

ORIGINAL RESEARCH ARTICLE

Spatial and temporal changes of ecological footprint of water resources in Hohhot-Baotou-Ordos-Yulin urban agglomeration and evaluation of sustainable utilization

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ABSTRACT

The Yellow River Basin is currently facing a fragile water ecological environment and severe water resources security situation, located in the Yellow River a few bends inside the city group of Hoh-hot-Baotou-Ordos-Yulin also presents the contradiction of limited water resources carrying capacity and in-creasing water demand. Based on the ecological foot-print model, the temporal and spatial variation characteristics of the ecological footprint of water resources in Hohhot-Baotou-Ordos-Yulin urban agglomeration from 2001 to 2019 are analyzed. The influencing factors of the ecological footprint are analyzed by using the correlation test, and the sustainable utilization of water re-sources in Hohhot-Baotou-Ordos-Yulin urban agglomeration is discussed. It is found that there is an obvious gap between the ecological footprint of water resources per capita and the ecological carrying capacity of Hoh-hot-Baotou-Ordos-Yulin urban agglomeration. The eco-logical pressure index is always higher than the standard value, and the ecological deficit of Ordos is the most serious. The contradiction between the social development of urban agglomeration and the utilization of water resources is more prominent, and the utilization situation of water resources is not optimistic.

Keywords: Water Resources; Ecological Footprint; Sustainable Use; Hohhot-Baotou-Ordos-Yulin Urban Agglomeration

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1. Introduction

In 2019, General Secretary of China proposed a major national strategy for ecological protection and high-quality development of the Yellow River Basin^[1], which clearly promotes the intensive use of water resources in the Yellow River Basin. The Yellow River basin is still facing fragile ecological environment and serious water resources security form problems, many problems appear in the Yellow River, but the root cause is in the watershed. Hoh-hot-Baotou-Ordos-Yulin urban agglomeration is the most important urban agglomeration in the middle and upper reaches of the Yellow River. It has the typical characteristics of fragile ecological environment and key protection areas for water and soil loss of the Yellow River. The problems of its water resources are closely related to the protection and governance of water resources in the Yellow River Basin. Therefore, the study on the sustainable utilization of water resources in Hohhot-Baotou-Ordos-Yulin urban agglomeration is of great significance to promote the high-quality development of the Yellow River Basin. The ecological footprint model, as an effective indicator of sustainable development to measure water resource consumption, has been widely used since it was proposed by William^[2], a Canadian ecological economist, in 1992. It was perfected

Wackernagel^[3] in 1996 to measure the degree of human use of natural resources and the life support service function provided by nature for human beings. The traditional ecological footprint model includes cultivated land, grassland, forest land, construction land, fossil energy land and water area. In 2001, Xu^[4] introduced the water resources account as the seventh account and included it in the ecological footprint accounting. Research at home and abroad mainly focuses on the ecological carrying capacity of water resources^[5,6], the change of ecological footprint of water resources^[7,8], the ecological security assessment of water environment^[9,10], the sustainable utilization assessment of water resources^[11,12], the ecological compensation of water resources^[13], the fairness and balance of ecological footprint^[14] and the coordinated development of water resources and economy^[15]. It is widely used in the analysis of water resources utilization in domestic provinces^[8], cities^[9], and watersheds^[5]. However, the current analysis of the ecological footprint of water resources is mostly based on small and medium-sized case studies, and there is a lack of urban agglomeration level research from the overall perspective.

Hohhot-Baotou-Ordos-Yulin urban agglomeration has a vast land area and is located along the Yellow River in the west of North China, with developed agriculture and animal husbandry and large water consumption. In 2019, agricultural production water consumption accounted for 73.92% of production water consumption and 61.27% of total water consumption. However, due to the unique landform and climate characteristics, Hohhot-Baotou-Ordos-Yulin urban agglomeration, as a typical resource-based water shortage area, maintains the local industrial development and residents' survival with the fragile water system. Based on the ecological footprint model, this paper analyzes the temporal and spatial changes and influencing factors of the ecological footprint of water resources in Hohhot-Baotou-Ordos-Yulin urban agglomeration from 2001 to 2019, so as to provide a reference for the sustainable utilization of water resources in urban agglomeration.

1. Materials and research methods

1.1 Status of the study area

Hohhot-Baotou-Ordos-Yulin urban agglomeration includes Hohhot, Baotou, Ordos and Yulin. As the "Golden Triangle" of Inner Mongolia Autonomous Region, Hohhot, Baotou and Ordos are located in the core area of the central and western part of Inner Mongolia Autonomous Region. They are arranged in a triangle shape with Yulin City and distributed in strips along the Yellow River. In the spatial pattern of "one axis, one belt and multiple districts" constructed by Hohhot-Baotou-Ordos-Yulin urban agglomeration, Hohhot plays the role of regional central city, while Baotou, Ordos and Yulin have the status of regional important node cities. In 2019, Hohhot-Baotou-Ordos-Yulin urban agglomeration gathered 18% of the population with an area of 12.58% in Inner Mongolia Autonomous Region and Shaanxi Province, consumed 16.88% of the water resources, and created 30.8% of the regional GDP¹. The ecological environment of Hohhot-Baotou-Ordos-Yulin urban agglomeration is fragile. Improper development is easy to aggravate soil erosion and sandstorm. The problem of large evaporation but small precipitation restricts the regional surface runoff. The unique climate characteristics and geomorphic pattern have caused the prominent contradiction between supply and demand of water resources in Hohhot-Baotou-Ordos-Yulin urban agglomeration. In the past 19 years, the per capita water resources occupation of Hohhot-Baotou-Ordos-Yulin urban agglomeration was 609.97 m³, between the extreme water shortage line (<500 m³) and the serious water shortage line (<1,000 m³)^[16,17]. In recent years, the population expansion and urbanization process have increased the demand for water resources, and the shortage of water resources is threatening the economic development of the urban agglomeration and the safety of residents' lives.

¹ Data source: calculated from the 2019 statistical yearbook of each city.

1.2 Data source

The data comes from the Water Resources Bulletin of Inner Mongolia Autonomous Region and Shaanxi Province from 2001 to 2019 and the statistical yearbooks of Hohhot, Baotou, Ordos and Yulin cities.

1.3 Research methods

1.3.1 Water resources ecological footprint model

The ecological footprint of water resources refers to converting the amount of water resources consumed into the production area of the corresponding account, and obtaining the comparable equilibrium value of each region after equalization, so as to measure the demand capacity of regional population economy for water resources. According to the classification of water use, water resources accounts are divided into production water account P_{EF} , domestic water account L_{EF} and ecological water account E_{EF} ^[18]. Production water includes agricultural water (including water for agriculture, forestry, animal husbandry and fishery) and industrial water. The productive consumption of water resources is calculated by calculating the ecological footprint of water resources, which provides an important basis for the sustainable use of water resources. The ecological footprint of water resources can be compared with the ecological carrying capacity of water resources to reasonably measure the regional sustainable development. The calculation equations are:

$$W_{EF} = N \times W_{ef} = N \times \gamma_w \times \frac{w}{P_w} \quad (1)$$

$$W_{EF} = P_{EF} + L_{EF} + E_{EF} \quad (2)$$

Where: W_{EF} refers to ecological footprint of water resources (hm^2); N is the number of people in the area (person); W_{ef} is the ecological footprint of water resources per capita (hm^2 /person); γ_w is the global equilibrium factor of water resources; w is the regional per capita water consumption (m^3); P_w is the global average production capacity of water resources (m^3/hm^2). Referring to the existing study^[19], γ_w was taken as 5.19, and P_w was taken as

3,140 m^3/hm^2 .

1.3.2 Water resources ecological carrying capacity model

The ecological carrying capacity of water resources measures the biological living area that the regional water resources can carry, and measures the maximum extent that the regional water resources can accommodate the population economy, indicating the supporting capacity of water resources to the regional economic and social development. Among them, at least 60% of the exploitable capacity of water resources shall be deducted to maintain biodiversity and ecological balance^[20]. The calculation equation of ecological carrying capacity of water resources is:

$$W_{EC} = N \times W_{ec} = 0.4 \times \varphi \times \gamma_w \times \frac{V}{P_w} \quad (3)$$

Where: W_{EC} is the ecological carrying capacity of water resources (hm^2); W_{ec} is the per capita ecological carrying capacity of water resources (hm^2 /person); φ is the yield factor of water resources, and its calculation equations are:

$$\varphi = P/P_w \quad (4)$$

$$P = V/S \quad (5)$$

Where: P is the average production capacity of regional water resources (m^3/hm^2); V is the total amount of regional water resources (m^3), and S is the regional area (hm^2). According to the calculation, the average production factor φ of Hohhot-Baotou-Ordos-Yulin urban agglomeration from 2001 to 2019 (Table 1).

1.3.3 Ecological profit and loss of water resources

Water resources ecological profit and loss (W_{ED}) can measure the relationship between regional water resources development and utilization and reserves^[21], and its calculation equation is:

$$W_{ED} = W_{EF} - W_{EC} \quad (6)$$

Where: $W_{ED} > 0$ is the ecological surplus of water resources, indicating that the water resources

in the region can meet the needs of population and economic development and are in a state of sustainable development; $W_{ED} < 0$ refers to the ecological deficit of water resources, which indicates that the region is short of water resources, cannot meet the balanced development with population and economy, and is in a state of unsustainable utilization.

Table 1. Water resources ecological footprint parameters of Hohhot-Baotou-Ordos-Yulin urban agglomeration

League (City)	Water resources yield factor
Hohhot	0.210
Baotou	0.090
Ordos	0.085
Yulin	0.163
Hohhot-Baotou-Ordos-Yulin urban agglomeration	0.117

1.3.4 Water resources ecological footprint intensity

Water resources ecological footprint intensity (W_{ES}) measures the utilization efficiency of water resources by calculating the ecological footprint of water resources per unit of GDP^[22], and its calculation equation is:

$$W_{ES} = W_{EF}/GDP \quad (7)$$

Where: the higher the ecological footprint required per 10,000 Yuan of GDP, the lower the level of sustainable water use.

1.3.5 Ecological pressure index of water resources

The ecological pressure index of water resources (I_{WEP}) can better measure the pressure intensity of population and society on water resources and represent the sustainability of urban water resources supply to meet demand^[23], and its calculation equation is:

$$I_{WEP} = W_{EC}/W_{EF} \quad (8)$$

Where: when $I_{WEP} > 1$, the consumption of water resources is greater than the supply, and the water resources are not sustainable; $I_{WEP} < 1$, the supply of water resources is greater than the consumption, and the water resources can be used sustainably.

1.3.6 Water resources load index model

Water resources load index (c) is an evaluation index to measure the utilization degree of water resources based on population size, regional GDP, total water resources and precipitation. Its calculation equation is^[22]:

$$c = k\sqrt{PG} / V \quad (9)$$

Where: k is the rainfall coefficient; P is the population (million persons); G is the regional GDP (100 million yuan); V is the total amount of water resources (100 million m³).

$$k = \begin{cases} 1.0 & R \leq 200 \\ 1.0 - 0.1(R - 200)/200 & 200 < R \leq 400 \\ 0.9 - 0.2(R - 200)/400 & 400 < R \leq 800 \\ 0.7 - 0.2(R - 200)/800 & 800 < R \leq 1600 \\ 0.5 & R > 1600 \end{cases} \quad (10)$$

Where: R is rainfall (mm). See **Table 2** for the classification of water resources load index.

Table 2. Classification of water resources load index

C	Level	Development and utilization degree of water resources	Continuous development evaluation
>10	I	Very high	Cross flow water transfer required
5-10	II	High	Difficulty
2-5	III	Moderate	Secondary
1-2	IV	Lower	Easier
<1	V	Low	Easily

2. Result analysis

2.1 Analysis on sustainable utilization of ecological footprint of water resources in Hohhot-Baotou-Ordos-Yulin urban agglomeration

Due to the special geographical location, the ecological environment of Hohhot-Baotou-Ordos-Yulin urban agglomeration is fragile, and the desertification phenomenon is more prominent. How to solve the contradiction between economic development and efficient utilization of water resources and realize the sustainable utilization of water resources while enjoying the resource dividend is an urgent problem to be solved in the development of Hohhot-Baotou-Ordos-Yulin urban agglomeration.

From 2001 to 2019, the average ecological footprint of water resources in Hohhot-Baotou-Ordos-Yulin urban agglomeration was 700.03 hm^2 (Figure 1A), which was generally stable. Affected by precipitation from 2001 to 2007, it fluctuated greatly; due to the expansion of the resident population, the ecological footprint of water resources per capita decreased from the maximum value of $0.73 \text{ hm}^2/\text{person}$ in 2006 to $0.65 \text{ hm}^2/\text{person}$ in 2019; the ecological carrying capacity is unstable and fluctuates greatly; the intensity of ecological footprint has decreased at an average annual rate of 13.57%, and the output efficiency of water resources in Hohhot-Baotou-Ordos-Yulin urban agglomeration has increased year by year. However, the gap between

the ecological footprint of water resources and the ecological carrying capacity has widened year by year. Water resources are difficult to support the sustainable development of population and economy in Hohhot-Baotou-Ordos-Yulin urban agglomeration, and water resources are still facing the problem of unsustainable utilization; in the ecological footprint accounts of water resources per capita, the ecological footprint of production water accounts for 95.59% (Figure 1B), in which the ecological footprint of agricultural water is the closest to the ecological footprint of water resources in terms of stock and trend, which is similar to the contribution of grassland agriculture and industry in the economy.

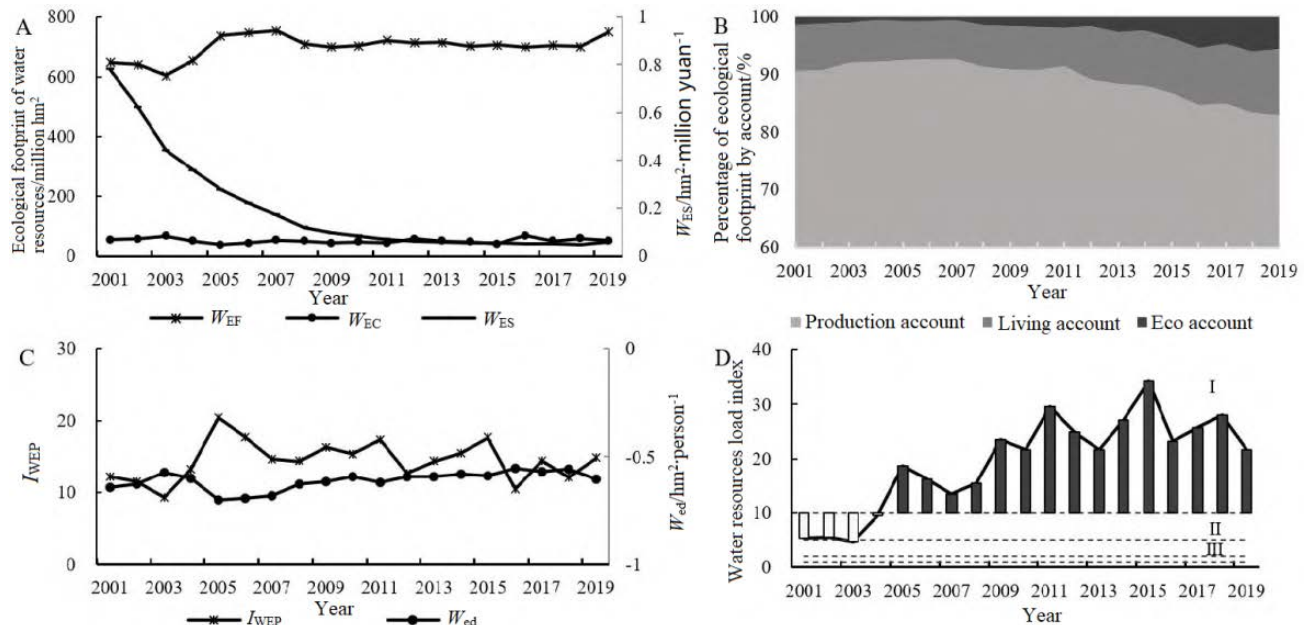


Figure 1. Ecological footprint of water resources in Hohhot-Baotou-Ordos-Yulin urban agglomeration from 2001 to 2019. Note: **A.** Ecological footprint of water resources, ecological carrying capacity of water resources and ecological footprint intensity; **B.** Ecological footprint ratio of each water account; **C.** Ecological pressure index of water resources, ecological surplus per capita; **D.** Water resources loading index.

In recent years, due to the adjustment of industrial structure and the improvement of water use efficiency, the ecological footprint of production water has decreased from 0.69 hm^2 per capita in 2006 to 0.54 hm^2 per capita in 2019, but it is still far ahead of the living account and ecological account. Industrial water and agricultural water have water-saving potential. Improving industrial water use efficiency and irrigation agricultural water use efficiency can significantly reduce the ecological footprint of water resources in urban agglomerations.

The ecological footprint of living accounts and ecological accounts has increased to varying degrees with the sharp decline in the proportion of production accounts. In particular, the proportion of ecological accounts has increased from 1.49% in 2001 to 5.64% in 2019. The importance of urban agglomerations on the ecological environment has gradually increased.

Although the ecological deficit of water resources per capita in Hohhot-Baotou-Ordos-Yulin urban agglomeration showed a downward trend

from 2001 to 2019 (Figure 1C), the ecological pressure index was always higher than 9, and the utilization of water resources had exceeded the safe state range. Besides, the water resources load index (Figure 1D) was grade III in 2003, and it was difficult to continue the development of water resources in other years. Since 2004, the water resources load index has averaged 22.99. Inter basin water transfer is required to maintain normal economic development and people's lives. The development and utilization of water resources has reached a high level, and the potential for further development is relatively small. The contradiction between social development and water resources utilization intensifies the pressure on water resources. The total amount of water resources is not enough to meet the agricultural, industrial production and people's lives of Hohhot-Baotou-Ordos-Yulin urban agglomeration. It is difficult to achieve the balanced development of regional population and economy, and is in a state of unsustainable utilization.

2.2 Spatial and temporal differences of water resources ecological footprint in Hohhot-Baotou-Ordos-Yulin urban agglomeration

From 2001 to 2019, there were great differences in the ecological footprint of water resources in Hohhot-Baotou-Ordos-Yulin urban agglomeration (Table 3). From the perspective of time dimension, the ecological footprint of water resources and the profit and loss of water resources in Yulin have fluctuated the most in the past 19 years, and the ecological carrying capacity and ecological pressure index in Ordos have changed the most; from the perspective of spatial dimension, the regional difference of ecological pressure index of water resources is the largest, and the regional difference of ecological footprint and ecological profit and loss is gradually decreasing, but the spatial variation coefficient of ecological carrying capacity is between 0.45 and 0.77, and the inter-annual variation of the difference is large.

Table 3. Variation coefficient of water resources ecological footprint of Hohhot-Baotou-Ordos-Yulin urban agglomeration from 2001 to 2019

Dimension	Project	Water resources ecological footprint	Ecological carrying capacity of water resources	Ecological profit and loss of water resources	Ecological pressure index of water resources
Time coefficient of variation	Hohhot	0.080	0.177	0.097	0.219
	Baotou	0.085	0.155	0.090	0.199
	Ordos	0.049	0.250	0.054	0.297
	Yulin	0.127	0.243	0.176	0.236
Space coefficient of variation	2001	0.424	0.695	0.513	0.794
	2003	0.399	0.709	0.518	0.704
	2005	0.402	0.655	0.455	0.770
	2007	0.394	0.486	0.427	0.766
	2009	0.370	0.531	0.413	0.776
	2011	0.362	0.515	0.406	0.731
	2013	0.306	0.614	0.361	0.767
	2015	0.300	0.622	0.342	0.820
	2017	0.267	0.762	0.321	0.785
	2019	0.283	0.540	0.314	0.795

From 2001 to 2019, the per capita ecological footprint of the four cities of Hohhot-Baotou-Ordos-Yulin urban agglomeration fluctuated little (Figure 2). Hohhot surpassed Baotou only in 2001–2003, and the ecological footprint of water resources in other years basically ranked from large to small as Ordos > Baotou > Hohhot > Yulin.

Ordos City covers a large area and consumes a lot of water, but the number of permanent residents is only 53% of Yulin city. Therefore, the ecological footprint of water resources per capita is much higher than that of the other three cities, showing a decreasing trend year by year. In 2003, the rate of decline reached 10.05%. Although the rate of de-

cline has slowed down since then, it is still more than twice that of the three cities in 2019. Yulin has a low ecological footprint of per capita water resources due to its small land area and large population. In the past 19 years, the ecological carrying capacity of the three cities of Hohhot-Ordos-Yulin has little difference, and the change trend is similar. However, Baotou has a stable change, which is always lower than the other three cities, and the av-

erage value is 69%–75% lower than that of Hohhot-Ordos-Yulin. The intensity of ecological footprint has decreased year by year since 2001. Although Ordos City is significantly higher than the other three cities, it has the largest decline, reaching 95.29%. The water use efficiency of the four cities in the urban agglomeration is improving, especially in Ordos.

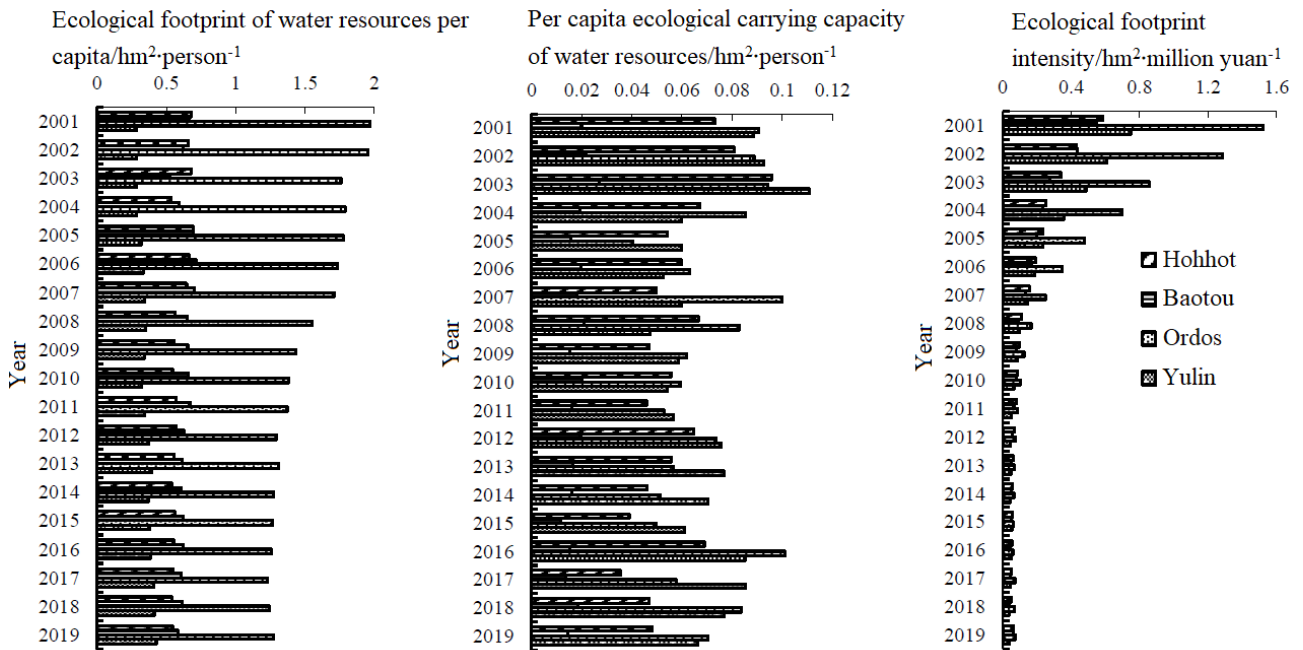
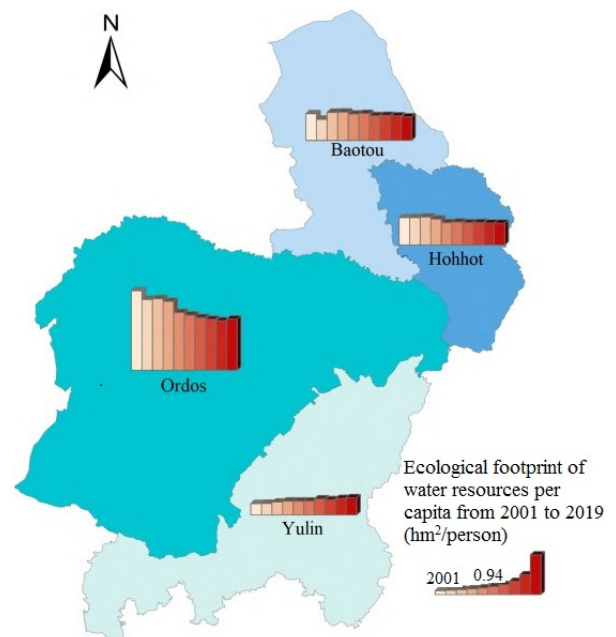


Figure 2. Water resources ecological footprint per capita, ecological carrying capacity per capita and ecological footprint intensity in Hohhot-Baotou-Ordos-Yulin urban agglomeration from 2001 to 2019.

From 2001 to 2019, there was ecological deficit in water resources in the four cities of Hohhot-Baotou-Ordos-Yulin urban agglomeration, and its change trend and range were very similar to the ecological footprint of water resources per capita (Figure 3). Water resources were in a state of unsustainable utilization. Ordos has the largest total water use and ecological footprint. Although the per capita ecological deficit is decreasing, it is still $-1.20 \text{ hm}^2/\text{person}$ in 2019, which is much higher than $-0.49 \text{ hm}^2/\text{person}$ in Hohhot, $-0.57 \text{ hm}^2/\text{person}$ in Baotou and $-0.36 \text{ hm}^2/\text{person}$ in Yulin. Among the four cities, only Yulin has a rising ecological deficit of water resources, and the pressure on water resources is still increasing.



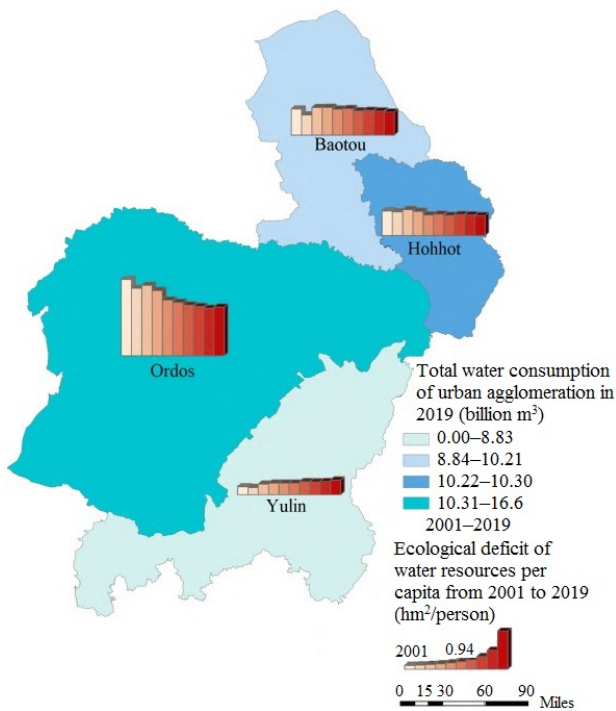


Figure 3. Spatial patterns of water resources ecological footprint per capita and water ecological deficit in Hohhot-Baotou-Ordos-Yulin urban agglomeration from 2001 to 2019.

2.3 Inspection of influencing factors

In order to further explore the factors affecting the ecological footprint of water resources in Hoh-

hot-Baotou-Ordos-Yulin urban agglomeration, the correlation test was carried out by using Stata. See **Table 4** for the correlation analysis results of per capita water resources ecological footprint. In the correlation analysis between population scale factor and water resources ecological footprint, “population” has a significant negative correlation with the water resources ecological footprint of Hohhot and Ordos (the correlation coefficient is -0.785^{**} , -0.974^{**}), “urbanization” has a significant negative correlation with Ordos (the correlation coefficient is -0.927^{**}), while it has a significant positive correlation with Yulin (the correlation coefficient is 0.930^{**}). Except Baotou City, economic development has a significant impact on all cities; the water consumption for farmland irrigation in Baotou City and Ordos City, the water consumption for forestry, animal husbandry and fishery in Hohhot City and Yulin City, the industrial water consumption and domestic water consumption in Yulin city all have a great impact on the ecological footprint of water resources.

Table 4. Correlation analysis of per capita water resources ecological footprint of Hohhot-Baotou-Ordos-Yulin urban agglomeration

Project	Index	Urban Agglomera- tion	Hohhot	Baotou City	Ordos City	Yulin City
Population size	Population/million	-0.666	-0.785 ^{**}	-0.239	-0.974 ^{**}	-0.312
	Urbanization rate/%	-0.657	-0.631	-0.164	-0.927 ^{**}	0.930 ^{**}
	GDP/100 million yuan	-0.740 [*]	-0.751 ^{**}	-0.192	-0.968 ^{**}	0.935 ^{**}
Economic devel- opment	Secondary industry production value/100 million yuan	-0.722 [*]	-0.774 ^{**}	-0.125	-0.961 ^{**}	0.922 ^{**}
	Tertiary industry production value/100 million yuan	-0.747 [*]	-0.733 [*]	-0.239	-0.966 ^{**}	0.939 ^{**}
	Total amount of farmland irrigation water/100 million m ³	0.730 [*]	0.664	0.735 [*]	0.920 ^{**}	-0.446
Water	Total water consumption for forestry, animal husbandry and fishery/100 million m ³	-0.290	0.964 ^{**}	-0.288	-0.296	0.903 ^{**}
	Industrial water consumption/100 million m ³	-0.269	-0.420	0.294	-0.637	0.946 ^{**}
	Domestic water consumption/100 million m ³	-0.602	-0.600	0.080	-0.873 ^{**}	0.847 ^{**}

Note: ^{**} indicates significant correlation at the level of 1%, ^{*} indicates significant correlation at the level of 5%, the same as below.

See **Table 5** for the correlation analysis results of per capita water resources ecological carrying capacity. The per capita ecological carrying capacity of water resources in Hohhot is significantly negatively correlated with the “population” (the correlation coefficient is -0.780^{**}). Water resources reserves, especially surface water resources, are

significantly correlated with the ecological carrying capacity of water resources in Hohhot, Baotou and Yulin, with correlation coefficients of 0.760^{**} , 0.750^{**} , 0.847^{**} , respectively. Effective water pollution control has a very significant impact on improving the ecological carrying capacity of water resources per capita in Baotou.

Table 5. Correlation analysis of per capita water resources ecological carrying capacity of Hohhot-Baotou-Ordos-Yulin urban agglomeration

Project	Index	Urban agglomeration	Hohhot	Baotou City	Ordos City	Yulin City
Population size	Population/million	-0.510	-0.780**	-0.667	-0.413	0.379
Climatic conditions	Annual average temperature/°C	-0.152	-0.127	-0.174	0.029	0.096
	Annual average rainfall/mm	0.596	0.488	0.596	0.650	0.473
Water resources reserves	Surface water resources/100 million m ³	0.821**	0.760**	0.750**	0.128	0.847**
	Groundwater resources/100 million m ³	0.820**	0.725*	0.856**	0.613	0.670
Pollution control	Industrial wastewater discharge/million tons	-0.370	-0.413	0.716*	-0.277	0.021
	Sewage treatment capacity/million tons	-0.247	-0.531	-0.605	-0.290	0.050

3. Conclusion and discussion

The middle and upper reaches of the Yellow River are important water producing areas of the Yellow River. Its water quantity and quality affect the economic and social development of cities in the lower reaches. As the most important urban agglomeration in the middle and upper reaches of the Yellow River, the shortage of water resources is becoming increasingly serious. The limited carrying capacity of water resources and the contradiction between supply and demand of water resources have not only become the bottleneck restricting the economic and social development and people's living standards of Hohhot-Baotou-Ordos-Yulin urban agglomeration. It also brings a series of problems to the fragile ecological environment in the region. The study on the temporal and spatial changes of water resources ecological footprint of Hohhot-Baotou-Ordos-Yulin urban agglomeration is helpful to analyze the problems existing in water resources utilization, understand the water resources carrying capacity of each league city, and has a certain reference value for improving the mode of water resources utilization and promoting the intensive utilization of water resources in the Yellow River Basin.

(1) The ecological footprint of water resources per capita in Hohhot-Baotou-Ordos-Yulin urban agglomeration is decreasing year by year, in which the agricultural water account accounts for a large proportion. The per capita ecological carrying capacity of water resources fluctuates greatly, and the

change is relatively unstable; Hohhot-Baotou-Ordos-Yulin urban agglomeration has a large ecological deficit of water resources, the supply and demand of water resources are seriously unbalanced, and the water resources are in a state of unsustainable development; the ecological footprint intensity of water resources is decreasing year by year, but the water ecological pressure index is large, and the utilization of water resources is in a very unsafe state.

(2) Among the four cities, Baotou and Ordos have a relatively severe water resource situation, while the ecological deficit of water resources in Yulin is still rising year after year.

(3) With the urbanization process of Hohhot-Baotou-Ordos-Yulin urban agglomeration, such phenomena as the expansion of population scale and the expansion of construction land have accelerated the consumption of water resources. The huge pressure of urban water ecosystem has oppressed the ecological carrying capacity of water resources. Pollution control is conducive to the improvement of water resources carrying capacity of heavily industrialized Baotou city.

Hohhot-Baotou-Ordos-Yulin urban agglomeration should strengthen the water-saving transformation of chemical industry and agriculture, improve the utilization rate of water resources, and promote the development of water-saving industries; build a water resources supply guarantee system for mutual aid of multiple water sources, accelerate the construction of cross regional water rights trading platforms, and establish a stepped water

price system; implement the long-term governance of rivers and lakes, build water conservancy projects, do a good job in water and soil conservation, return farmland to forests and grasslands, and make reasonable ecological compensation; we will encourage water resources protection and water pollution control to ensure that economic development is commensurate with the carrying capacity of the water environment.

In this paper, the study on water resources ecological footprint of Hohhot-Baotou-Ordos-Yulin urban agglomeration does not involve the accounting of water quality ecological footprint, so the calculated value of ecological footprint is small. The accounting of water quality ecological footprint of Hohhot-Baotou-Ordos-Yulin urban agglomeration needs further study.

Conflict of interest

The authors declare that they have no conflict of interest.

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