Analysis based on water ecological footprint for sustainable utilization of water resources in the Guanzhong Plain, China

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Abstract. Dynamically analysed the sustainable development of water resources in Guanzhong Plain by calculating the water ecological footprint, along with its depth and breadth, the water ecological carrying capacity and the ecological pressure index of each city from 2011 to 2016, and give some suggestions to improve the water use efficiency. The results showed that: (1) The average value about water ecological footprint of the Guanzhong Plain was $8.6558 \times 10^4$ hm$^2$ and it was 3.20 about water ecological pressure index. So we could conclude that the water demand exceeds supply and the development of water resources sustainable exploration is low. (2) Affected by climate and rainfall, the water ecological footprint size of the Guanzhong Plain is in a down trend. Compared with other cities, Yangling County gets the lowest. (3) The result that the water ecological footprint depth of the Guanzhong Plain all higher than 1 shows that the water resources do not meet the need of its own requirements, and the sustainable utilization of water resources is low. However, among all the cities in the Guanzhong Plain (Xi’an, Baoji, Weinan, Xianyang, Tongchuan and Yangling County), Baoji has water ecological surplus, its water resources can basically meet the need of human own requirements, and water resources are also sustainable. Here we give some suggestions as follows: Guanzhong Plain can optimize the spatial allocation of water resources by inter-annual water transfer. For example, continue to improve facilities in the Hanjiang to Weihe River Project to meet water demand. Meanwhile, cities should also adjust their industrial structure according to their own water resource and distribution. On the basis of its own regional advantage, develop the economy so as to achieve the water resources sustainable utilization.

1. Introduction
Water resource is the core and foundation of the sustainable economic and social development in Guanzhong Plain. The Guanzhong Plain is located in the central of Shaanxi Province, Baoji to the west, Tongguan to the east, Qinling Mountains to the south and north link to the Bei-mountian near the Weihe River. There has flat terrain, fertile soil and warm climate. The irrigated agriculture has been famous since ancient times, where abounds with wheat and cotton. The Guanzhong Plain consist of Xi’an, Baoji, Xianyang, Weinan, Tongchuan and Yangling County, which is the core area of Guanzhong-Tianshui Economic Zone, and the important bearing areas in “The Belt and Road” program [1]. With the increase of population and development in economic society, the conflicts about competition for water among all walks of life become sharper. The increase of industrial and agricultural water leads to the water resource shortage and the water environment deterioration,
coupled with the new water demand for ecological construction. The water shortage and water pollution make the water supply and demand conflict more conspicuous [2], which also caused serious obstacles to the sustainable development of the economy, society environment. Water shortage has become a major restrictive factor in the sustainable development. Therefore, the sustainable use of water resource is an important strategic issue in the development of Guanzhong Plain. This paper took the Guanzhong Plain as a research object. Based on the relevant scholar results, we established a water ecological footprint model, and combined the water ecological footprint with the water ecological carrying capacity to reckon the water ecological pressure index, the breadth and depth of the water ecological footprint, the Ten thousand yuan GDP water ecological footprint. At last, we proposed some suggestions based on the analysis and comparison of the Guanzhong Plain water resources sustainable utilization.

2. Research methods and data sources

2.1. The water ecological footprint model establishment

Water ecological footprint transform water resources consumption into water area, which means the ecological productive area required to maintain water consumption and absorb water pollution under a certain population and economic scale [3]. The sustainable use of water resource is related to the water volume and water quality in the area. Therefore, we divided the water ecological footprint into two parts, the one is “freshwater ecological footprint” and the other is “water pollution ecological footprint”. Moreover, we calculated it.

- Freshwater ecological footprint

In this paper, the calculation of freshwater ecological footprint mainly includes the agricultural water ecological footprint, industrial water ecological footprint, domestic water ecological footprint, and eco-environment water ecological footprint. The calculation formula is as follows.

\[ EF_{wr} = P \cdot e_{fr} = \gamma \cdot \frac{W}{\omega} \]  

Where \( EF_{wr} \) is the regional freshwater ecological footprint; \( P \) is the number of people in the area; \( e_{fr} \) is the per capita water ecological footprint, and the unit is hm\(^2\); \( \gamma \) is the global water balance factor; \( W \) is the total water resources; \( \omega \) is the global average production capacity of water resources. These main parameters are referenced by Fan [4] and Huang [5], \( \gamma \) is 5.19, \( \omega \) is 3140 m\(^3\)/hm\(^2\).

- Water pollution ecological footprint

According to the Shaanxi Environmental Status Bulletin (2011-2016), the main pollution indicators affecting the water quality in the Guanzhong Plain are the chemical oxygen demand (COD) and ammonia nitrogen (NH) emitted. Therefore, we only calculated the COD and NH, the formulas are as follows.

It can be concluded that the main pollution indicators that affect the water quality in the Hexi Inland River Basin are chemical oxygen demand (COD) and ammonia nitrogen.

\[ EF_{wq} = \max(EF_{COD}, EF_{NH}) \]  

\[ EF_{COD} = C_{COD}/P_{COD} \]  

\[ EF_{NH} = C_{NH}/P_{NH} \]  

Where \( EF_{wq} \) is the regional water pollution ecological footprint; \( EF_{COD} \) is the regional chemical oxygen demand pollution of water ecological footprint; \( EF_{NH} \) is the regional ammonia nitrogen pollution water ecological footprint; \( C_{COD} \) is the emission for regional COD (t); \( P_{COD} \) is the global average ability to absorb chemical oxygen demand in waters; \( C_{NH} \) is regional NH emissions; \( P_{NH} \) is the ammonia nitrogen global average capacity. \( P_{COD} \) is 120 t/hm\(^2\), \( P_{NH} \) is 25 t/hm\(^2\).
2.2. Water ecological carrying capacity
Water ecological carrying capacity means the ability of a region's maximum supply of water resources to support the sustainable development of resources, environment and society in a specific historical development stage [5]. In the case of emphasizing the satisfaction of ecological demand, the largest land area provided by regional water production capacity. This paper referred to the literature on the ecological carrying capacity theory of Sun [6] and Daly [7]. The formula is as follows.

\[ EC_w = 0.4 \times \gamma_w \times \theta \times Q / \omega \]  

(5)

Where \( EC_w \) is water ecological capacity, \( \theta \) is regional water resource production factor, \( Q \) is total amount of regional water resource, Referring to Sun Caizhi's study on the production factors of various provinces across the country, the value of \( \theta \) is 0.59 [8].

2.3. Indicators of sustainable utilization of water resources

- Water ecological pressure index
  
  The water ecological pressure index is the ratio of the water ecological footprint to the water ecological carrying capacity [9]. The calculation formula is as follows.
  
  \[ EQ = \frac{EF_w}{EC_w} \]  

(6)

If the calculation result belongs to (0, 1) interval, the water supply in this area is greater than the consumption, and the utilization of water resources is safe. If the calculation result is 1, it proves a balance of supply and demand of water in this area, and at this time it is in a critical state. If the calculation result is greater than 1, the water supply in the area is less than the consumption, and at this time, water resources are unsustainable. The greater the calculation result is, the greater threat the water resources received.

- Size and depth of water ecological footprint
  
  The size of the water ecological footprint represents the occupancy level of water resources in the process of social-economic development [10]. The water ecological footprint depth represents the degree of human consumption of water resources in social-economic production and life. According to the research results of the ecological footprint, we derived a formula of the water ecological footprint size and depth as follows.
  
  Water ecological footprint size:
  
  \[ EF_{ws} = \min(EF_w, \ EC_w) \]  

(7)

Water ecological footprint depth:

\[ EF_{wds} = 1 + \min(\frac{EF_w}{EC_w}) \]  

(8)

If \( EF_w \leq EC_w \), it indicates that the total flow of water resources in the area can meet the needs of its own development, then \( EF_{ws} = 1 \). If \( EF_w > EC_w \), it shows that the total flow of water resources in the area can hardly meet the needs of human social life and production, and it needs to use water resources stock, then \( EF_{wds} > 1 \); The greater the \( EF_{ws} \) is, the more water could be consumed and the water resources be more unsustainable.

- Ten thousand yuan GDP water ecological footprint
  
  The ten thousand GDP water ecological footprint is to evaluate the degree of sustainable utilization of water resources by combining the water resources and GDP [11]. It expresses how much number of water ecological footprints each ten thousand yuan GDP need, and its formula is as follows.
  
  \[ \text{Ten thousand yuan GDP water ecological footprint} = \frac{EF_w}{\text{GDP}} \]  

(9)

Where the smaller the calculation result is, the higher efficiency of water use is.

2.4. Data source
This paper selects the Guanzhong Plain (Xi'an, Baoji, Xianyang, Weinan, Tongchuan, and Yangling County) as the research area. The data mainly comes from Shaanxi Statistical Yearbook (2012-2017) and Shaanxi Water Resources Bulletin (2011-2016), Shaanxi Status Environmental Bulletin (2011-2016).

3. Results and analysis

3.1. Dynamic analysis of water ecological footprint

- Water ecological footprint

The results calculated according to equations (1-4) are as follows (table 1, figure 1). Figure 1 shows that the overall water ecological footprint of the Guanzhong Plain is on an upward trend, reaching the maximum in 2015 and starting to decline from 2016. The growth rate in 2015 is also the fastest. Table 1 shows that the average annual water ecological footprint in the Guanzhong Plain was 8.6558×10^6 hm^2 in 2011-2016. The average water ecological footprint of Xi'an, Baoji, Weinan, Tongchuan, Yangling County and Xianyang is 2.8556×10^6 hm^2, 1.1986×10^6 hm^2, 2.5622×10^6 hm^2, 1.4848×10^3 hm^2, 6.2530×10^1 hm^2, 1.8284×10^6 hm^2, Xi'an has the largest water ecological footprint, Weinan is the second, Xianyang is the third, and Yangling County is the smallest. The water ecological footprints in the Guanzhong Plain vary from city to city, and the water resources allocation and utilization are extremely unbalanced.

**Table 1.** Water ecological footprint values of each city (×10^4 hm^2).

| Year | Xi'an   | Baoji  | Weinan | Tongchuan | Yangling | Xianyang | Guanzhong Plain |
|------|---------|--------|--------|-----------|----------|----------|-----------------|
| 2011 | 266.277 | 106.279| 258.343| 15.206    | 5.785    | 185.452  | 837.342         |
| 2012 | 272.227 | 117.849| 255.864| 15.041    | 6.281    | 187.600  | 854.863         |
| 2013 | 280.161 | 121.155| 255.203| 14.876    | 6.281    | 181.981  | 859.656         |
| 2014 | 288.591 | 110.412| 259.169| 15.041    | 6.116    | 181.981  | 861.309         |
| 2015 | 300.822 | 130.907| 258.343| 15.041    | 6.446    | 183.964  | 895.523         |
| 2016 | 305.284 | 132.560| 250.409| 13.884    | 6.611    | 176.030  | 884.779         |
| Mean | 285.560 | 119.860| 256.222| 14.848    | 6.253    | 182.835  | 865.579         |

**Figure 1.** Dynamic change of water ecological footprint.

- Total freshwater ecological footprint

Calculated the index of freshwater ecological footprint in the Guanzhong Plain from 2011 to 2016 based on the freshwater ecological footprint model. Table 2 shows that the average of water ecological footprint, industrial water ecological footprint, domestic water ecological footprint, ecological water ecological footprint, and total freshwater ecological footprint in the Guanzhong Plain during the period from 2011 to 2016 were respectively 5.1771×10^6 hm^2, 1.4548×10^6 hm^2, 1.7093×10^6 hm^2, 3.1460×10^5 hm^2 and 8.6558×10^6 hm^2.
Table 2. Freshwater ecological footprint index (×10^4 hm^2).

| Year | Agricultural Ecological footprint | Industrial Ecological footprint | Domestic Ecological footprint | Ecological water Ecological footprint | Total Freshwater Ecological footprint |
|------|----------------------------------|-------------------------------|-------------------------------|--------------------------------------|-------------------------------------|
| 2011 | 515.364                          | 137.188                       | 161.816                       | 22.975                               | 837.342                             |
| 2012 | 523.132                          | 139.337                       | 168.923                       | 23.471                               | 854.862                             |
| 2013 | 515.033                          | 143.965                       | 171.733                       | 28.925                               | 859.565                             |
| 2014 | 522.802                          | 148.593                       | 157.849                       | 32.066                               | 861.309                             |
| 2015 | 518.669                          | 154.693                       | 181.485                       | 39.669                               | 895.523                             |
| 2016 | 511.232                          | 148.097                       | 183.799                       | 41.652                               | 884.779                             |
| Mean | 517.705                          | 145.480                       | 170.934                       | 31.460                               | 866.759                             |

Figure 2. Dynamic change of freshwater ecological footprint.

Figure 2 shows that the agricultural ecological water footprint in the Guanzhong Plain during 2011-2016 is much higher than any other types of water ecological footprint, accounting for 59.81% of the total freshwater ecological footprint, followed by the ecological footprint of domestic water use, which accounts for 19.75% of the total freshwater ecological footprint. The third is the ecological footprint of industrial water, which accounts for 16.81%. The proportion of ecological water ecological footprint is the lowest. Total freshwater ecological footprint shows a fluctuating upward trend, reaching a maximum of 8.9552×10^6 hm^2 in 2015, and dropped to 8.8478×10^6 hm^2 in 2016. In 2012, 2014 and 2015, the agricultural ecological water footprint is more than the average value. During the study period, the trend of agricultural water ecological footprint was relatively stable. The improvement of agricultural irrigation water use efficiency has a significant effect on reducing the ecological footprint of freshwater. The proportion of agricultural water in the Guanzhong Plain is relatively high, which showed a problem in the water utilization structure. The water footprint of industrial water in 2011-2015 showed a smaller increasing trend, and it decreased from 2016, and the degree of declining was also small. The ecological footprint of domestic water is in a state of fluctuating growth, which only declined in 2014. The ecological footprint of ecological water is increasing, so the whole water ecological footprint is in an ascent stage. With the development of economy, people's living environment has deteriorated, especially the aquatic ecological environment. For this reason, the governments of various administrative regions in the Guanzhong Plain began to pay more attention to the problem of occupied ecological water and strengthened the control of ecological water.

* Ecological footprint of water pollution

The core of the water pollution ecological footprint is the changes of water quality, that is, the loss of water resources caused by water pollution. According to the water pollution ecological footprint model, we calculated the COD and NH pollution water ecological footprints in the Guanzhong Plain.
during 2011-2016 (table 3, figure 3). From table 3, we analyzed that the COD water pollution ecological footprint in the Guanzhong Plain got the largest in 2013, which was 2.4607 hm$^2$. At this time, the COD emission load also reached the maximum. In recent years, the COD pollution water ecological footprint was greater than the NH pollution water ecological footprint, approximately 3 times of the NH pollution ecological footprint. It can be seen from figure 3 that there is a downward trend of the water pollution ecological footprint in the Guanzhong Plain, showed that the water pollution control in the Guanzhong Plain achieved effects, but it should also continue to focus on the governance of water ecology, especially in reducing COD water pollution ecological footprint.

### Table 3. Indicators of water pollution ecological footprints.

| project                                      | 2011     | 2012     | 2013     | 2014     | 2015     | 2016     |
|----------------------------------------------|----------|----------|----------|----------|----------|----------|
| COD emissions (ten thousand tons)           | 17.4707  | 16.7926  | 17.8647  | 14.2352  | 11.2279  | 4.9526   |
| NH emissions (ten thousand tons)             | 1.3179   | 1.1437   | 1.2659   | 1.3706   | 0.5018   | 0.1128   |
| COD water pollution ecological footprint     | 2.4064   | 2.3130   | 2.4607   | 1.9607   | 1.5465   | 0.6822   |
| NH Water Pollution Ecological Footprint (hm$^2$) | 0.8713   | 0.7561   | 0.8370   | 0.9061   | 0.3318   | 0.0746   |
| Water pollution ecological footprint (hm$^2$) | 2.4064   | 2.3130   | 2.4607   | 1.9607   | 1.5465   | 0.6822   |

**Figure 3.** Dynamic change of water pollution ecological footprint.

### 3.2. Water ecological carrying capacity

The water ecological carrying capacity can reflect the overall situation of the social-economic conditions and natural resources simultaneously. It can be seen from figure 4 that the inter-annual changes in water ecological carrying capacity in Guanzhong Plain changed a lot, from the maximum
value of $4.4740 \times 10^6$ hm$^2$ in 2011 became the minimum value of $1.9947 \times 10^6$ hm$^2$ in 2016, the maximum is twice the minimum. In other years, the water ecological carrying capacity has decreasing trend. Overall, the water ecological carrying capacity of the Guanzhong Plain has continued to decline.

**Figure 5.** Dynamic change of water ecological carrying capacity.

As can be seen from figure 5, the water ecological carrying capacity of Baoji in the Guanzhong Plain is the largest, but it is continuously decreasing and the rate of reduction is the fastest. The water ecological carrying capacity of Tongchuan is the smallest, although it is also decreasing, the speed is the slowest. The water ecological carrying capacity of Xianyang showed downtrend, but in 2015 it suddenly broke out, even surpassed Baoji, but had a sharp fall back in 2016; the water ecological carrying capacity of Weinan showed a fluctuant downtrend. There is no trend of continuous increase or decrease in the changes; Xi'an's water ecological carrying capacity showed a fluctuant downtrend, with the largest decline in 2012. In general, the water ecological carrying capacity in the Guanzhong Plain showed a downtrend, and its distribution in the cities was extremely unbalance.

### 3.3. Sustainable utilization of water resources

- **Water ecological pressure index**

  It can be seen from figure 6 that the water ecological pressure index in the Guanzhong Plain is above 1.5 and the maximum value even reaches 4.44, which indicated that the water resources is in an unsafe state. The ecological pressure index of water is constantly rising from 2011 to 2016, and got the largest growth rate in 2012. The water ecological pressure index fluctuates by a large margin, from 1.87 in 2011 to 4.44 in 2016. There has a certain connection with the change in water resources and population. The total water resources in the Guanzhong Plain is decreasing, and the total population is constantly increasing, so that the water ecological pressure index rising constantly, the use of water resources unsustainably.

**Figure 6.** Dynamic change of water ecological pressure index.
Size and depth of water ecological footprint

Based on the formula above, the water ecological footprint size in the Guanzhong Plain can be calculated, the results are shown in table 4 and figure 7. In figure 7, the water ecological footprint size is fluctuating. With the increase of regional water ecological footprint, the water ecological footprint size of each year is higher than the water ecological carrying capacity, which illustrates that the occupancy of water resources by human production and life has exceeded the limit. In order to satisfy water demand, people began to consume the stock of water resources, the sustainable utilization of water resources has got a dangerous state.

Table 4. The water ecological footprint size.

| Year | Xi'an  | Baoji  | Weinan | Tongchuan | Yangling | Xianyang | Guanzhong Plain |
|------|--------|--------|--------|-----------|----------|----------|----------------|
| 2011 | 135.29 | 106.28 | 55.17  | 15.21     | 0.87     | 33.73    | 447.40        |
| 2012 | 71.07  | 117.85 | 37.53  | 9.50      | 0.49     | 23.55    | 287.65        |
| 2013 | 71.11  | 121.16 | 34.97  | 7.84      | 0.45     | 22.27    | 274.42        |
| 2014 | 82.61  | 107.70 | 48.01  | 8.86      | 0.60     | 22.23    | 270.02        |
| 2015 | 84.72  | 97.53  | 37.99  | 8.03      | 0.53     | 20.24    | 249.02        |
| 2016 | 67.91  | 75.71  | 35.05  | 5.80      | 0.53     | 14.47    | 199.47        |
| Means| 85.45  | 104.37 | 41.45  | 9.20      | 0.58     | 22.75    | 288.00        |

Figure 7. Dynamic change of water ecological footprint size.

Combined with table 1 and table 4, we can see that the average water ecological footprint of Xi'an, Baoji, Weinan, Tongchuan, Yangling County and Xianyang for six years is greater than the upper limit of local water ecological carrying capacity. The water resources has been completely occupied, and Yangling County has the lowest water ecological footprint, just only 0.58×10^4 hm²s. It’s only 0.56% of Baoji, which has the highest water ecological footprint size. The per capita water resources is 1/81. The main reason for the low water ecological footprint size in the area is the water shortage.

Table 5 shows that the average depth of water ecological footprint in the Guanzhong Plain is 6.34. The depth of water ecological footprint is greater than 1 in each year, of which 7.75 in 2016. It is the maximum depth of water ecological footprint in Guanzhong Plain during the study period. Social production and life do not require the use of water resources stock from 2011 to 2013. Since 2014, the depth of its water ecological footprint has shown an increasing trend, and the pressure on water resources in Baoji has been greater, but in terms of deficits and surpluses of water resource in Baoji is overall surplus. The amount of water resources can basically meet the needs of human production and life, and the use of water resources can be sustainable. The average depth of water ecological footprint in Tongchuan is 2.57. The water ecological footprint has been in deficit, except in 2011, which may be related to the small amount of water resources and rainfall in Tongchuan. Xi'an has the third highest water ecological footprint, with an average value of 4.55. The water ecological footprint has been in
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deficit since six years ago, indicating the sustainable development of water resources in Xi’an is pessimistic. It is urgent to make adjustments in time. The water ecological footprints of Xianyang, Weinan, and Yangling are all higher than 7, which are 9.51, 7.36, and 12.38. Respectively, their natural ecology water ecological system capacity neither could support the region's population consumption patterns, nor meet the needs of economic and social development of the area. The water resource is in unsustainable development.

Table 5. The water ecological footprint depth.

| Year | Xi'an | Baoji | Weinan | Tongchuan | Yangling | Xianyang | Guanzhong Plain |
|------|-------|-------|--------|------------|----------|-----------|----------------|
| 2011 | 2.97  | 1.00  | 5.68   | 7.67       | 6.50     | 4.14      |
| 2012 | 4.83  | 1.00  | 7.82   | 13.82      | 8.96     | 6.50      |
| 2013 | 4.94  | 1.00  | 8.30   | 2.90       | 14.89    | 9.17      |
| 2014 | 4.49  | 2.03  | 6.40   | 11.14      | 9.18     | 5.99      |
| 2015 | 4.55  | 2.34  | 7.80   | 13.22      | 10.09    | 6.81      |
| 2016 | 5.50  | 2.75  | 8.14   | 13.53      | 13.16    | 7.75      |
| Means| 4.55  | 1.69  | 7.36   | 9.51       | 9.51     | 6.34      |

- Ten thousand yuan GDP water ecological footprint

Table 6 shows that the ten thousand yuan GDP water ecological footprint has been declining year by year, from 0.108 hm² in 2011 to 0.071 hm² in 2016 with the percentage of 20.58%. Accounting for 79.42% of the Ten thousand yuan GDP water ecological footprint in 2011, the fastest decline is from 2012 to 2013. It demonstrated that the GDP growth in the Guanzhong Plain is not due to the development of the high water consuming industries, but the water resources output efficiency improvement, which is closely related to the adjustment of industrial structure in some administrative districts in Shaanxi Guanzhong Region, improvement of water reuse rate, and emphasis on water conservation.

Table 6. Ten thousand yuan GDP water ecological footprint (hm²).

| Year | Xi'an | Baoji | Weinan | Tongchuan | Yangling | Xianyang | Guanzhong Plain |
|------|-------|-------|--------|------------|----------|-----------|----------------|
|      |       |       |        |            |          |           |                |
|      |       |       |        |            |          |           |                |
|      |       |       |        |            |          |           |                |
|      |       |       |        |            |          |           |                |
| Mean | 0.0690.0900.251 | 0.065 | 0.095 | 0.136 | 0.108 | 0.067 | 0.018 | 0.0210.003 |
|      | 0.0620.0860.221 | 0.055 | 0.092 | 0.119 | 0.097 | 0.059 | 0.016 | 0.0190.003 |
|      | 0.0570.0780.193 | 0.046 | 0.073 | 0.098 | 0.085 | 0.051 | 0.014 | 0.0170.003 |
|      | 0.0530.0670.182 | 0.046 | 0.063 | 0.087 | 0.078 | 0.047 | 0.013 | 0.0140.003 |
|      | 0.0520.0730.181 | 0.049 | 0.061 | 0.085 | 0.077 | 0.045 | 0.013 | 0.0160.003 |
|      | 0.0490.0690.168 | 0.045 | 0.055 | 0.074 | 0.071 | 0.041 | 0.012 | 0.0150.003 |
| Mean | 0.0570.0770.199 | 0.051 | 0.073 | 0.100 | 0.086 | 0.052 | 0.014 | 0.0170.003 |

The proportion of ten thousand yuan GDP water ecological footprint in agricultural water use is the largest, which declined from 0.067 hm² in 2011 to 0.041 hm² in 2016. In 2016, the ecological footprint of ten thousand yuan GDP in agriculture is 61.32% of which in 2011. It shows a rapid decline from 2012 to 2013, indicating that the efficiency of agricultural water use in the Guanzhong Plain has been
greatly improved from 2011 to 2016. The ten thousand yuan GDP water ecological footprint of industrial water use has been declined from 0.0118 hm$^2$ in 2011 to 0.012 hm$^2$ in 2016. It shows a large decrease from 2012 to 2014, indicating that the industrial water use efficiency in the Guanzhong Plain also has been a certain increase, but the improvement is slower than agricultural water use. The domestic water ecological footprint of the ten thousand yuan GDP showed a downward trend of volatility, which fell from 0.021 hm$^2$ in 2011 to 0.015 hm$^2$. The decrease was large from 2012 to 2014, indicating that the water consumption in the Guanzhong Plain for the period during 2011 to 2016 has also been a certain degree of improvement, which is slower than the agricultural water and faster than industrial water. The ecological water of ten thousand yuan GDP footprint is the smallest, but stable.

On the whole, the total water resources use efficiency in the Guanzhong Plain has been rapidly improved from 2011 to 2016, and the utilization efficiency of agricultural water resources has maintained a good development momentum. However, Guanzhong Plain is a water scarcity area, and agriculture is one of development features. Especially the Yangling County is in there, which is the first demonstration area for agricultural high-tech industries in China. But there is still a certain gap compared to the overall situation in the province. Nowadays, continuing to improve the efficiency of agricultural water use is one of the main ways to solve the water shortage. The increase in the efficiency of industrial water use is mainly rely on the control of water-saving work in high-water-consuming industries, the economic-industrial structure adjustment, extensive economic growth patterns improvement and emphasis on the utilization of water resources. Meanwhile, we should focus on the development of tertiary industries such as tourism and service industries with low consumption of water resources.

4. Conclusion and foresight

4.1. Research conclusions

- The average value of water ecological footprint in the Guanzhong Plain is 8.6558×10$^6$ hm$^2$. Xi'an has the largest water ecological footprint, followed by Weinan, Xianyang, and Yangling, and the water ecological footprint among the Guanzhong Plain has great differences. Water resource allocation and utilization are unbalanced. Total freshwater ecological footprint is fluctuating upward. Agricultural water ecological footprint > domestic water ecological footprint > industrial water ecological footprint > eco-environment water ecological footprint, the proportion of agricultural water ecological footprint is higher than other types. There are several problems with the water structure.

- The water ecological pressure index in the Guanzhong Plain is too large and increased by years. The average value during the research is 3.20. Water resources are unsafe, and the supply is less than demand. Sustainable development and utilization is in a low degree.

- The water ecological footprint of the Guanzhong Plain is affected by climate and rainfall. It is in a down trend. The water ecological footprint size of each year is greater than the water ecological carrying capacity. The occupancy of water resources by human production and life has exceeded the limit. People started consumption of water resources stock capital. The water ecological footprint of Yangling and Tongchuan differs greatly from other cities. During the study period, the water ecological footprint of Guanzhong is greater than 1, the average is 6.34, and the maximum is 7.75. The depth of the footprint is relatively large. The overall decrease from east to west, the sustainable utilization of water resources is in a low degree. Only Baoji has a water ecological footprint surplus, and the use of water resources is sustainable.

- The water ecological footprint of the Ten thousand yuan GDP in the Guanzhong Plain has been declining year by year, indicating that its GDP growth is not due to the development of the high water consumption industry, but the increase in the efficiency of water resources output.

4.2. Further outlook
The development of water resources in the Guanzhong Plain is directly related to regional capacity for sustainable economic and social development, social production and human settlement stability and coordination. The further development of the economy will lead to a sharp increase in the demand of water resources, which will intensify the contradiction in water use. It caused industrial and agricultural domestic water consumption occupying eco-environment water, water environment deterioration, vegetation degradation, land desertification. Ecological problems will hinder the economic development of the area. We researched water ecological footprint and water ecological carrying capacity in the Guanzhong Plain and the balance between water supply and demand, giving some suggestions for the sustainable development of local water resources, which provide scientific basis for ecological construction and social economic development.

- Optimize the allocation of water resources and improve the structure of water use. Accelerate the construction of key water resources projects. Such as “Hanjiang to Weihe River Project” and “Qing to Qiu River Project”. Constantly improve supporting facilities to transfer water to the Guanzhong Plain as soon as possible. Increase the development and utilization and uniform allocation of unconventional water resources. Build plain reservoirs and groundwater reservoirs in areas of severe water shortage. Fully store and utilize flood resources, encourage municipal governments and enterprise to strengthen the use of reclaimed water, brackish water and mine drainage water. Replenish source water to optimize resource allocation pattern.

- Pay attention to water conservation and water control technologies, improve water use efficiency. We will develop high-tech industries and gradually establish an industrial distribution system which is compatible with regional water resources carrying capacity. Vigorously implement agricultural water-saving irrigation projects and widely promote water-saving technologies such as canal seepage prevention, pipeline water delivery, sprinkler irrigation, drip irrigation and comprehensively implement water-saving reform for more than 10,000 mu irrigation districts. In-depth development of establishing water-saving enterprises, units, communities, irrigation area and water efficiency leader activities to achieve water-saving efficiency.

- Strengthen the resource protection and improve water area environment. Further improve the capacity of domestic sewage treatment, strictly implement the "double standards" for the total discharge and concentration of major pollutants in key industries. So the water quality of Weihe River and important tributaries can reach the standard. Carry out activities to ensure the safety and security standards for water function areas and wellhead protection zone to ensure that water quality in water function areas meets standards and the water source environment is safe. Vigorously implement the construction of aquatic ecological projects and strengthen the overall protection, system restoration, and comprehensive management of the lake in the landscape.

Acknowledgments
This study has been partly supported by the National Natural Science Foundation of China (No.51479160, 71774132), Natural Science Foundation Research project of Shaanxi Province (No.2016JQ5061).

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