2}$$

$$\begin{cases} \theta_{pri} = \dfrac{V_{pri}}{C_{pri}} \\ \theta_{sec} = \dfrac{V_{sec}}{C_{sec}} \\ \theta_{ter} = \dfrac{V_{ter}}{C_{ter}} \end{cases} \tag{3}$$

Water-use efficiency (θ) is divided into primary industry water-use efficiency (θ_{pri}), secondary industry water-use efficiency (θ_{sec}), and tertiary industry water-use efficiency (θ_{ter}), which is expressed by the ratio of the total output value of a certain department (GDP) and the total water consumption of the department. V_{pri}, V_{sec}, and V_{ter} are the GDP for the primary industry, secondary industry, and tertiary industry. C_{pri}, C_{sec}, and C_{ter} are the water consumption of the primary industry, secondary industry, and tertiary industry. For θ, the weight of water consumption of all sectors should be considered. The weights of primary industry water, secondary industry water, and tertiary industry water in all the total water consumption, respectively, are a, b, c.

It can be obtained from Equation (1) that the efficiency of regional water usage and the amount of local groundwater available are directly related to the carrying capacity of groundwater resources. The maximum theoretical groundwater resource carrying capacity (C_{max}) of the study area can be calculated by choosing the largest one under different water-use efficiencies for the chosen study area when the maximum groundwater availability for the study region at that moment is known. The actual and maximum theoretical carrying capacity of groundwater resources can be calculated as follows:

$$C_{act} = A \times \theta \quad (4)$$

$$C_{max} = A_{max} \times \theta_{max} \quad (5)$$

2.4. Evaluation Method of Groundwater Resource Carrying Capacity

The groundwater resource carrying capacity assessment index (I) is used in this study to represent the degree of groundwater exploitation (D_E) on the degree of economic development (D_C). The ratio between economic development supported by groundwater resources and groundwater extraction is the correlation [38,39]. The specific formulas are as follows:

$$D_C = \frac{C_{act}}{C_{max}} \quad (6)$$

$$D_E = \frac{W}{A} \quad (7)$$

$$I = \frac{D_C}{D_E} \quad (8)$$

where W is groundwater withdrawal (m^3), A is groundwater resources amount (m^3), I is assessment index, and I is non-dimensional. The formula for the economic development degree of groundwater resources is the ratio between normal and maximum water-use efficiency, thus the total value is less than one. The higher the I value, the lower the carrying capacity of groundwater resources, the greater the contribution of groundwater exploitation to economic development, and the more serious the groundwater exploitation overload. On the contrary, groundwater exploitation is not overburdened.

The degree of overloading for I can be divided into 3 parts [38]: no overload ($I \leq 30\%$), overload ($30\% < I < 50\%$) and serious overload ($I \geq 50\%$).

3. Results and Discussion

3.1. Analysis of Water Supply and Water-Use Situation in Hebei

According to the *Technical Outline of the National Water Resource Carrying Capacity Monitoring and Early Warning Mechanism* issued by the Ministry of Water Resources in 2016, Hebei carried out the water resource carrying capacity evaluation for the first time (with 2015 as the current assessment year) to determine water resource carrying capacity of the whole province and calculate the pressure and bearing load of water resources caused by economic and social development. Figure 2 shows the proportion of water consumed by all industries and the changes in water supply sources in Hebei Province during the past eight years, from 2010 to 2017.

From the perspective of water supply structure, the water supply of Hebei Province is mainly from underground sources, followed by surface sources, and the proportion of other sources is the smallest. The water supply structure of Hebei Province was basically stable from 2010 to 2017 and the variation range was small. In recent years, the water-saving consciousness of all industries in Hebei Province has been enhanced continuously and a series of underground water pressure exploitation measures have been implemented simultaneously. The proportion of underground water supply decreased from 79.2% in 2010 to 68.0%, showing a downward trend year by year. The proportion of surface water supply increased from 18.9% in 2010 to 28.1% in 2017, showing an increasing trend year by year. The proportion of water supply from other sources increased from 1.9% in 2010 to 3.9% in 2017.

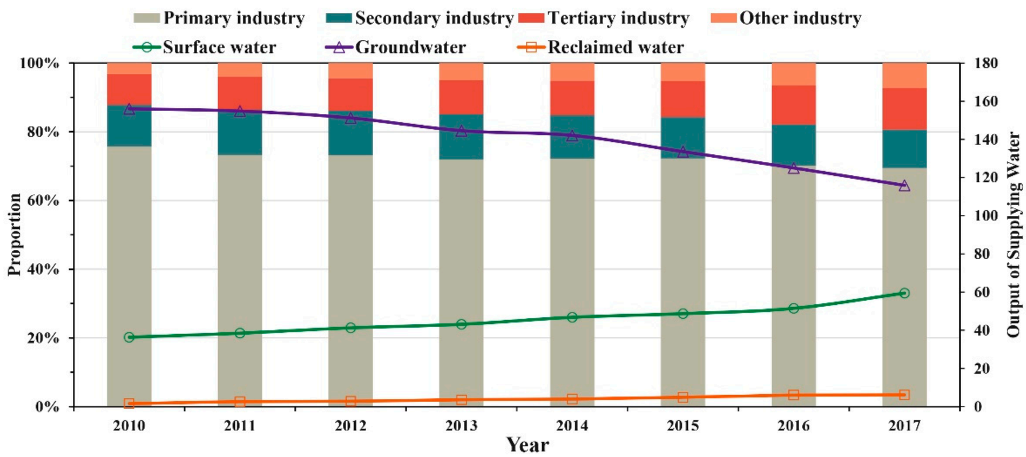

Figure 2. Proportion of water consumed by all industries and the changes in water supply sources in study area from 2010–2017.

From the analysis of water consumption structure, Hebei Province is a big agricultural province and agriculture has always been a big user of water. In the eight years from 2010 to 2017, agricultural water consumption accounted for 71.6%, industrial water consumption for 12.9%, urban and rural living water consumption for 13.1%, and artificial ecology and other environmental water consumption for 2.4% of the total water consumption in Hebei Province. Agricultural water consumption has been decreasing year by year. As Hebei Province has made great efforts to reform the agricultural water consumption mode, vigorously advocated water-saving agriculture construction, developed agricultural water-saving technology, formulated agricultural water-saving policies, and established a series of agricultural water-saving related systems and laws and regulations, the awareness of agricultural water-saving has been significantly enhanced. Industrial water consumption shows a decreasing trend on the whole. In recent years, Hebei Province has carried out the construction of a water-saving society, implemented underground water pressure mining, strengthened the industrial water-saving technology transformation, and adjusted the industrial structure. The most fundamental reason for the increase in water consumption in the tertiary industry and other industries year by year is the increase in water consumption in urban residents, which is the inevitable result of the steady promotion of urbanization by governments at all levels in Hebei Province in recent years.

3.2. Analysis of Groundwater Resource Carrying Capacity in Hebei

3.2.1. Temporal and Spatial Variation Characteristics of GDP and Water-Use Efficiency

In this study, all industries in Hebei Province are divided into three categories (primary industry, secondary industry, and tertiary industry) for discussion. From the perspective of the time series, the three industries from 2010 to 2017 are all in a stage of rapid growth and the overall GDP is also in a state of continuous growth (Figure 3). In terms of the primary industry, although Hebei has vigorously reformed the agricultural water consumption mode in recent years and the water consumption has decreased to some extent, Hebei is a big agricultural province and its GDP still rises steadily, with an increase rate of 26.56%. From 2010–2017, the GDP growth rate of the tertiary industry was the largest, reaching 108%, followed by that of the secondary industry, which reached 50.85%, and that of the secondary industry was the lowest at 26.56%. The overall GDP growth rate reached 70.19%. From 2010 to 2017, water consumption per 10,000 yuan of GDP in Hebei Province decreased year by year, achieving negative growth from 94 m^3 in 2010 to 55 m^3 in 2017, a cumulative decrease of 41.4%.

In terms of the spatial distribution of GDP in all industries (Figure 4), the distribution characteristics of the primary industry, the secondary industry, the tertiary industry, and the overall GDP are basically the same, increasing from the north and the south to the middle, and finally the largest GDP converged in Tangshan, Shijiazhuang, and Baoding. The GDP in agriculture is the smallest in Xingtai, Shijiazhuang, Handan, and Baoding in the west and Zhangjiakou in the south, while the GDP in Tangshan and Baoding in the east is larger. In terms of industrial GDP, Tangshan and Shijiazhuang are the largest, while the industries in the surrounding areas are relatively small. In terms of tertiary industry GDP, Shijiazhuang and Tangshan are the largest, while Hengshui, Xingtai, Qinhuangdao, and Chengde are smaller.

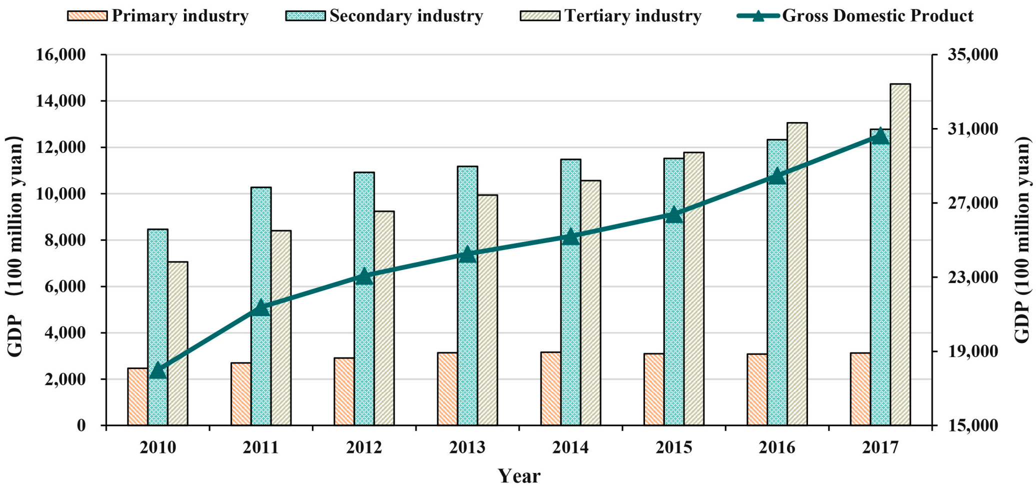

Figure 3. Temporal variation in GDP for all industries in Hebei from 2010 to 2017.

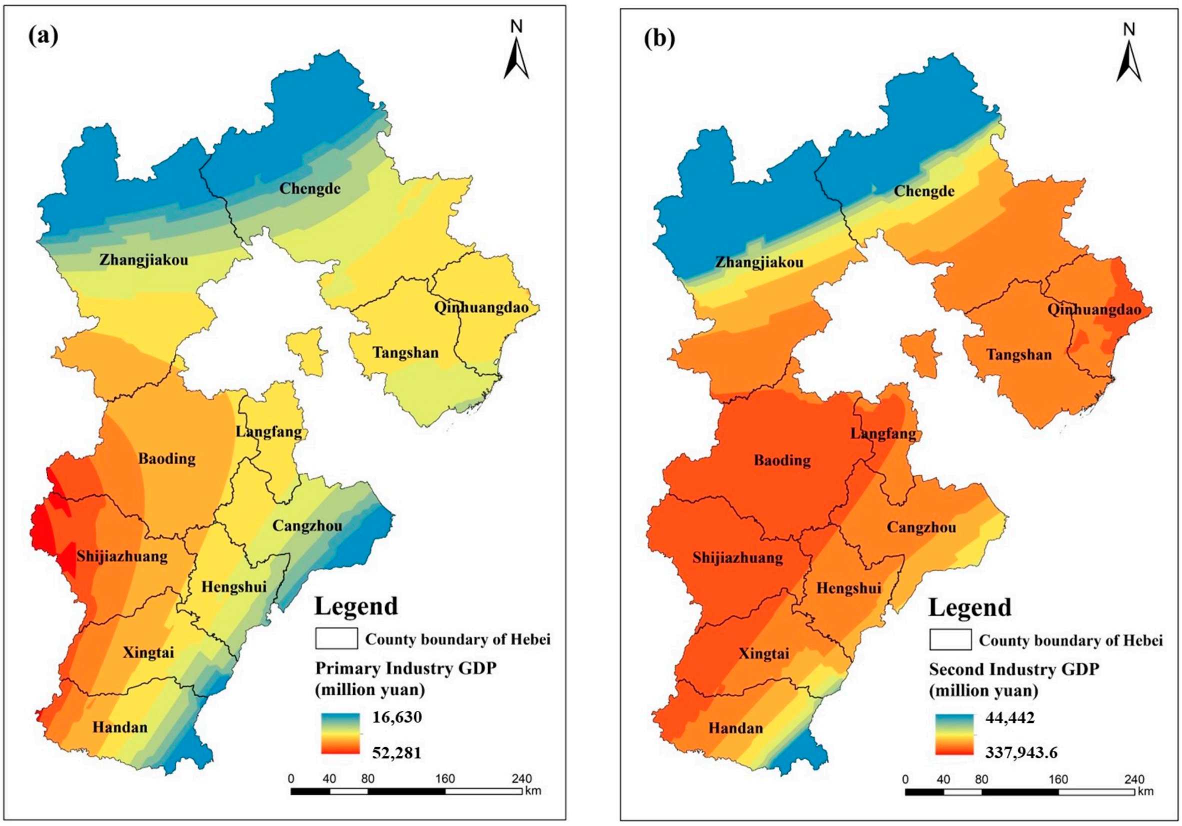

Figure 4. *Cont.*

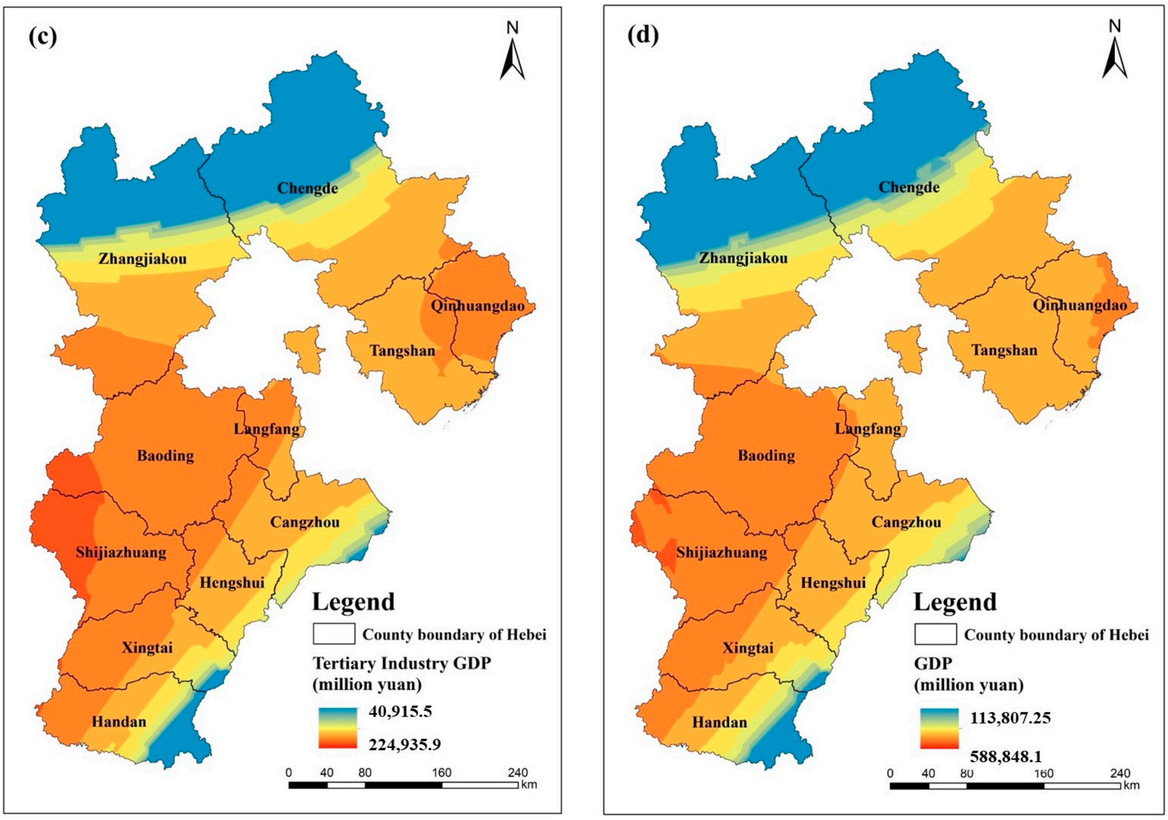

Figure 4. Spatial variation characteristics of GDP for primary industry (**a**), secondary industry (**b**), tertiary industry (**c**), and total (**d**) during 2010–2017 in Hebei.

When the GDP of each industry in Hebei Province changes, the water-use efficiency of each industry also changes. Figures 5 and 6 show the spatial–temporal variation characteristics of industrial WUE in Hebei Province from 2010–2017. Due to the need to evaluate the spatial distribution of industrial WUE in each region of the study area, the units of industrial water consumption and groundwater availability need to be converted into depth representation (mm) according to the area of the study area, so the unit of WUE after conversion is yuan/mm.

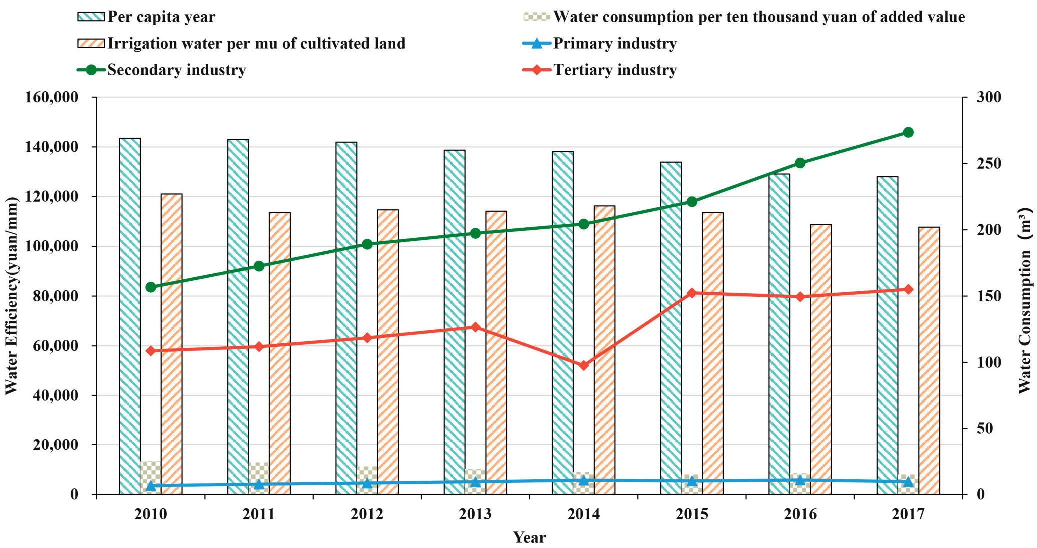

Figure 5. Temporal changes of water-use efficiency and some indexes in various industries in Hebei Province from 2010 to 2017.

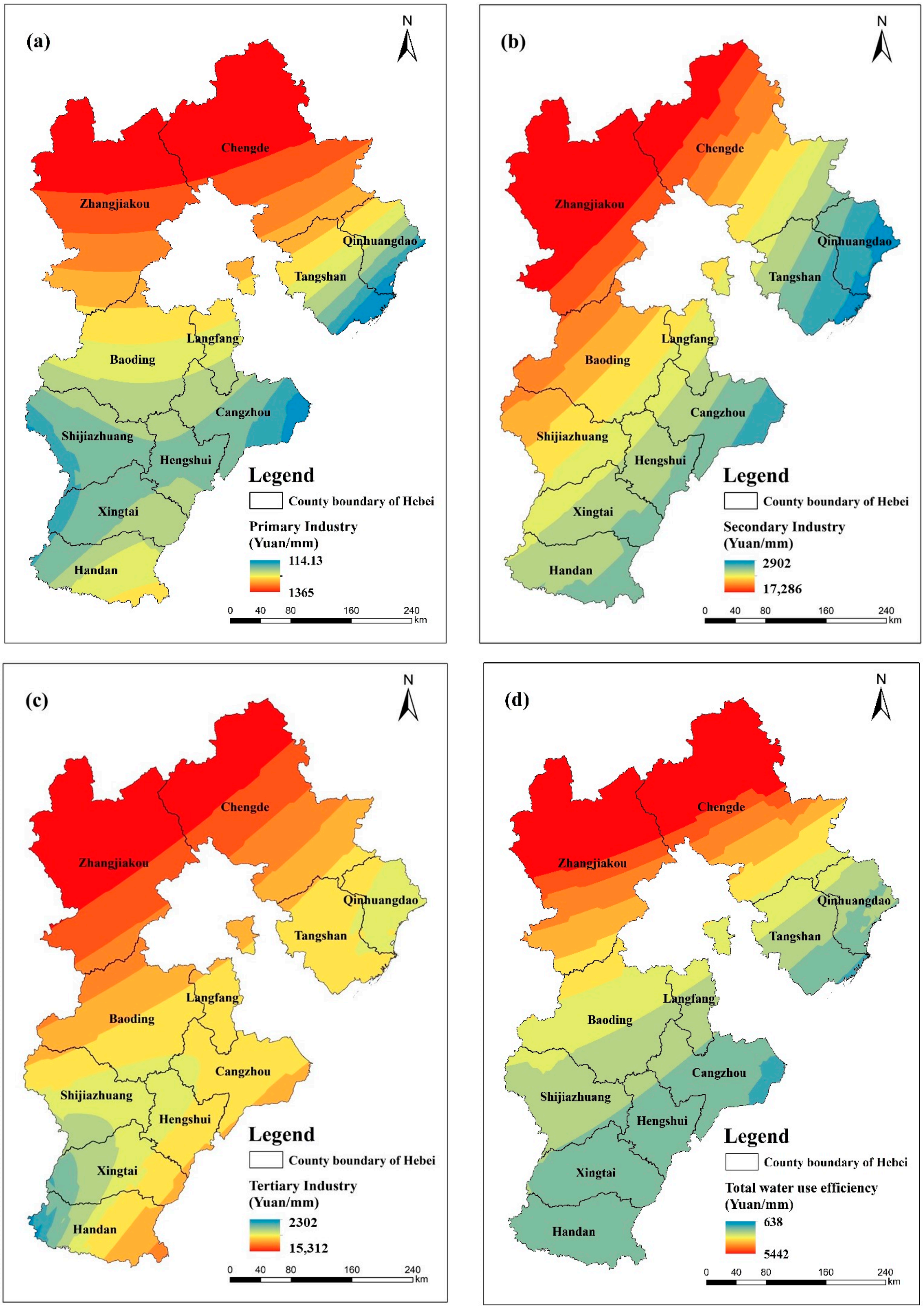

Figure 6. Spatial variation characteristics of water efficiency for primary industry (**a**), secondary industry (**b**), tertiary industry (**c**), and total industries (**d**), during 2010~2017 in Hebei.

As can be seen from Figure 5, the change range of WUE in the secondary industry and the tertiary industry is on the rise, with an increase rate of 74.6% and 42.7%, respectively, while the WUE in the primary industry increases first and then decreases mainly due to the vigorous development of agricultural water saving. Relying on the construction of small irrigation and water conservancy facilities, we will vigorously develop high-efficiency, water-saving irrigation projects, and promote the development of regional and large-scale high-efficiency, water-saving irrigation. From 2010 to 2017, the per capita annual water consumption in Hebei Province showed a downward trend year by year, from 269 m^3/year in 2010 to 242 m^3/year in 2017, with a cumulative decrease of 10.0%. The industrial water consumption per 10,000 yuan of added value decreased from 25 m^3 in 2010 to 16m^3 in 2017, with a cumulative decrease of 36.0%. The average irrigation water consumption per mu of cultivated land decreased from 227m^3 in 2010 to 204 m^3 in 2017, a cumulative decrease of 10.1%.

In terms of spatial distribution (Figure 6), the water-use efficiency of primary industry in Hengshui City, Xingtai City, the northwest of Handan City, Qinhuangdao City, and the southeast of Tangshan city is low, and the other is a relatively high trend. The industrial water-use efficiency in Zhangjiakou is the highest, followed by Chengde, Baoding, and Shijiazhuang. However, this cannot fully indicate that the industrial development of Zhangjiakou is better, because the cities with larger industrial GDP in Hebei Province are Tangshan and Shijiazhuang. While water efficiency is high, the goal should also be to reduce overall industrial water use rather than simply increase water efficiency. In the tertiary industry, the WUE in the westernmost area of Xingtai and Handan is low while the WUE in other areas is relatively high, and the highest is Zhangjiakou and the northern part of Chengde. The above results indicated that the total WUE in Hebei Province increased gradually from southeast to northwest.

3.2.2. Temporal and Spatial Variation Characteristics of Assessment Index

At the same time that the water-use efficiency in all industries in Hebei Province changes, the bearing capacity of groundwater resources, namely the economic scale GDP, also changes accordingly. According to the research method calculated in Section 2, the maximum resource carrying capacity of groundwater resources can be obtained by determining the water-use efficiency of the maximum years under the premise of obtaining the maximum available amount of inland water in the study period (Figure 7). The corresponding maximum carrying capacity of groundwater resources is 3154.2 billion yuan, while the actual carrying capacity of Hebei Province shows a constant changing trend, rising from 1177.7 billion yuan in 2010 to 2039.1 billion yuan in 2013, and falling to 1228 billion yuan in 2014 due to a decline in groundwater resources. It rose to 2832.2 billion yuan in 2016 and slightly decreased to 2226.1 billion yuan in 2017. On the whole, although the actual GDP supported by groundwater in Hebei Province is lower than the maximum groundwater resource carrying capacity, the growth rate of 89% from 2017 to 2010 does not mean that we can arbitrarily exploit groundwater resources for economic development. From 2010 to 2017, the actual carrying capacity of groundwater was constantly close to the maximum carrying capacity of groundwater resources, and the carrying capacity of groundwater resources was close to saturation. The proportion of economic development degree also increased from 0.37 in 2010 to 0.7 in 2017, and decreased to 0.38 in 2014. It rose to 0.89 in 2016, then fell again in 2017.

The development and utilization of Hebei Province is still faced with severe challenges. In terms of groundwater extraction, the over-extraction proportion reached 62.5% during the evaluation period. After 2015, this phenomenon improved somewhat, that is, there was no trend of overexploitation. One reason for the relief was that with the implementation of comprehensive treatment measures for groundwater overexploitation areas in North China, the exploitation volume gradually decreased, the overexploitation phenomenon was gradually curtailed, and the proportion of external water diversion gradually increased, from 171 million m^3 in 1981. It increased to 256 million m^3 in 2016 and 3.68 billion m^3 in 2019, significantly increasing the dependence on external water diversion.

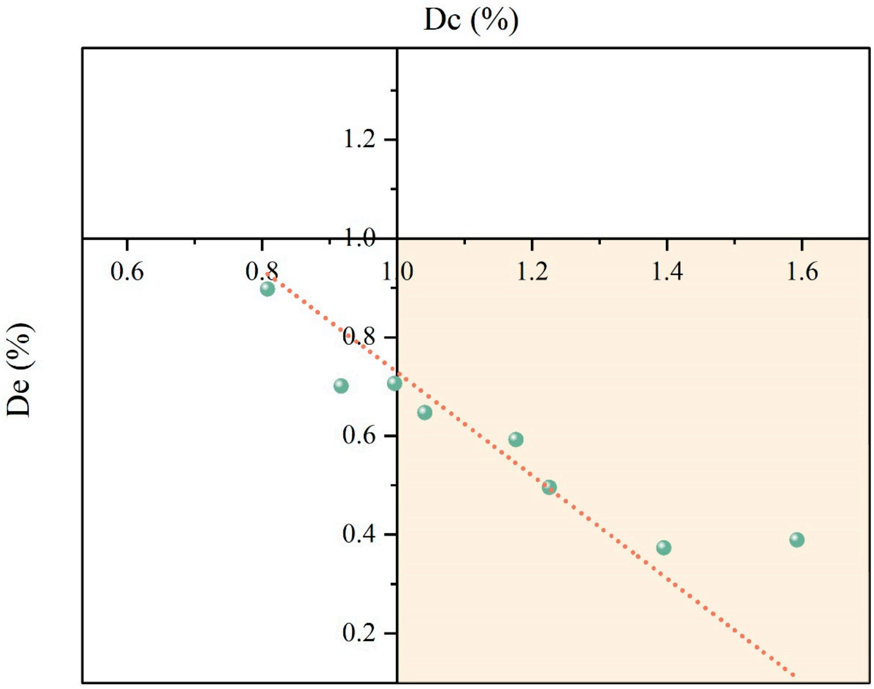

Figure 7. Relationship between groundwater exploitation and economic development supported by the groundwater resources in Hebei from 2010 to 2017.

According to the groundwater resource carrying capacity evaluation index of Hebei Province, in 2010 and 2014 there was no overdraft, accounting for 25%, 12.5%, and 62.5%, respectively. At the same time, industrial GDP is in the stage of rapid growth, and the economic development depends more and more on the exploitation of groundwater. However, the degree of groundwater exploitation also keeps increasing, which indicates that with the excessive dependence of regional economic development on groundwater resources, the evaluation index keeps rising, and the supporting capacity of groundwater resources will become more fragile.

Figure 8 shows the spatial distribution characteristics of the multi-year mean value of the groundwater resource carrying capacity assessment index in Hebei Province during the 2010–2017 time series. According to the above classification criteria, it can be concluded that only Hengshui City is not in the state of groundwater overload, with an index of 23.04%. Zhangjiakou City, Chengde City, Qinhuangdao City, Baoding City, and Xingtai City are in the state of groundwater resource overload, with an index of 41.72%, 43.71%, 45.19%, 33.95%, and 30.81%, respectively. Handan City, Shijiazhuang City, Langfang City, Cangzhou City, and Tangshan city are in the state of serious overloading of groundwater resources, with an index of 50.19%, 53.91%, 65.98%, 67.69%, and 73.53%, respectively. It shows that under the current water-use efficiency, if there is no increase in groundwater availability, groundwater resources will constitute an important constraint factor for future development. Administrative regions with over-exploitation account for 90%. From the perspective of groundwater utilization, the degree of groundwater exploitation has approached saturation state. While economic development relies on groundwater resources to a low degree, water efficiency needs to be improved and water-saving space is large. Therefore, it is still very necessary to pressure and recharge groundwater through a series of comprehensive treatment measures for over-exploitation.

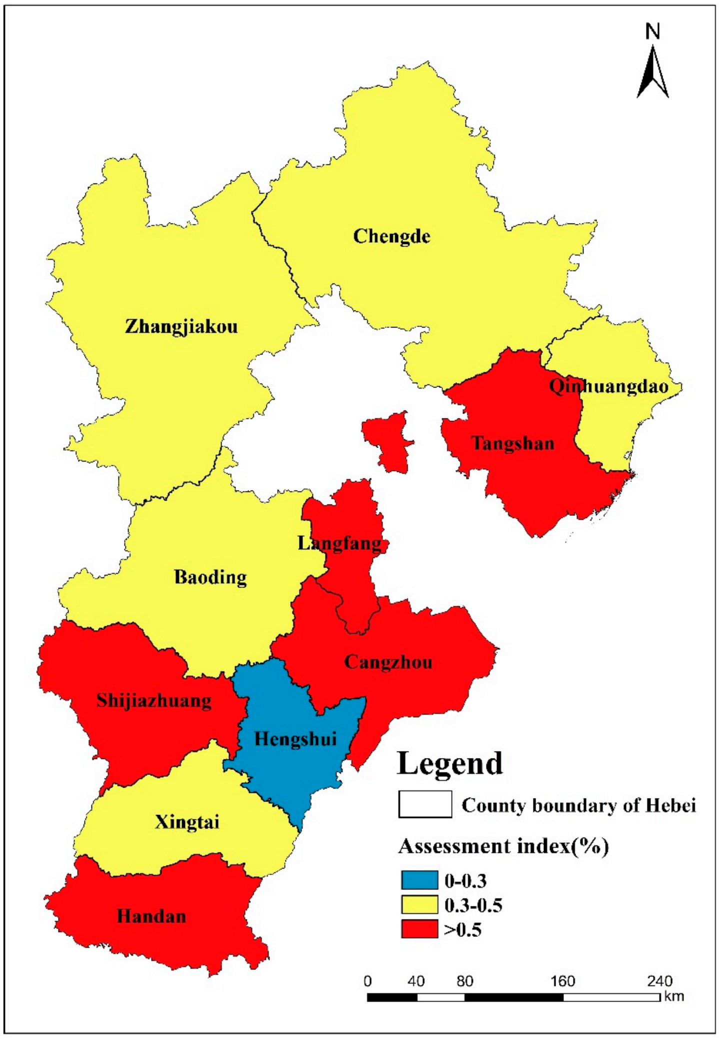

Figure 8. Spatial variation characteristics of groundwater carrying capacity assessment index in Hebei from 2010 to 2017.

3.3. Control Countermeasures and Methods of Groundwater Resource Carrying Capacity in Hebei

The water resource endowment of Hebei Province is poor and the total water resources are small, accounting for less than 1% of the total water resources of the country. The water resources per capita and per mu are at a low level in the country. Water availability is very limited. In the future, with economic and social development and population growth, especially the construction of the "Xiongan New Area" and the adjustment of economic structure, the per capita water resource utilization and available consumption will continue to decrease. Therefore, it is necessary to improve water-saving measures and increase external water sources, especially river and yellow water diversion, to maintain the economic and social development of our province [40,41].

With the transformation of economic and social development modes and the adjustment of industrial structures, the water consumption structure of our province is also changing, with a decrease in agricultural and industrial water consumption and an increase in domestic and ecological water consumption. With the development of economy and society and the continuous improvement of living standards, the structure of water use will continue to change. The increase in water consumption for living and the ecological environment of urban and rural residents puts forward higher requirements for the guarantee of water supply and the pattern of water supply will be more severe. At the same time, under the influence of surface sewage infiltration and agricultural non-point source pollution, the shallow groundwater source in some areas is also polluted to varying degrees [42]. In short, the water supply security system should be established, water resource management should be strengthened, the efficiency and benefit of water resources should be improved, and the changes between the buried depth of groundwater level and the amount of water in groundwater should be studied to determine the changes in the amount of groundwater available.

4. Conclusions

This study examines the maximum support capability of groundwater resources for local economic growth using the functional link between groundwater availability and water usage efficiency. In order to assess the carrying capacity of groundwater resources, or to establish the classification criterion of groundwater exploitation overload, the ratio of the contribution of groundwater exploitation to economic development is also utilized. The main conclusions are as follows: the comprehensive water-use efficiency in Hebei Province increased from 19,776 yuan/mm in 2010 to 35,914 yuan/mm in 2017. The total GDP of the actual carrying capacity of groundwater in Hebei Province increased rapidly from 1177.7 billion yuan in 2010 to 2226.1 billion yuan in 2017, with a growth rate of 89% in the past eight years, and the proportion of years of over-extraction in the area was 75% from 2010 to 2017. From the perspective of space, the proportion of overexploitation area in administrative distribution is 90%. The key factors to improve the carrying capacity of groundwater resources are to increase the available amount of groundwater resources by increasing and decreasing the overextraction control measures and to optimize and promote the industrial structure and water-saving technology to further improve water efficiency. According to the implementation of the follow-up project of the east route of the south-to-north water transfer project, water-resource related planning should be carried out in advance to optimize the allocation of water resources. At the same time, the water supply pattern should be adjusted in time to ensure water supply safety and promote the healthy and sustainable development of Hebei's economy and society.

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