Study on sustainable development of water resources in Gansu Province

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Abstract. Water resources play an irreplaceable role in the survival, life and production of human being. It is the foundation of social stability and economic development. The sustainable utilization of water resources is one of the important factors affecting social and economic development. The water resources of various administrative regions in Gansu Province in 2006-2015 were evaluated by using evaluation indexes such as water resources development and utilization rate, water resources ecological capacity and sustainable development index and other evaluation indicators, the results show that: Gansu Province has a higher level of water resources development and utilization, but the amount of water resources cannot meet the current water load, and the water shortage in some areas is serious; The ecological footprint of water resources in Gansu Province is less than its carrying capacity. However, the water resources are in a sustainable use state. Considering the increasing demand for water resources for economic and social development activities, it needs to further consider the cost of water in the future development process; the water resources in Gansu Province can continue to develop, its development conditions are optimistic, and water resources can effectively guarantee the rapid development of the economy and society.

1. Introduction

Water resources play an irreplaceable role in the survival, life and production of human being. It is the foundation of social stability and economic development [1]. The sustainable utilization of water resources is one of the important factors affecting social and economic development [2]. However, the amount of water resources is limited, so under certain conditions, there may be conflicts between different water use channels and regions, and there is a contradiction between water use and supply. It has always been one of the core contents of water resources research that how much economic and social scale can water resources in a region or basin support, which is also an important constraint to regional or watershed development. In recent years, with the population growth, the contradiction between water supply and demand is being increasing, and the water environment is being deteriorating, coupled with the uneven distribution of water resources in time and space, it has become

an important area of water science research today that how to solve the problem of water resources and make the limited water resources play the biggest social, economic and environmental benefits [3,4].

Under the influence of climate change and human activities, the water resources system in Gansu Province is always in the process of change, and its bearing capacity must also change accordingly. In addition, along with the development of human society, the level of science and technology and water efficiency will continue to increase, which will also promote the improvement of water resources carrying capacity [5]. Under the guidance of the idea of sustainable utilization of water resources, the managers of Gansu province have carried out the construction of water-saving society and the construction of water ecological civilization, and established the strictest water resources management system based on the law of economic and social development and the natural law of water circulation .water resource ecological capacity and sustainable development index to evaluate the water resources in various administrative regions of Gansu Province in 2006-2015, and it is of great practical significance to study the sustainable development of water resources in Gansu Province under environmental changes.

2. Data sources and research methods

2.1. Data sources
The data sources are mainly published in the 2006-2009 "Gansu Yearbook" published by the Gansu Yearbook Editorial Committee, the 2010-2015 Gansu Development Yearbook published by the Gansu Development Yearbook Editorial Committee, and the 2006-2015 Water Resources Bulletin of Gansu Province publicly released by the Gansu Provincial Water Resources Department. According to the actual situation of each city and state and the reliability of the data, the water consumption of the four cities (states) in agriculture, industry, life and ecology will be selected for the sustainable development of water resources in 2006-2015.

2.2. Research methods

2.2.1. Utilization rate of water resources development. Water Resources Development and Utilization Rate (WDUR) refers to the ratio of water resources in a basin or region W to the total amount of water resources w_T, that is:

$$\text{WDUR} = \frac{w_c}{w_T} \times 100\% \tag{1}$$

The utilization rate of water resources reflects the degree of development and utilization of water resources. It is generally believed that the development and utilization of a river cannot exceed 40% of its water resources. If it exceeds 40%, it indicates that the river is seriously deficient in water and the water resources are insufficient. The ecological flow is severely squeezed, and the self-purification capacity of the water environment is sharply reduced, which may restrict economic development and lead to social stability and environmental safety. Therefore, the sustainable use of water resources has become a strategic issue for China's economic and social development, and its core is to improve water use efficiency and build a water-saving society [6-9].

2.2.2. Water resources ecological capacity index. The Water Resources Ecological Footprint Index (WECI) is the difference between the ecological carrying capacity of per capita water resources ec_w and the ecological footprint of per capita water resources ef_w, that is:

$$\text{WECI} = ec_w - ef_w \tag{2}$$

The Water Resources Ecological Capacity Index (WECI) measures the extent to which water resources are continuously used in a region. When WECI>0, indicating that the ecological footprint of water resources in the region is less than its carrying capacity, water resources are in a sustainable use state, and the water resources are in surplus, which can not only ensure a virtuous cycle of economy, ecology and environment, but also meet the further needs of regional development. When WECI =0 indicates that the ecological footprint of water resources is equal to the carrying capacity, and the regional water resources are ecologically balanced, which can meet the consumption and production patterns of the local population. Under the current water use level, the water resources utilization limit has reached the maximum; When WECI<0, it indicates that the ecological footprint of water resources in the region is greater than its carrying capacity. The utilization of water resources is in an unhealthy state. The water resources in the region are tight, unable to meet the needs of socio-economic, ecological and environmental development, and may even maintain regional development at the expense of environmental damage [10-12].

2.2.3. Water resources sustainable development index. The Water Resources Sustainable Development Index (WSDI) is the ratio of the difference between the ecological carrying capacity of water resources EC_w and the ecological footprint of water resources EF_w to the ecological carrying capacity of water resources, that is:

$$WSDI = \frac{EC_w - EF_w}{EC_w} \tag{3}$$

WSDI quantitatively evaluates the sustainability of regional development of water resources, its size reflects the extent and efficiency of sustainable development of water resources, and it can assess the future social and economic development conditions. According to the calculation results, it is generally divided into five grades (seen table 1). If WSDI<-1 indicates that the development of water resources in the region is seriously unsustainable, the development conditions are seriously insufficient, and even because of the water resources constraints, it seriously affect regional development [13-17].

Table 1. Water resources sustainable development index scale.

WSDI	Water Resources Sustainable Development Degree	Evaluation of Future Development
0.5—1	Strong and sustainable	The development conditions are very optimistic and can be developed in the long-term.
0—0.5	Weak and sustainable	Development conditions are optimistic, and development is stable
-0.5—0	Weak and unsustainable	Development conditions are not optimistic, and development is limited
-1—-0.5	Strong and unsustainable	No development conditions and developed difficultly
<-1	Serious and unsustainable	The development conditions are seriously inadequate and cannot be developed

3. Water resources evaluation

3.1. Water resources development and utilization

According to formula (1), calculate the water resources development and utilization WDUR of various administrative regions in Gansu Province in 2006-2015 (see table 2). It can be seen from the table that the utilization rate of water resources development in Gansu Province in the past ten years is 49.9%, which is greater than the warning line of 40%, indicating that the water resources development and utilization degree in Gansu Province is high, the water resources cannot meet the current water load,

and some areas have serious water shortages.

Table 2. Water resources development and utilization rate of various administrative regions in Gansu Province in 2006-2015 (%).

	2006	2008	2009	2010	2011	2012	2013	2014	2015	WDUR
Jiu quan	92.7	106	101	86.9	108	116	126	148	115	107
Jia yuguan	2360	2772	2533	2316	2619	3126	3142	3688	3708	2812
Zhang ye	67.4	78.5	72	69.4	78.8	74.7	77.2	75.3	73.1	72.5
Jin chang	809	970	869	809	887	809	1195	827	924	878
Wu wei	143	215	210	187	185	119	188	134	161	163
Lan zhou	794	1818	1897	1749	1748	1050	638	688	762	1040
Bai yin	438	480	462	471	404	419	439	420	489	438
Lin xia	65.9	50.6	82.8	67	86.2	34	52.5	45.1	119	56.2
Ding xi	53.8	47.9	63.9	81.7	62.5	30.3	29.5	40.2	42.8	46.4
Tian shui	45.3	50.4	48.7	29.4	23.1	31.5	15.1	51.4	55.4	32.9
Ping liang	77.9	95	126	51.8	43.7	56.1	29	46.9	45.9	56.6
Qing yang	26.1	25.6	43.1	43.8	54.8	30.9	23.3	37.1	54.4	35.5
Gan nan	0.47	0.53	0.59	0.71	0.59	0.48	0.78	1	1.33	0.67
Long nan	8.37	4.84	4.23	3.84	3.29	4.38	2.66	5.25	5.86	4.40
Gansu	55.9	57.9	51.0	49.7	46.6	42.3	41.5	53.9	61.4	49.9

Analysis of the water resources development utilization rate of various administrative regions in Gansu Province in 2006-2015 shows that the water resources development and utilization rate of Gansu Province has been above the warning line of 40% in the past ten years. In 2013, the water resources development utilization rate was 41.5%, which is the minimum value in recent years. In 2015, it reached a maximum of 61.4% in recent years.

In many administrative areas of Gansu Province, the utilization rate of water resources for many years, except Tian shui, Qing yang, Gan nan and Long nan, the other cities and states water resources development and utilization rate are greater than 40% of the warning line, of which Jiu quan, Jia yuguan, Jin chang, Lan zhou, Wu wei and Bai yin water resources development utilization rate exceeds 100%, significantly more than 40% of the alert Line, indicating that the above-mentioned regional water resources cannot meet the needs of economic and social development, and it need to adjust water or increase water conservation, otherwise it will further restrict economic and social development; Zhang ye, Lin xia, Ping liang water resources development and utilization rate are 72.5%, 56.2%, 56.6% respectively.

3.2. Water resources ecological capacity index

According to formula (2), the water resources ecological capacity index WECI of various administrative regions in Gansu Province in 2006-2015 is calculated (see table 3). It can be seen from the table that the ecological capacity index of water resources in Gansu Province in the past decade is 13.4 mu/cap, which indicates that the ecological footprint of water resources in Gansu Province is less than its carrying capacity, and the water resources are in a sustainable use state.

Analysis of the water resources ecological capacity index of various administrative regions in Gansu Province from 2006 to 2015 shows that the ecological capacity index of water resources in Gansu Province has shown an increasing trend in the past decade. The ecological capacity index of water resources in 2012 was 24.3 mu/cap, and the ecological capacity index of water resources in 2013 was 25.0 mu/cap, reaching the maximum in the past ten years. Since then, the ecological capacity index of water resources has shown a downward trend. In 2015, it fell to the bottom. The ecological capacity index of water resources is only 4.26 mu/cap, indicating the demand for water resources is increasing with the economic and social development in the past two years, and further consideration

is needed in the future development process.

Table 3. Water resources ecological capacity index (mu/cap) of various administrative regions in Gansu Province from 2006 to 2015.

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	WECI
Jiu quan	-43.3	-40.9	-46.8	-44.9	-39.3	-48.1	-51.4	-57.1	-58.4	-50.2	-48.4
Jia yuguan	-22.4	-20.4	-24.2	-19.6	-18.5	-19.2	-21.4	-21.9	-20.9	-22.0	-21.0
Zhang ye	63.9	88.5	38.3	55.3	66.1	38.5	49.2	40.3	47.6	54.6	53.8
Jin chang	-35.5	-34	-35.4	-33.4	-34.3	-34.2	-34.9	-39.0	-38.6	-37.3	-35.7
Wu wei	-11.2	-11.7	-20.6	-19	-17.4	-17.2	-6.72	-16.4	-10.6	-14.4	-15.0
Lan zhou	-12.4	-12.3	-13.8	-13.3	-12.3	-12.3	-11.3	-9.62	-9.15	-9.03	-11.5
Bai yin	-13	-12.7	-12.5	-12.3	-12.7	-12.5	-12.7	-13.8	-13.0	-13.2	-12.8
Lin xia	4.38	22.9	10.2	1.16	4.26	0.69	29.30	13.6	19.8	-1.56	8.8
Ding xi	1.92	2.78	2.89	0.23	-1.43	0.44	12.90	11.8	5.37	3.71	3.50
Tian shui	5.56	14.7	3.83	4.60	16.3	27.7	15.9	60.7	3.29	1.70	12.5
Ping liang	-0.21	-0.94	-1.40	-2.40	4.61	8.30	4.88	15.4	5.45	3.52	2.78
Qing yang	0.52	0.46	0.64	-0.23	0.10	-1.10	1.31	3.85	0.35	-1.14	0.36
Gan nan	1073	1477	1030	1382	967	1341	2319	1620	1268	704	1286
Long nan	60.5	172	110	212	265	358	215	345	81.7	68.7	173
Gansu	7.78	16.7	6.91	11.9	14.1	17.8	24.3	25.0	9.54	4.26	13.4

According to the water resources ecological capacity index of various administrative regions in Gansu Province, the ecological capacity index of Jiu quan, Jia yuguan, Jin chang, Wu wei, Lan zhou, Bai yin water resources is less than 0, indicating that the water resources utilization in these areas is in an unhealthy state. The water resources in the region are tight and the deficit is serious, which is unable to meet the current social economy and ecology. And the need for environmental development, if not changing the state, development may be at the expense of the environment. The water resources ecological capacity index of the rest of the region is greater than 0, indicating that the water resources are in a sustainable use state and can meet the needs of economic and social development in Gansu Province. Particularly, Gan nan, Long nan and Zhang ye is significantly greater than 0, and Gan nan water resources show a huge surplus, which can fully guarantee its virtuous circle of economic, social, ecological and environmental.
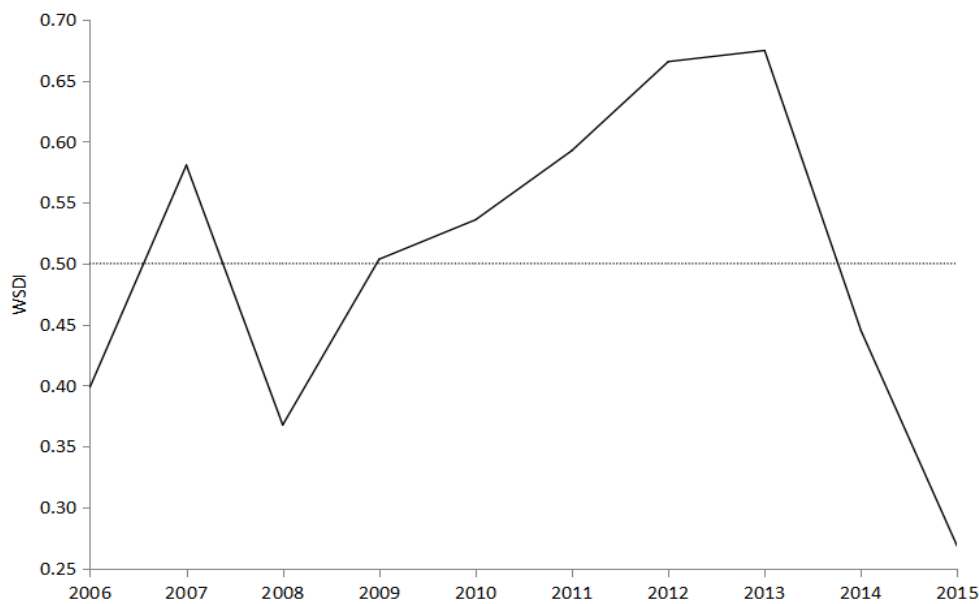
3.3. Water resources sustainable development index
Calculate the WSDI of the Water Resources Sustainable Development Index for 2006-2015 in various administrative regions of Gansu Province according to formula (3) (see table 4). It can be seen from the table that the sustainable development index of water resources in Gansu Province in the past decade is 0.53, which has been fluctuating under the critical line, indicating that water resources in Gansu Province can continue to develop and the development conditions are optimistic. Water resources can effectively ensure the rapid development of the economy and society.

The water resources sustainable development index of various administrative regions in Gansu Province from 2006 to 2015 is seen (see figure 1). In the past ten years, the water resources sustainable development index of Gansu Province has changed steadily, except for the 2006, 2008, 2014 and 2015 water resources sustainable development indexes are below 0.5, the index of the remaining years is above the 0.5, of which the smallest in 2015 is only 0.27, the largest are in 2012 and 2013, reaching 0.67. Overall, the water resources in Gansu Province can continue to develop.

Table 4. Index of water resources sustainable development in 2006-2015 in various administrative regions of Gansu Province.

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	WSDI
Jiu quan	-2.63	-2.16	-3.63	-3.25	-1.78	-3.09	-3.57	-3.92	-6.2	-3.53	-3.22
Jia yuguan	-205	-193	-253	-260	-208	-256	-326	-320	-451	-429	-275
Zhang ye	0.58	0.65	0.45	0.54	0.57	0.44	0.5	0.46	0.49	0.53	0.53
Jin chang	-36.7	-34.0	-53.0	-44.5	-38.2	-46.3	-37.3	-74.36	-34.9	-45.6	-42.8
Wu wei	-0.69	-0.66	-2.7	-2.9	-2.33	-2.32	-0.38	-2.78	-0.9	-1.72	-1.47
Lan zhou	-25.4	-26.9	-125	-141	-119	-119	-45.3	-18.4	-22.8	-28.6	-44.6
Bai yin	-19.9	-15.0	-25.4	-23.7	-24.5	-17.8	-18.9	-19.2	-18.6	-25.4	-20.4
Lin xia	0.49	0.83	0.69	0.2	0.48	0.13	0.86	0.72	0.79	-0.42	0.65
Ding xi	0.34	0.42	0.45	0.06	-0.54	0.1	0.77	0.77	0.59	0.52	0.48
Tian shui	0.64	0.83	0.55	0.59	0.84	0.9	0.83	0.95	0.52	0.38	0.8
Ping liang	-0.06	-0.33	-0.61	-1.79	0.53	0.67	0.52	0.82	0.59	0.53	0.42
Qing yang	0.28	0.25	0.32	-0.11	0.03	-0.57	0.36	0.63	0.12	-0.73	0.14
Gan nan	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Long nan	0.96	0.99	0.98	0.99	0.99	0.99	0.99	0.99	0.98	0.97	0.99
Gansu	0.40	0.58	0.37	0.50	0.54	0.59	0.67	0.67	0.44	0.27	0.53

Figure 1. Line chart of water resources sustainable development index for various administrative regions of Gansu Province in 2006-2015.

The multi-year water resources sustainable development index classification figure of various administrative regions in Gansu Province (see figure 2) shows that the Jiu quan, Jia yuguan, Jin chang, Wu wei, Lan zhou, and Bai yin water resources sustainable development index is far less than -1, indicating that the water resources in these six regions are not sustainable, and the development conditions are seriously insufficient. If water resources cannot be guaranteed, the local economy and society will not be able to further enhance development; the Zhang ye, Lin xia, Tian shui, Gan nan and Long nan water resources sustainable development index is greater than 0.5, especially Gan nan and Long nan is close to 1, indicating that water resources are sustainable, and the conditions are very optimistic and can be developed rapidly (see figure 3).

Figure 2. Classification of water resources sustainable development index for various administrative regions in Gansu Province.
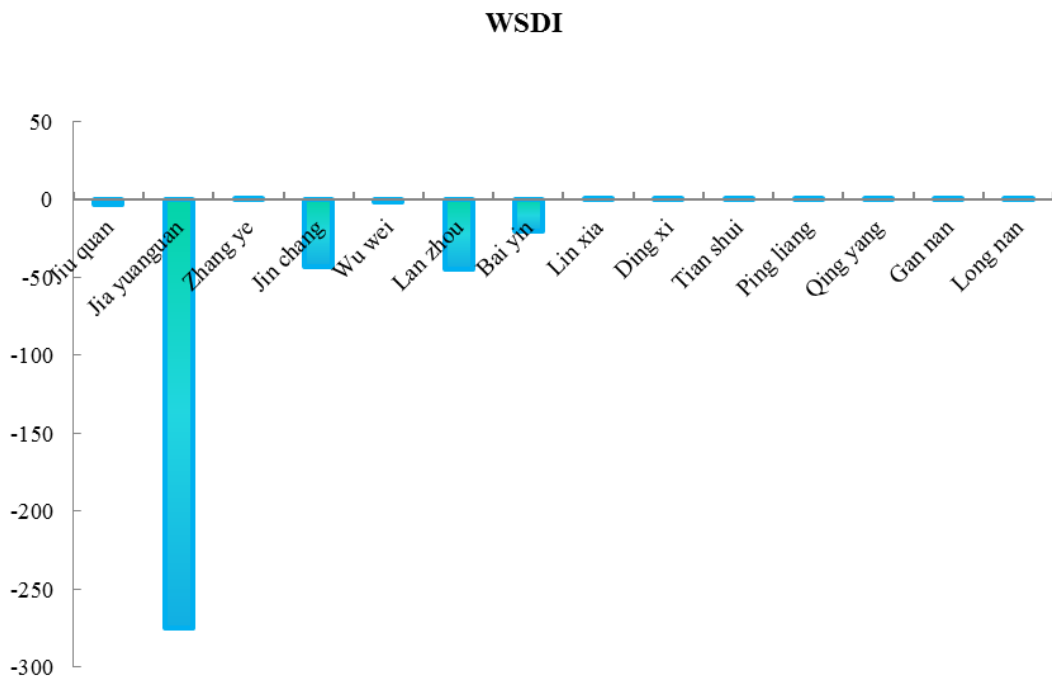
WSDI

Figure 3. Bar graph of the sustainable development index of water resources in various administrative regions of Gansu Province.

4. Conclusions and discussion

The water resources of various administrative regions in Gansu Province in 2006-2015 were evaluated by using evaluation indexes such as water resources development and utilization rate, water resources ecological capacity and sustainable development index and other evaluation indicators, The evaluation

indicators generally reflect the significant improvement of water resources utilization, efficiency and economic benefits in Gansu Province, and have sustainable development conditions. Water resources development and utilization are in a relatively safe state, which can guarantee local economic and social development, but the demand has further increased on water resources in the basin with the development of economy and society, the ecological capacity has been decreasing year by year, the development potential and sustainable use space have been shrinking, and the problem of water shortage has become increasingly prominent.

The two regions of Gan nan and Long nan water resources are not used at a high level. The development and utilization are in a safe state, the water resources are in surplus, which can continue to use water resources, the load is small, the development potential and space are huge, and the development conditions are currently very optimistic. Conditions can effectively guarantee regional economic and social development.

The utilization of water resources in these six regions Jia yuguan, Lan zhou, Jin chang, Bai yin, Jiu quan and Wu wei is very high, the development and utilization are in an unsafe state, the water resources are very tight, which cannot be used sustainably, the load is too large, the development potential is not great, the development conditions are seriously insufficient, and the external watershed adjustment needs to be considered to further protect economic and social development.

Acknowledgments

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