Analysis on Gini Coefficient of scarce Water Resources Considering both Visible and Virtual Water in the Ningxia Hui Autonomous Region, China

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Abstract

Water resource is scarce and can be the limit of economic progress, reasonable and appropriate allocation of water resource is essential for the long-term sustainable development of society. Both visible and virtual water are considered, which will give more comprehensive view of the regional water usage. Based on Gini coefficient, the matching degree of water resource/water footprint and population, regional GDP, and economic benefits from different industries is analyzed in the Ningxia Hui Autonomous Region. Accordingly, specific suggestion are given.

Keywords

Water resource allocation, Gini Coefficient, virtual water, sustainable development, Ningxia Hui Autonomous Region.

1. Introduction

Water resources are the material base of all the social and economic activities. However, due to the rapid industrial and urban developments, significant pressure have been put on natural resources [1]. Even though water covers 71% of the Earth's surface, only 2.5% of this water is freshwater, with 98.8% of this being ice or groundwater, and only 0.3% being available for consumption from rivers, lakes, and the atmosphere [2]. Water is a scarce resource worth fighting for, inappropriate water resource allocation can lead to famine, food insecurity, ecological destruction, resource-based conflicts and even humanitarian catastrophes [3]. Therefore, a scientific analysis on the water resource allocation will give significant guidance on the long-term sustainable development of one region.

Ningxia Hui Autonomous Region locates between 35°14~39°23 North latitude and 104°17~107°39 East longitude. It belongs to continental semi-humid and semi-arid climate, and the rainy season is concentrated between June and September. The average elevation is above 1,000 meters, due to its geographic factors, the spatial distribution of water resource is uneven. It's the most water-deficient area in China. Previous studies have tended to focus on its water utilization [4, 5] or water resources ecological carrying capacity [6]. To the author's best knowledge, the analysis on water resource equitable allocation of Ningxia Hui Autonomous Region is rare.

When analyzing the water resources utilization, researchers tended to focus on visible water [4, 5]. However, virtual water is also of great importance and it helps to give comprehensive analysis on water resource allocation. Virtual water was first proposed by Allan [7] to refer to the quantity of fresh water required to produce each agricultural and industrial product. In 2002, Hoekstra [8] introduced the concept of the water footprint, which is the link between "consumer goods or a consumption pattern" and "water use and pollution". By importing goods from water-abundant region, which is also virtual water transfer, water-deficient region can alleviate its water stress.

Gini coefficient [9] is a measure of inequality and it is originally used to measure the inequality of income allocated in society. Previous scholars have extended it to measure the inequality of water resource allocation and the method is widely accepted [10, 11]. Therefore, this paper uses Gini coefficient to analyze the matching degree between water resources/water footprint and population, regional GDP, and economic benefits from different industries in the Ningxia Hui Autonomous Region.

The remainder of this paper is as follows. Section 2 gives the detailed methodology. Section 3 presents the results and accordingly, specific suggestions is given. Section 4 concludes with a summary.

2. Methodology

2.1 The computation of the original Gini coefficient.

As it is shown in Fig. 1, Gini coefficient is calculated based on the Lorenz curve, suppose the area between the equality line and Lorenz curve is A, the area under the Lorenz curve is B. Then, the value of Gini coefficient is A/(A+B) [9]. Because of A+B=1/2, the Gini coefficient is equal to 1-2B [10].

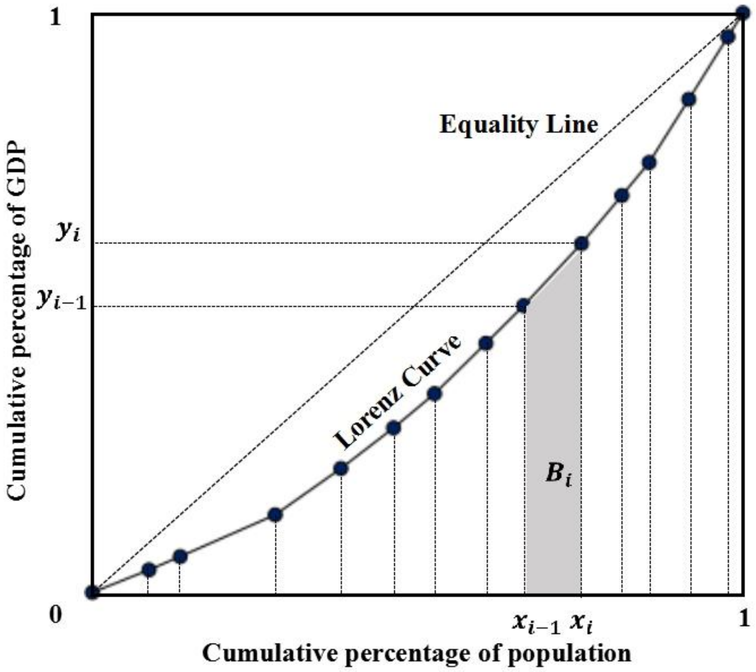

Fig. 1 Lorenz curve for income allocation

Table 1 Gini Coefficient Evaluation Criteria

Gini coefficient	0~0.2	0.2~0.3	0.3~0.4	0.4~0.5	0.5~1
Equality degree	absolutely equal	very equal	relatively equal	relatively unequal	highly unequal

If one region is composed of n subregions, for each subregion, compute the ratio of its GDP over its population. Then, rank all the values in ascending order, the rank of the subregions is also determined. Therefore, the Gini coefficient is mathematically calculated as:

$$\text{Gini coefficient} = 1 - 2\sum_{i=1}^{n} B_i = 1 - \sum_{i=1}^{n} (x_i - x_{i-1})(y_i + y_{i-1}) \quad (1)$$

where xi is the cumulative percentage of population, yi is the cumulative percentage of GDP. As it is shown in Table 1, the smaller the value of Gini coefficient, the more equal the allocation.

2.2 The computation of Gini coefficient in this paper.

The regional consumption water footprint (WF) can be calculated using a top-down approach: the water footprint within a region (WFarea) plus the virtual water imported (Vi) minus the virtual water exported (Ve):

$$WF = WFarea + Vi - Ve \tag{2}$$

To extend the original Gini coefficient to measure the matching degree of water resources allocation and population, regional GDP, and different sectoral water demand in the Ningxia Hui Autonomous Region, we can simply change the original yi to depict the cumulative percentage of water resources and water footprint respectively; while xi represents population, regional GDP and economic benefits from different industries respectively.

2.3 2.3 Data collection.

The data for the population, GDP, and the economic benefits from different industries of the subregions of the Ningxia Hui Autonomous Region is obtained from the 2017 Ningxia Hui Autonomous Region Statistical Yearbook [12], and the data is shown in Table 2.

Table 2 Water resource, Water footprint, Population and GDP Data of Various Administrative Regions of the Ningxia Hui Autonomous Region

Administrative region	Water resource (108 m3)	Water footprint (108 m3)	Population (104)	Primary industry (10,000CNY)	Secondary industry (10,000CNY)	Tertiary industry (10,000CNY)
Yinchuan	1.942	40.26	217.7609	586145	8256113	7334812
Shizuishan	1.011	21.68	79.1571	260901	3235647	1639196
Wuzhong	1.333	42.10	138.0905	553370	2504950	1365962
Guyuan	3.734	18.80	121.6083	490916	611318	1295825
Zhongwei	1.564	27.71	114.7701	524905	1491077	1375307

3. Result and suggestion

3.1 Result.

By using the methodology, the matching degrees of water resource/ water footprint and population, GDP, and economic benefits from different industries are shown in Table 3. Considering virtual water, the allocation of water resources is generally acceptable. However, when only visible water is taken into consideration, the matching degree between water resource and GDP (Fig. 3) is relatively unequal - mainly due to the mismatch between water resource and the economic benefits produced by secondary and tertiary industry.

Water resource and population is highly coordinated, as can be seen from Fig. 2 and Fig. 4. The water resource in Guyuan City takes up 38.96% of the total water resources in the Ningxia Hui Autonomous Region, however, it only produced 7.61% of the total GDP. In comparison, Yinchuan City produced 51.31% of the total GDP with 20.26% of the total water resources. This is the main cause of the uncoordination between water resource and GDP.

Table 3 Gini Coefficient Based on Water resource and Population, GDP and Economic benefits from different industries

Item	Gini coefficient	Equality degree
Water resource- Population	0.2568	very equal
Water resource- GDP	0.4707	relatively unequal
Water resource- Primary industry	0.2288	very equal
Water resource- Secondary industry	0.5168	highly unequal
Water resource- Tertiary industry	0.4700	relatively unequal
Water footprint- Population	0.1373	absolutely equal

Water footprint- GDP	0.3053	relatively equal
Water footprint- Primary industry	0.1372	absolutely equal
Water footprint- Secondary industry	0.3386	relatively equal
Water footprint- Tertiary industry	0.3559	relatively equal

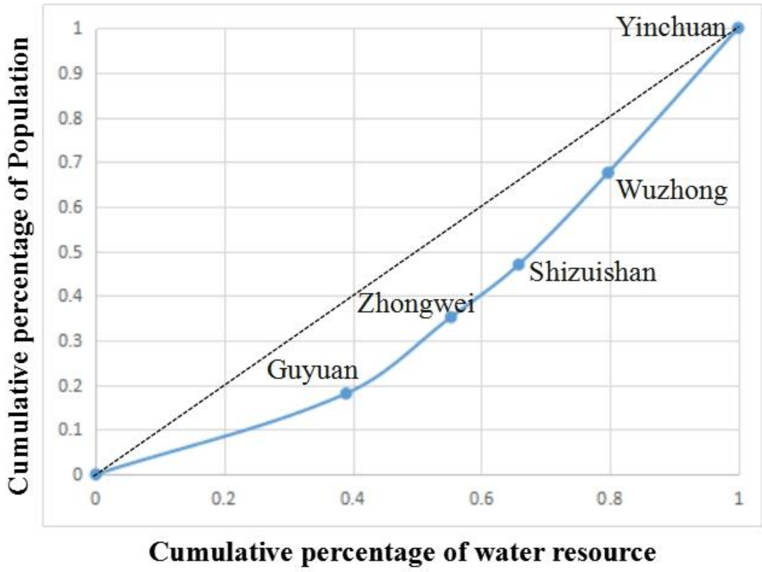

Fig. 2 Lorenz curve for Water resource and Population

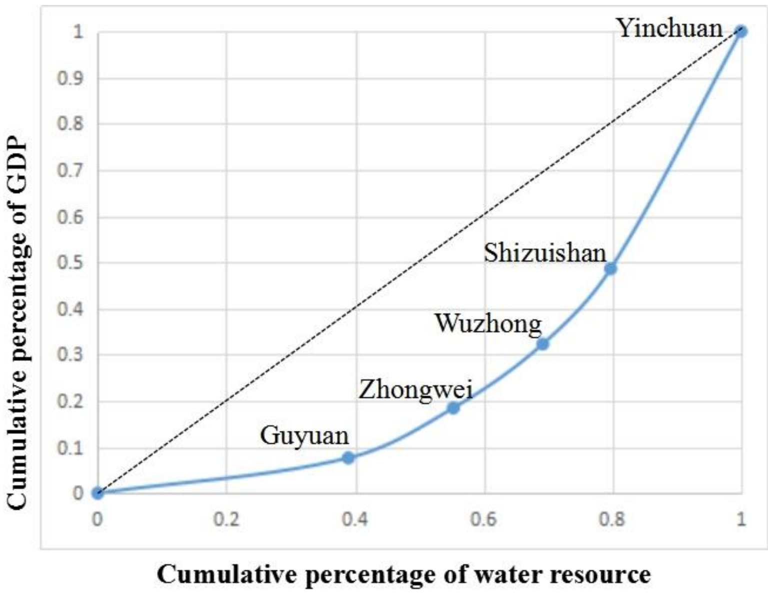

Fig. 3 Lorenz curve for Water resource and GDP

Yinchuan City is the capital city of the Ningxia Hui Autonomous Region, and it takes up the largest percentage of population in this region. Besides, Yinchuan City has multiple tourist attractions, such as “Rock Paintings in Helan Mountain”, “Western Xia Imperial Tombs”, which contributes to the prosperity of the tertiary industry. As for Guyuan City, due to the unreasonable exploitation and utilization in the earlier period of the foundation of China, water loss and soil erosion is severe. Methods have been taken to deal with these problems and the situation is being improved.

According to the information in [12], Fig. 6 is drawn, and it shows the main changes in the industrial structure of the Ningxia Hui Autonomous Region. As it is shown in Fig. 6, the proportions of the primary industry and the secondary industry are generally decreasing, which is beneficial to the long-term sustainable development of this region, because of its fragile ecological status and semi-humid and semi-arid climate.

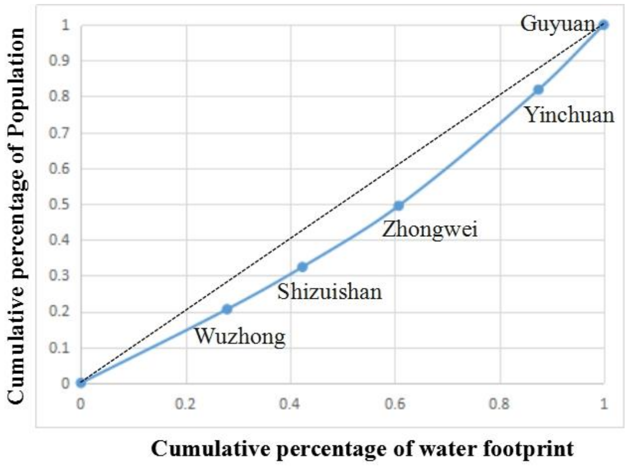

Fig. 4 Lorenz curve for Water footprint and Population

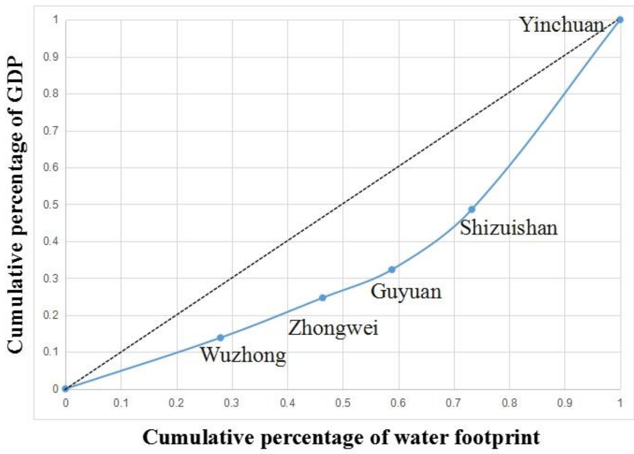

Fig. 5 Lorenz curve for Water footprint and GDP

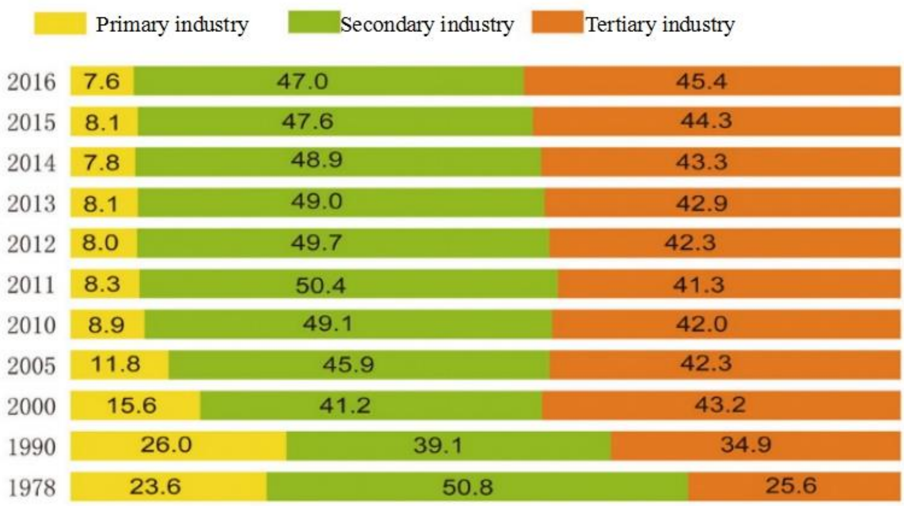

Fig. 6 Composition of Gross Domestic Product (%)

3.2 Suggestion.

Based on the Gini coefficient values, the water resource allocation is generally acceptable and equal. The specific suggestions are given as follows.

The matching degree between water resource and population is high, however, as the development of urbanization, this equilibrium may be break. To ensure the harmonious urban and rural development of the Ningxia Hui Autonomous Region, measures should be taken to avoid the over-migration to big cities. Moreover, water-saving methods should be universalized in the Ningxia Hui Autonomous Region.

Considering virtual water, the matching degrees are generally high. Therefore, it is appropriate to import water-intensive products to alleviate the regional water resource tension. When buying goods from other regions, related department should give Ningxia Hui Autonomous Region some allowances to help it recover from water loss and soil erosion.

As shown in Fig. 6, the secondary industry and the tertiary industry contribute most to GDP, and the proportion of the primary industry is decreasing. The other four subregions should help Guyuan City to recover from water loss and soil erosion, which will benefit the long-term sustainable development of the whole region.

4. Conclusion

Gini coefficient is useful and powerful in measuring the equality of resources. This paper mainly uses Gini coefficient to analyze the matching degree between water resource/ water footprint and population, GDP, economic benefit from different industries in the Ningxia Hui Autonomous Region. Based on the results, specific suggestions were given to help achieve sustainable development in this region. Moreover, the consideration of virtual water emphasizes the reasonability and practicability to ease the tension of water by importing water-intensive goods.

This methodology is also applicable in other regional water resources analysis.

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