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Estimation of Ecological Compensation Standards in the Yellow River Basin

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Abstract: It is crucial to establish a reasonable ecological compensation mechanism for the Yellow River Basin. This study uses a calculating model to estimate the value of the total cost of ecological protection in the upstream. On this basis, an apportion model is used to reach the ecological compensation standard value of each province in the midstream and downstream. The results provide a scientific reference for the ecological compensation standards in the Yellow River Basin.

Keywords: Ecological compensation; PES; Yellow River Basin

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1. Introduction

The Yellow River is the foundation and lifeblood of social and economic progress in China [1]. With the proposal of ecological protection and high-quality development, the establishment and improvement of the ecological benefit compensation mechanism for this basin is essential. It is necessary to consider the present stage and future of the Yellow River Basin under the environmental constraints. Various policies are emphasizing the core role of eco-compensation in the development of the Yellow River Basin and guiding the establishment of an eco-compensation mechanism for the basin.

The existing eco-compensation mechanism for the Yellow River Basin is flawed. This paper designs a model to reach the compensation value and proposes the key directions for promoting and improving the future construction of eco-compensation for the Yellow River Basin. The construction of a higher-level eco-compensation is called for in order to support the environment and usher in a better eco-service. This study reaches the exact values of the compensation, thus providing reference for the eco-compensation of the Yellow River Basin.

2. Literature review

The concept of "ecological compensation" is mostly attributed to payment for ecological services (PES), which involves the coordination of the interests of all parties through institutional arrangements and the internalization of the externality of ecosystem services. Its essence embodies the contribution of the party that destroys the ecosystem to the contributors of ecological protection [2, 3].

A scientific and reasonable eco-compensation standard is the key to balancing the interests of the compensation subject (usually the downstream area) and the object (usually the upstream area), which affects whether the compensation mechanism can function effectively [4-6]. At present, the standard accounting methods for eco-compensation in basins include the method of production service function value and measuring willingness, as well as the method of cost and expense [7]. The majority of scholars believe that the key to determining the eco-compensation standard is to estimate the opportunity cost and eco-service value provided. In social practice, special attention should be paid to opportunity cost and information asymmetry. The actual implementation of ecological compensation standards should be between the opportunity cost sacrificed by ecological service providers and the benefits earned by beneficiaries [8-13].

There are apparent regional differences in terms of development among the provinces of the Yellow River Basin. The development quality and resource efficiency of the central cities in the east are better than those in central and western areas [13]. In the upstream, the ecological environment is fragile; hence, the protection and improvement of eco-services should be the main focus. In the midstream and downstream, the balance between economic and ecological development should be ensured through systems such as eco-compensation [14].

Lack of institutional arrangements, uncertain compensation standards, and other loopholes are emerging in the compensation practice in China [15-17]. Domestic scholars tend to focus on the quantification of compensation in basins, the determination of the system, and the division of the scope of protection. The majority of studies are only based on a single reach of the Yellow River Basin [18,19]. Therefore, this paper analyzes and constructs the game behaviors and strategies of the upstream and downstream of the transboundary watershed. Adopting the opportunity cost method to measure the loss in the upstream area and calculate the compensation amount in the midstream and downstream may provide a reference for improving the horizontal eco-compensation mechanism and promoting the improvement of the river basin ecosystem as well as the realization of the overall economic balanced development of basins.

3. Study area and data

3.1. Study area

The flow area of the Yellow River Basin accounts for about one-third of China’s land area. However, the comprehensive development level of the basin is relatively subpar. The differences in characteristics, the ecological vulnerability of the basin, and over-exploitation problems are evident; the regional economic gap is widening; the ecological environment endowments, the environmental carrying capacity, and environment itself are limited, with scarce water resources. In recent years, there have been many interruptions, and the midstream is under great pressure to control the discharge of pollutants in the watershed.

The study area is based on the nine provinces of the basin. The upstream provinces included Qinghai, Gansu, Inner Mongolia, Sichuan, and Ningxia, while the midstream and downstream provinces included Shaanxi, Shanxi, Henan, and Shandong. Since the economic value of primary and secondary industries in Sichuan is higher than the average level of all the provinces in China, this study did not consider the compensation for Sichuan Province.

3.2. Data collection

The eco-compensation standard is a complex system. Based on existing studies [19,20], we selected several indicators to construct a model that could be used to measure the value of compensation, considering different relating factors of eco-compensation, data availability, and scientific objectivity. The values of gross national product, ecological construction and protection cost, investment in the treatment of wastes, and other data in the provinces from 2011 to 2020 are also obtained from China Statistical Yearbook and China Environmental Statistical Yearbook.

4. Materials and methods

4.1. Construction of an evaluation index system

There are different relating factors of eco-compensation. Based on scientific objectivity and data availability, we selected several indicators to construct an evaluation index system of standards of eco-compensation for the basin to measure the value of compensation.

$$R = C_t \times K_f \times K_m \times E_d \quad (1)$$

Among them, C_t is the total annual cost of ecological protection in the upstream, and K_f represents water allocation coefficients; K_m represents the water quality correction coefficient, while E_d represents the benefit distribution coefficients. Since the water quality of the Yellow River's main stream is generally good, with 90.93% of the water reaching Class III water standard, take 1 as the value of K_m.

The water allocation coefficient is the proportion of water consumed in the downstream area to the total:

$$Kf = W_d/W_t \, , 0 < K_f < 1 \quad (2)$$

According to the hydrological series from 1956 to 2010, adopted in the "Revision Report on Hydrological Design Achievements of the Yellow River Basin," the annual average natural runoff reaches 48.2 billion m^3, of which the total water diversion in the upper streams is 13.39 billion m^3; thus, $K_f = 0.278$.

4.2. Basin eco-compensation model based on opportunity cost

We selected relevant indicators to construct an evaluation system to measure the cost. Based on previous literature [20], we calculated the cost and compensation amount of the upstream from three aspects: water quantity, water quality, and benefit distribution. We collected the data from the statistical yearbooks of various provinces. The calculation model of the annual compensation amount is as follows:

$$C_t = C_1 + C_2 \quad (3)$$

where C_t is the total annual cost of ecological protection in the upstream, C_1 is the water allocation coefficient, K_m is the water quality correction coefficient, and C_2 is the benefit distribution coefficient.

$$C_2 = (D_r - U_r) \times N_r + (D_c - U_c) \times N_c \quad (4)$$

D_r is the per capital income of farmers in the midstream and downstream; U_r is the per capital income of farmers in upstream; N_r is the agricultural population in the upstream; D_c is the per capital income of urban residents in the midstream and downstream; U_c is the per capital income of urban residents in the upstream; and N_c is the average urban resident population in the upstream.

4.3. Basin eco-compensation apportion model

When determining the specific value of the ecological compensation amount, the economy of the compensation areas must be considered. Hence, the benefit distribution coefficient is introduced, with the following formula:

$$E_d = \frac{e^{\varepsilon} \times GDP_d}{(1 + e^{\varepsilon}) \times GDP} \quad (5)$$

where ε is the Engel coefficient of the provinces in the midstream and downstream; GDP_d is the GDP of the provinces in the midstream and downstream; and GDP is the gross national product of the year. The Engel coefficient and GDP data of the provinces in the midstream and downstream in 2011–2020 are obtained from the statistical yearbook data of each province. The corresponding benefit distribution coefficients and compensation amount are calculated according to formula (5).

5. Results analysis

The total cost of ecological protection in the upstream is calculated based on formulae (3) and (4). From **Table 1**, it can be seen that the value of the cost among upstream provinces varied from 2011 to 2020, fluctuating between 11 billion and 19.85 billion yuan; however, the values are high in each province. The cost of ecological protection is inextricably linked to the ecological and social differences between them. The mean value of the total cost reached more than 164 billion yuan.

As is indicated in **Table 2**, the values of benefit distribution coefficients of the midstream and downstream varied from 0.0160 to 0.0816. The values in Shandong and Henan are relatively high, with a mean value over 0.05, whereas the values in Shanxi and Shaanxi are below 0.03. The differences among downstream provinces indicated the different stages of economy in each province.

We calculated the compensation amounts of midstream and downstream provinces based on formula (1). It can be seen from **Table 3** that the values of compensation ranged from 229 million yuan to 1,440 million yuan. Compared with the cost paid by upstream provinces, the values of compensation are relatively low. The compensation of each province is closely linked to the economic conditions of different regions. The four compensated midstream and downstream areas are listed in the following order, from the highest to lowest ecological compensation amount to be paid: Shandong, Henan, Shaanxi, and Shanxi Province. Shandong Province has the highest GDP among them, and its amount of ecological compensation is also the highest.

Table 1. Total cost of upstream provinces (monetary unit: one hundred million yuan)

Year	Inner Mongolia	Gansu	Qinghai	Ningxia	Total
2011	336.61	959.38	220.61	180.27	1,696.88
2012	352.08	1097.40	241.67	191.68	1,882.83
2013	376.50	1243.32	288.73	218.30	2,126.86
2014	221.94	1107.04	243.89	223.80	1,796.68
2015	189.92	1142.92	279.65	252.68	1,865.16
2016	110.52	1181.02	281.41	260.14	1,733.08
2017	114.22	1239.19	255.76	267.59	1,648.31
2018	148.64	1985.07	239.57	239.57	2,115.57
2019	226.33	1451.45	267.51	269.74	1,662.37
2020	389.35	1419.53	252.60	285.44	2,346.92
Mean	246.61	1282.63	257.14	238.92	1,887.47

Table 2. Benefit distribution coefficients of the midstream and downstream

Year	Shanxi	Shandong	Henan	Shaanxi
2011	0.0227	0.0816	0.0550	0.0254
2012	0.0217	0.0798	0.0538	0.0263
2013	0.0202	0.0798	0.0533	0.0268
2014	0.0188	0.0789	0.0537	0.0270
2015	0.0172	0.0803	0.0538	0.0260
2016	0.0160	0.0787	0.0539	0.0255
2017	0.0174	0.0757	255.76	0.0258
2018	0.0174	0.0725	239.57	0.0260
2019	0.0172	0.0715	267.51	0.0261
2020	0.0176	0.0718	252.60	0.0257
Mean	0.0186	0.0771	0.0540	0.0261

Table 3. Compensation amounts of the midstream and downstream (monetary unit: one hundred million yuan)

Year	Shanxi	Shandong	Henan	Shaanxi
2011	3.24	11.62	7.83	3.62
2012	3.45	12.67	8.55	4.17
2013	3.65	14.40	9.62	4.84
2014	2.92	12.27	8.36	4.21
2015	2.67	12.48	8.37	4.04
2016	2.31	11.38	7.79	3.69
2017	2.43	10.56	7.52	3.60
2018	2.90	12.10	9.06	4.35
2019	2.29	9.51	7.24	3.48
2020	2.59	10.57	7.88	3.78
Mean	2.84	11.76	8.22	3.98

5. Conclusion

Based on the actual situation of the Yellow River Basin, an accounting model is designed for the ecological compensation quota of the Yellow River Basin from the following three aspects: water quantity, water quality, and benefit distribution. The opportunity cost method and the comprehensive cost method are used to measure the annual ecological protection of the upstream. Combined with Engel coefficient and the actual payment capacity of each region (reflected by the ratio of GDP), the compensation fees payable by the beneficiaries in the midstream and downstream are determined.

From the empirical results, the four compensated midstream and downstream areas are listed in the following order, from the highest to lowest ecological compensation amount to be paid: Shandong, Henan, Shaanxi, and Shanxi Province. The economic development level of Shandong is the highest among the 9 provinces of the Yellow River Basin, and the amount of ecological compensation it needs to pay is also the highest. The ecological compensation amount in the compensation area is moderate, in line with the local economic development and payment capacity. Comparing the calculated final compensation amount with the opportunity cost loss value in the upstream, the compensation amount is much lower than the cost loss value, and it is not enough to make up for the cost of ecological protection.

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Disclosure statement

The authors declare no conflict of interest.

Author contributions

S.W. conceived the idea of the study and wrote the thesis, Y.Z. analyzed the data and wrote the paper. All authors contributed to the paper and approved the final manuscript.

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