The water resources supporting capacity for the new-type urbanization of Gansu Province, China

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Abstract. The entropy evaluation method was used to measure the urbanization system and water resources system respectively. The supporting capacity between urbanization and water resources was measured by using the compound coordination model. The research result showed that the supporting capacity of the water resources system to the new-type urbanization development of Gansu Province was continuously increasing from 2000 to 2013. But the overall supporting capacity of water resource system to new-type urbanization of Gansu Province showed a fluctuating declining trend from 2014 to 2017, indicating that the contradiction between new-type urbanization and water resources began to appear with the acceleration of urbanization construction. The supporting capacity of water resources in all regions of Gansu Province was at a low level and the supporting capacity of most regions was undesirable. The relationship between the supporting capacity of water resources in Gansu Province and time series showed a inverted U-shape curve. The supporting capacity of the future water resources will continuously decrease, indicating that the contradiction between new-type urbanization and water resources will be further upgraded.

1. Introduction

Urbanization is the basic strategy of China’s social and economic development and is an important mean of realizing the leapfrog development and modernization of the economic society. During the construction of new-type urbanization, evaluating the comprehensive impact of water resources on the regional urbanization, revealing the coupling effect of spatial pattern of urbanization and water resources, shaping and regulating the spatial pattern of urbanization adapted to the carrying capacity of water resources, guarantying the high quality development of the urban area are the critical questions of new-type urbanization construction [1-3].

Located in the loess plateau, the core area of the ecological barrier of the Qinghai-Tibet plateau and the northern sand control belt, Gansu Province is an important ecological security barrier for the country. Due to the drought and lack of rain, water resources are the largest natural constraint faced by Gansu Province for ecological protection and social and economic development. In this paper, the support capacity of water resources for new-type urbanization construction in Gansu Province and in each region is measured, and the level of support capacity is divided and predicted, providing ideas and data support for the sustainable utilization of water resources and the high-quality development of urbanization in Gansu Province. It also has certain reference significance for further exploring the healthy development of new urbanization in Northwest China under the condition of water shortage.
In the research field of coordinated development of water resources carrying capacity with an area or a region, although domestic and foreign scholars have done a lot of theoretical research and practical exploration and have certain research results [4-7], the researches on the carrying capacity of urban water resources mainly focused on the results of water resources supply and demand analysis theory and systematical theory has not been formed. There is a lack of research specific on the evaluation of the coordinated development of water resources and urban economic society, which is not enough to solve the highly comprehensive water problems such as how to coordinate the carrying capacity of urban water resources with the coordinated development of economy and society, especially in larger area and region, further researches are necessary to be conducted.

2. Methods and materials

2.1. Compound system coordination model
The new-type urbanization of Gansu Province and water resources of Gansu Province were regarded as independent systems respectively and the supporting capacity of water resources for new-type urbanization in Gansu Province was calculated by using the compound system coordination model. Assumed \( H_{se} \) was the comprehensive level of new-type urbanization and \( R_{se} \) was the comprehensive level of water resources, then the calculation equation was:

\[
H_{se} = \sum_{j=1}^{n} \alpha_j Z(X_{ij})
\]

(1)

\[
R_{re} = \sum_{j=1}^{n} \beta_j Z(Y_{ij})
\]

(2)

\( Z(X_{ij}) \) was the standardized value of the \( j^{th} \) index of new-type urbanization system of the \( i^{th} \) year; \( Z(Y_{ij}) \) was the standardized value of the \( j^{th} \) index of water resource system of the \( i^{th} \) year; \( \alpha_j \) was the proportion of each index of the new-type urbanization (the sum is 1); \( \beta_j \) was the proportion of each index of the water resource system (the sum is 1).

In the equation (3), \( T \) was the coordination coefficient of the systematic layer, the larger \( T \) value was, the higher comprehensive development level of the 2 evaluation systems was.

\[
T = \left( \frac{H_{se} \times R_{re}}{(H_{se} \times R_{re})^2} \right)^2
\]

(3)

Therefore, the coordination degree \( D \) of the development of new-type urbanization and water resources, the comprehensive development level \( V \) and system coordination coefficient \( T \) of the compound system consisted of new-type urbanization system and water resource system can be calculate according to equation (4) and equation (5). The larger the system coordination degree \( D \) was, the stronger the supporting capacity of water resource for new-type urbanization construction was. \( \alpha \) was the proportion of new-type urbanization (in this paper was selected as 0.6 by referring to other researches), \( \beta \) was the proportion of water resource system (0.4), the calculation equation of coordination degree is shown as below:

\[
D = \sqrt{TV}
\]

(4)

\[
V = \alpha H_{se} + \beta R_{se}
\]

(5)

2.2. Selection of new-type urbanization indexes
The core of new-type urbanization is people-oriented, with the coordinated development of economy, society and ecological environment. With the reference to the evaluation indexes selected in the pilot project of New-type urbanization in Gansu Province, the index system of urban development level in Gansu Province in this paper were selected from four aspects including population, economy, infrastructure and public service, ecological civilization. The evaluation system of the whole
urbanization system was divided into three layers: the first level was the system level, represented by “comprehensive level of new-type urbanization development”; the second level was the subsystem level, which mainly included population urbanization, economic development, infrastructure and public services, and ecological environment; the third level was the index level, 19 representative specific indexes were selected through demonstration.

Some of the indexes selected in this paper can be obtained from “Gansu Province Development Yearbook”, ESP and other databases; some of the indexes can be obtained through calculation. The specific illustration is shown as follows:

1. The proportion of the urban population, which was the proportion of the urban population to the total population (residential population). It can reflect the degree of population agglomeration and the development level of population urbanization.
2. Registered urban unemployment rate, which was the total working-age population divided by the total population of registered urban employed people. The urban employment status was measured by using the index of “1-registered urban unemployment rate”.
3. Number of urban workers insured with basic old-age insurance referred to the number of the workers that have established payment record file in the social security administration department. The number of urban workers insured with basic old-age insurance was used in this paper to measure the perfection degree of security.
4. The ratio of per capita disposable income of urban residents to that of rural residents, which was using the disposable income of urban residents to divide that of the rural residents. The smaller the ratio value was, the greater the difference between the disposable income of urban residents and that of the rural residents was, and vice versa.
5. GDP per capita referred to the ratio of the gross domestic product calculated by the present value of that year divided by the average population in that year and was used to measure contribution of the value created by the residents of a region to the economic development of the region.
6. The disposable income of urban residents referred to the actual income of the urban residents that can be used to arrange the daily life, which mostly was the income from wage and salary such as cash.
7. The proportion of output value of the secondary and tertiary industries to GDP referred to the proportion of the annual output value of the secondary and tertiary industries to the GDP of the regional gross domestic product and reflected the degree of non-agriculturization.
8. The total investment in fixed assets was one of the important powers that promote the development of urbanization. It had two main functions: on the one hand, it could promote the economic development of the region; on the other hand, it could improve the construction of urban facilities, which played an important role in the development of cities and towns and the improvement of living conditions of residents.
9. Local financial revenue referred to the income obtained by the local finance participating in the distribution of social products, which was the financial assurance for the realization of government functions.
10. Per capita urban road area referred to the average urban road area owned by each person in the urban area. This index reflected the urban traffic infrastructure and the convenience degree of residential travel.
11. Urban penetration rate of gas refers to ratio of the population of the gas user to the total population, which was used to measure the penetration rate of gas used by the residents in the region.
12. The number of public toilets owned by every 10 thousand people, which referred to the average number of the toilets owned by every 10 thousand people in the urban area, could be used to measure the level of urban infrastructure.
13. The penetration rate of mobile phones at the end of the year, which was the number of mobile phone users divided by the total population, was the mobile phone number owned by every 100 people and could be used to measure the mobile communication level of the region.
14. The number of college students in every 10 thousand people, it could be used to measure the
education level of the region.

(15) The number of the hospitals and beds that owned by every 10 thousand people, it could be used to measure the medical level of the region.

(16) The green coverage rate of the built-up area could be used to measure the greening degree of the urban area by using the ratio obtained from dividing the green area covered by the built-up area.

(17) Green park land area per capita referred to the average green park land area owned by each person in the urban area.

(18) The number of special vehicles for city appearance and sanitation owned by every 10 thousand people referred to the average number of special vehicles for city appearance and sanitation owned by every 10 thousand people and could be used to measure the waste treatment input level in the region.

(19) The rate of harmless disposal of domestic wastes referred to the proportion of the amount of wastes disposed harmlessly to the total amount of disposed wastes.

2.3. Selection of water resource system indexes
The index system establishment of water resource system was divided into three levels: the first level was the system level, represented by “water resource system”; the second level was the subsystem level, which mainly included the total amount of water resources, the utilization degree of water resources, the utilization efficiency of water resources and the management level of water resources; the third level is the index level, 9 representative specific indexes were selected through demonstration.

Some of the indexes adopted in the water resource system can be directly obtained from “Gansu Province Development Yearbook” and “Gansu Province Water Resource Bulletin”, some of the indexes can be obtained through calculation, the specific illustration is shown as below:

(1) Surface water per capita referred to the dynamic water amount owned by each person from rivers, lakes, glaciers and other surface water bodies, which was the total amount of surface water divided by the total population (residential population) in that region, it could reflect the background condition of the water resources.

(2) Underground water per capita referred to the average amount of underground water owned by each person.

(3) Water consumption per capita referred to the average amount of the water consumed by each person.

(4) Water production coefficient reflected the ability of converting the amount of precipitation to the usable water resources in the region. It could be calculated by dividing the total amount of water resources of the region by the total precipitation.

(5) Comprehensive water loss rate was the proportion of the total water loss to the total water consumption. The water loss here referred to the amount of water that is evaporated, drunk, or absorbed by the soil and cannot be recycled during the process of transportation and utilization of water resources.

(6) Output rate of water resources was the ratio of gross domestic product to the total water consumption. It could be used to measure the utilization efficiency of water resources. The higher the output rate of water resources was, the higher the water resources utilization efficiency was.

(7) Comprehensive production capacity of water supply at the end of the year was used to measure the comprehensive production capacity of water supply facilities in each region, including water intake, water supply and water delivery.

(8) Urban water penetration referred to the ratio of the population of people use water to the total population in the urban area.

(9) Daily treatment capacity of water sewage, which was used to measure the treatment capacity of sewage and waste water in the region.

3. Results
3.1. Entropy evaluation method and supporting capacity grading
The proportion of each index of new-type urbanization and water resource system of Gansu Province from 2000 to 2007 and the proportion of each index of new-type urbanization (Table 1) and water resource system (Table 2) of each prefecture-level city in Gansu Province were calculated by entropy evaluation method respectively.

| Index weight of urbanization system | time series | spatial sequence |
|------------------------------------|-------------|-----------------|
| Proportion of urban population (%) | 0.050       | 0.075           |
| 1-the urban unemployment rate (%)  | 0.046       | 0.027           |
| Number of participants in basic Endowment | 0.058 | 0.072 |
| Disposable income ratio of urban and rural residents | 0.021 | 0.021 |
| Per capita GDP (Yuan)              | 0.056       | 0.071           |
| Disposable income of urban residents | 0.056 | 0.018 |
| Industries accounts for the proportion of GDP (%) | 0.038 | 0.039 |
| Investment in fixed assets of the whole society (100 million yuan) | 0.100 | 0.052 |
| Local revenue (100 million yuan)   | 0.069       | 0.097           |
| Per capita urban road area (m²)    | 0.027       | 0.038           |
| urban gas penetration rate (%)     | 0.037       | 0.015           |
| Number of public toilets per 10,000 population | 0.035 | 0.034 |
| Mobile phone user penetration at the end of the year (%) | 0.062 | 0.095 |
| Number of college students per 10,000 population | 0.036 | 0.128 |
| Number of beds in hospital and hospital per 10,000 people | 0.106 | 0.054 |
| Green coverage rate in built-up area (%) | 0.027 | 0.028 |
| Per capita park green space area (m²) | 0.036 | 0.072 |
| Number of vehicles and equipment for city appearance and sanitation per 10,000 people | 0.085 | 0.050 |
| Innocuous treatment rate of domestic waste | 0.057 | 0.012 |

At present, most researches on water resources in China are the researches on the carrying capacity of water resources. Therefore, the supporting capacity of water resources were divided into 5 levels by referring to the relevant research and grading methods. The coordination degree of the system were calculated quantitatively according to the above compound system coordination model. The supporting capacity of the water resources for regional development will be the stronger when the coordination degree D is the greater. Adversely, the supporting capacity of the water resources for regional development will be the weaker if D is the smaller.

| Index weight of water resources system | time series | spatial sequence |
|--------------------------------------|-------------|-----------------|
| Surface water per capita (m³)        | 0.111       | 0.173           |
| Groundwater per capita (m³)          | 0.076       | 0.135           |
| Per capita water consumption (m³)    | 0.045       | 0.110           |
| Water production coefficient         | 0.080       | 0.088           |
| Comprehensive water consumption rate (%) | 0.315 | 0.049 |
| Water resources output rate (Yuan/ m³) | 0.129 | 0.061 |
Comprehensive production capacity of water supply at the end of the year (10^4 m^3/d) | 0.089 | 0.133
Water use penetration rate of urban population (%) | 0.062 | 0.012
Daily treatment capacity of municipal sewage (10^4 m^3/d) | 0.093 | 0.242

3.2. Supporting capacity analysis for new-type urbanization in Gansu Province

According to the compound system coordination model, the comprehensive level $H_{se}$ of new-type urbanization and the comprehensive level $R_{se}$ of water resource system in Gansu Province from 2000 to 2007 and the coordination degree D were calculated.

It can be known from Figure 1 that from 2000 to 2017 the comprehensive development degree of new-type urbanization in Gansu Province shows a gradual increasing trend, rising from 0.060 in the year of 2000 to 0.911. This is mainly due to the proposal of the Great West Development Strategy. Exploring the superior resources of the western region and encouraging the western provinces and cities to actively undertake the industrial transfer from the eastern regions through the rich driving the rich, so the urbanization of Gansu Province has been developed rapidly. The comprehensive level of water resource system in Gansu Province shows a trend of fluctuate increase from 2000 to 2017, this is mainly due to the large annual fluctuation of water resources and the continuously improvement of water resources development and utilization degree, the improvement of water resources utilization by water-saving measures and enhancement of water resource management at the same time. From 2012 to 2016, the water resource system shows a gradual decreasing trend due to the obvious of water resource background condition and water resources development and utilization degree. By 2017, the score of water resources system began to gradually increase. On the one hand, the background condition of water resources has increased; on the other hand, the management level of water resources has improved, resulting in the score increase of water resource system in 2017.

![Figure 1. The supporting capacity of water resources for urbanization in Gansu Province from 2000 to 2017](image)
for the construction of new-type urbanization in Gansu Province was extremely unsupported. In 2001 and 2002, the supporting capacity of water resource system for the construction of new-type urbanization in Gansu Province was relatively unsupported. From 2003 to 2007, the supporting capacity of water resource system for the construction of new-type urbanization in Gansu Province was basically supported. From 2018 to 2012, it was relatively supported and in 2013, it was very supported. This is due to the implementation of ecological civilization construction, promotion of economic transformation and sustainable development of Gansu Province since the Great Western Development. And in recent years, Gansu Province has rationally developed and optimized the allocation of water resources, while vigorously developing water-saving technologies, focusing on the recycling of water resources, and enhancing the support of water resources for economic and social development in the construction of new urbanization. From 2014 to 2017, the comprehensive coordination degree of new-type urbanization system and water resource system in Gansu Province has declined, which was relatively supported. This was because the comprehensive level of water resource system has decreased, resulting in the decline of supporting capacity and indicating that the contradiction between new-type urbanization and water resource system began to appear. Therefore, with the limited water resources, Gansu Province should insist to improve the degree of water resources development and utilization, water resource utilization efficiency and water resources management level to improve the supporting capacity of water resources system for the construction of new urbanization.

3.3. Supporting capacity analysis for new-type urbanization in each prefecture-level city

According to the compound system coordination model, the comprehensive level $H_{se}$ of new-type urbanization and the comprehensive level $R_{se}$ of water resource system in Gansu Province and the coordination degree $D$ in 2007 were calculated.

The comprehensive ranking of new-type urbanization score of all the prefecture-level cities in Gansu Province in 2017 is shown as below. Lanzhou city topped the list (0.08), followed by Jiayuguan city which ranked the second, the new-type urbanization comprehensive levels of Jinchang city, Jiuquan city, Zhangye city, Qinyang city, Baiyin city, Wuwei city and Tianshui city were in the middle, which were between 0.2 and 0.4. The new-type urbanization comprehensive levels of Pingliang city, Dingxi city, Linxia city, Longnan city and Gannan city were relatively low, which were all below 0.2. It can be seen that there were great differences in the development of new-type urbanization between different regions in Gansu Province. The comprehensive score of water resource system rank of Gansu Province in 2017 is shown as below. Gannanzhou ranked the first (0.434), followed by Jiuquan city (0.277), which ranked the second, Lanzhou, Zhangye and Longnan were in the middle and their scores were among 0.2 to 0.3. The comprehensive scores of water resources of the other regions in Gansu Province were relatively low (lower than 0.2), among which Dingxi city and Linxia city were the lowest and their comprehensive scores of water resources were only 0.077. The water resource supporting capacity distribution for all the regions in Gansu Province in 2017 is shown as follows. Wuwei city, Baiyin city, Linxia city, Dingxi city, Tianshui city, Longnan city, Pinglian city and Qingyang city were relatively unsupported, while the six regions including Jiuquan city, Jiayuguan city, Jinchang city, Zhangye city, Lanzhou city and Gannan city were basically supported. There were no relatively supported and very supported regions, indicating that the supporting capacities of water resources in all the regions of Gansu Province were at a low level. In combination with ArcGIS software, the supporting capacity of water resources for new-type urbanization of all the prefecture-level cities in Gansu Province in 2017 was visualized. The results are shown in Figure 2.
3.4. Prediction of water resource supporting capacity in Gansu Province

In order to more accurately understand the current and future supporting capacity of water resources for the new-type urbanization of Gansu Province, further prediction of water resource supporting capacity was carried out. SPSS22.0 statistical software was used to study the relationship between the water resource supporting capacity of Gansu Province and time, and the functional curve estimation of system coordination degree (D) and time (t) was made for the matching of time series evolution trajectory curve of water resource supporting capacity for new-type urbanization in Gansu Province.

In can be seen from figure 3, matching effect of dynamic evolution curve of water resource supporting capacity with the cubic function is the best with a matching degree of 92.25% and the function F check 0.00 < 0.05. Therefore, the function equation of coordination degree D and time t is:

The prediction of water resource supporting capacity in Gansu Province from 2018 to 2021 was conducted by using the function model of water resource supporting capacity for new-type urbanization in Gansu Province.

According to the prediction results in table 8, with the rapid promotion of new-type urbanization, the supporting capacity of water resources for new-type urbanization in Gansu Province has been decreased gradually. The supporting capacity of water resources in 2018 will be relatively supported, while that in the year 2019 and 2020 will be basically supported and in 2021 it will be relatively unsupported, indicating that the contradiction between the new-type urbanization system and the water resource system will be more intense and prominent. And as time goes on, it will be more and more intense. With the continuous development of new-type urbanization in Gansu Province, the demand for water resources will increase sharply and the waste of water resources and the pollution of water environment will be worse and worse. On the other hand, limited water resources will restrict and limit the rapid and healthy development of new-type urbanization in Gansu Province, leading to further escalation and deterioration of the contradiction between the two. As a typical arid area, only by increasing water saving efforts, improving water utilization efficiency, and rationally planning the distribution of water resources in the process of urbanization development in the future, can Gansu Province have sufficient water resources to support the rapid development of urbanization.
4. Conclusion
The distribution of formation lithology has a certain relationship with the development and distribution of debris flow. The process of formation, movement and accumulation of debris flow is the process of erosion, transportation and deposition of various unconsolidated deposits after rock destruction. The occurrence of debris flow depends to some extent on the weathering resistance and erosion resistance of the rocks. Different types of rocks differ in mineral composition and physics-mechanical properties, correspondingly differ in resistance to destruction and weathering rates, which influence the characteristics of forming and the property of debris flow.

With the guidance of relevant theories of new-type urbanization and water resource supporting capacity, this paper uses entropy evaluation method to measure the urbanization system and water resource system, and uses compound system coordination model to calculate the supporting capacity of water resource system for new-type urbanization of Gansu Province and other prefecture-level cities from two dimensions of time and space.

It can be seen from the time dimension that from 2000 to 2013, the supporting capacity of water resource system for the new-type urbanization development has gradually increased, while the overall supporting capacity of water resource system for the new-type urbanization shows a fluctuate decrease from 2014 to 2017, indicating that with the acceleration of urbanization construction, the contradiction between new urbanization and water resources begin to appear. On the space dimension, the water resource supporting capacity distribution in each region of Gansu Province in 2017 is shown as follows: 8 regions including Wuwei, Baiyin, Linxia, Dingxi, Tianshui, Longnan, Pingliang and Qingyang were relatively unsupported, and Jiuquan, Jiayuguan, Jinchang, Zhangye, Lanzhou and Gannan 6 regions were basically supported, which indicated that the supporting capacity level of water resources in all the regions of Gansu Province is relatively low and the supporting capacity of water resources in most regions were undesirable.

Through supporting capacity matching of water resources for urbanization in Gansu Province, it is found that the water resources supporting capacity and time series of Gansu Province show an inverted U-shaped curve relationship. The prediction of water resource supporting capacity in Gansu Province from 2018 to 2021 shows that the supporting capacity of water resources will be declining, which indicates the indicates the contradiction between water resources and urbanization development is further upgraded.

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