Research on Ecological Compensation Standard and Spatial Optimization of the Five Major River Basins in Jiangxi Province

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Abstract. Based on the actual situation of the river basin in Jiangxi Province and the related literature, we construct an estimation model for the ecological compensation standards of the Five Major River Basins in Jiangxi Province, and have measured the ecological compensation standard of each research area. We use ArcGis and Geoda software to analyze spatial autocorrelation and hotspots of ecological compensation standards. The above research results are used as the basis for spatial optimization of watershed ecological compensation standards, contributing to the further improvement of ecological compensation of the Five Major River Basins in Jiangxi Province.

1. Introduction
As one of the most important ecosystems in the world, watershed has great ecological value in material production, water conservation, waste treatment, water regulation and so on[1]. It plays an important role in alleviating or controlling eco-environmental pollution and promoting economic development. Many scholars generally believe that the construction of watershed ecological compensation mechanism is one of the most effective ways to effectively protect the source of rivers. The Five Major River Basins in Jiangxi Province play an important role in the continuous improvement of the ecological environment in Jiangxi Province. In order to effectively protect the ecological environment of the Five Major River Basins in Jiangxi Province, the government successively issued the “Jiangxi Provincial Basin Ecological Compensation Measures” in January 2018. This document publishes the specific basis for the calculation of compensation standards in different regions of Jiangxi Province, effectively overcomes the drawbacks of “one size fits all” in the ecological compensation standard for river basins, and has made effective efforts to formulate and implement watershed ecological compensation standards. However, the formulation of watershed ecological compensation standard only takes into account the integration of existing funds, and does not take into account the value of watershed ecosystem services, economic and social factors, which makes the ecological value of the Five Major River Basins in Jiangxi Province seriously underestimated. Then it may cause the compensation effect could not be better displayed. Meanwhile, the current policy does not distinguish and optimize the compensation standards of the Five Major River Basins in Jiangxi Province from a spatial perspective, making the limited compensation funds unable to play the largest role. Scholars have done a lot of researches on the
ecological compensation standard of river basin, and they usually use the travel expenditure method, conditional value assessment method, and avoid payment method to estimate the ecological compensation standard of river basin. There are relatively few studies on spatial optimization of watershed ecological compensation standards, and only some studies are analyzed from a qualitative perspective. At present, spatial autocorrelation and spatial hot spot analysis are the main methods for spatial optimization research. Spatial autocorrelation is widely used. Based on Moran’s I index, the scholars studied spatial autocorrelation such as the rare earth elements[2], phase separating mixtures[3], risk rating of forest insect outbreaks[4]. Meanwhile, spatial hot spot analysis is currently widely used in bioenergy[5], epidemic disease[6], crime[7]. In addition, the main application software of the above research is Geoda developed by Professor Anselin and ArcGis developed by Esri. Based on the above literature, we could find that scholars have made fruitful research on the ecological compensation standards for river basins. However, the current research on watersheds rarely combines the value of ecosystem services with local socio-economic conditions to determine ecological compensation standards. At the same time, there are relatively few spatial optimization studies for watershed ecological compensation standard, which lacks spatial quantitative analysis and may lack objectivity for compensation results. In view of this, this paper constructs an estimation model of ecological compensation standards for the Five Major River Basins in Jiangxi Province from the perspectives of ecosystem service function value, GDP of the research area and watershed area. In view of this, this paper constructs a standard estimation model of ecological compensation for Five Major River Basins in Jiangxi Province from the perspectives of ecosystem service value, GDP of the research area and watershed area. Based on this model, we have attempted to measure the ecological compensation standards of the each study area of the five river basins in Jiangxi Province, and then use ArcGis and Geoda software to analyze the spatial autocorrelation and hotspots of ecological compensation standards for the further improvement of the relevant policies of ecological compensation for the Five Major River Basins in Jiangxi Province.

2. General situation of the research areas

![Figure 1. Schematic Map of the Five Major River Basins in Jiangxi Province.](image)
3. Research methods

3.1. Estimation Model of Ecological compensation Standard of the Five Major River Basins

Referring to the research results of the related literature, we establish the ecological compensation standard estimation model of the Five Major River Basins in Jiangxi Province. Specifically, it is shown in formula (1).

\[ Y_i = Y_\phi - \bar{Y} = (RV_i - \frac{R_i}{X_i}GDP_i) - \left( \sum_{i=1}^{n} RV_i - \sum_{i=1}^{n} \frac{R_i}{X_i}GDP_i \right)/n \]  \hfill (1)

In the formula (1), \( Y_\phi \) represents the value of the ecosystem services function generated by a regional river basin minus the regional GDP generated by the river basin. \( Y \) represents the overall average value of the study area. \( Y_i \) represents whether the region has ecological surplus or ecological loss. \( RV_i \) represents the value of the ecosystem services for the county \( i \) which is covered by the Five Major River Basins in Jiangxi Province. \( R_i \) represents the drainage area of the county \( i \) covered by the Five Major River Basins in Jiangxi Province. \( X_i \) represents the administrative area of county \( i \) covered by the Five Major River Basins in Jiangxi Province. The data comes from the Jiangxi statistical yearbook. \( n \) represents the number of counties covered by the Five Major River Basins in Jiangxi Province.

3.2. Spatial autocorrelation estimation model

In this paper, we use the global Moran’s I index to analyze the spatial autocorrelation of ecological compensation standards for the Five Major River Basins in Jiangxi Province. The specific formula is as follows.

\[ I = \frac{n}{\sum_{i=1}^{n} \sum_{j=1}^{n} U_{ij} \times \sum_{i=1}^{n} \sum_{j=1}^{n} (y_i - \bar{y})(y_j - \bar{y})}{\sum_{i=1}^{n} (y_i - \bar{y})^2} \]  \hfill (2)

In the formula (2), \( n \) represents the number of counties covered by the Five Major River Basins in Jiangxi Province. \( U_{ij} \) represents the spatial weight value. \( y_i \) and \( y_j \) represent the observed values at position \( i \) and position \( j \), respectively. \( \bar{y} \) represents the average of the observed values. \( I \) represents the global Moran’s I index, which has a range of \([-1, 1]\).

3.3. Hot spot analysis model of ecological compensation standard for the Five Major River Basins in Jiangxi Province

In this paper, the \( G \) coefficient (\( G_i^* \)) in the local autocorrelation is adopted as the analysis method to conduct a hot spot analysis on ecological compensation standards for the Five Major River Basins in Jiangxi Province. Specifically, it is shown in formula (3).

\[ G_i^* = \frac{\sum_{j=1}^{n} U_{ij}y_j - y \sum_{j=1}^{n} U_{ij}}{S \sqrt{\frac{n\sum_{i=1}^{n} U_{ij}^2 - (\sum_{i=1}^{n} U_{ij})^2}{n - 1}}} \]  \hfill (3)

In the formula (3), \( G_i^* \) represents the Z value, which is used to judge the hot spots and cold spots of the ecological compensation standards for the Five Major River Basins in Jiangxi Province. If the Z value of a region is larger, indicating that the hot spot aggregation is closer, so the region should acquire priority compensation. On the contrary, it indicates that the cold point aggregation is closer, and then the region is the priority payment area. \( S \) stands for standard deviation. Other variables are consistent with the above, and we do not repeat them.
4. Ecological compensation standard of the Five Major River Basins in Jiangxi Province

The annual ecosystem service function value of the Five Major River Basins in Jiangxi Province is ¥327.284 billion. We substitute the collected data into formula (1), and we can obtain ecological compensation standards for each research area of the Five Major River basins in Jiangxi Province, as shown in Table 1.

Table 1. Ecological compensation standard for the Five Major River Basins.

| River Basin | County       | Standard (¥Billion /Year) | County       | Standard (¥Billion /Year) | County       | Standard (¥Billion /Year) |
|-------------|--------------|---------------------------|--------------|---------------------------|--------------|---------------------------|
| Ganjiang    | Zhanggong    | 19.10                     | Qingyuan     | -21.56                    | Luxi         | -13.32                    |
|             | Ganxian      | 25.37                     | Jizhou       | -32.33                    | Yushui       | -21.50                    |
|             | Nankang      | 11.56                     | Jinggangshan  | -6.60                     | Fenyi        | -8.31                     |
|             | Xinfeng      | 31.09                     | Ji’an        | -24.33                    | Yuanzhou     | -14.99                    |
|             | Dayu         | 12.20                     | Jishui       | -13.03                    | Fengcheng    | -61.51                    |
|             | Shangyou     | 15.83                     | Xiajiang     | -6.88                     | Gao’an       | -15.58                    |
|             | Chongyi      | 37.85                     | Xingan       | -6.05                     | Zhangshu     | -27.89                    |
|             | Longnan      | 16.78                     | Yongfeng     | -0.06                     | Wanzai       | -7.43                     |
|             | Quannan      | 14.79                     | Taihe        | 5.88                      | Shanggao     | -13.66                    |
|             | Jinggangshan | 19.10                     | Suichuan     | 25.34                     | Yifeng       | 1.55                      |
|             | Ganxian      | 25.37                     | Wan’an       | 2.22                      | Donghu       | -37.91                    |
|             | Xinfeng      | 31.09                     | Anfu         | -15.54                    | Xihu         | -36.18                    |
|             | Dayu         | 12.20                     | Yongxin      | 8.13                      | Qingyunpu    | -23.54                    |
|             | Shangyou     | 15.83                     | Le’an        | 0.85                      | Qingshanhu   | -26.04                    |
|             | Chongyi      | 37.85                     | Xingan       | -6.05                     | Xinjian      | -16.84                    |
|             | Quannan      | 14.79                     | Xiangdong    | -17.88                    | Nanchang     | -47.07                    |
|             | Jinggangshan | 19.10                     | Shangli      | -4.62                     | -            | -                         |
|             | Ganxian      | 25.37                     | Lianhua      | -4.65                     | -            | -                         |
| Fuhe        | Nanfeng      | 5.85                      | Yihuang      | 5.55                      | Linchuan     | -7.63                     |
|             | Guangchang   | 8.11                      | Le’an        | 7.74                      | Fengcheng    | -6.34                     |
|             | Lichuan      | 8.36                      | Jinxu        | 1.14                      | Nanchang     | -24.92                    |
|             | Nancheng     | 4.12                      | Chongren     | -0.30                     | Jinxi        | -4.62                     |
|             | Zixi         | 3.97                      | Dongxiang    | -0.46                     | Yugan        | -0.57                     |
| Raohe       | Fuliang      | 90.28                     | Changjiang   | -57.82                    | Poyang       | -30.99                    |
|             | Wayuan       | 76.41                     | Zhushan      | -78.10                    | Wannian      | -26.78                    |
|             | Dexing       | 44.59                     | Leping       | -17.59                    | -            | -                         |
| Xinjiang    | Guangfeng    | 15.14                     | Hengfeng     | 11.75                     | Yuehu        | -44.04                    |
|             | Shangrao     | 36.55                     | Xinzhou      | -42.72                    | Yujiang      | -15.25                    |
|             | Yushan       | 65.90                     | Yiyang       | -10.00                    | Guixi        | -9.06                     |
|             | Yanshan      | 12.24                     | Yugan        | -20.51                    | -            | -                         |
| Xiuhe       | Wuning       | 25.95                     | Lianxi       | -23.44                    | Gongqingchen | -15.62                    |
|             | Xiushui      | 31.81                     | Xunyang      | -46.44                    | Wanli        | -13.33                    |
|             | Yongxiu      | 21.54                     | Jiujian      | -15.55                    | Xinjan       | -7.48                     |
|             | Fengxin      | 26.06                     | De’an        | -11.32                    | Anyi         | -1.32                     |
|             | Yifeng       | 40.64                     | Duchang      | -7.71                     | Gao’an       | -12.7                     |
|             | Jing’an      | 13.74                     | Hukou        | -15.51                    | Lushan       | -3.53                     |
|             | Tonggu       | 38.99                     | Pengze       | -6.3                      | Ruichang     | -18.48                    |

Note: The research units are marked with italics are the upper reaches of the river basin.
According to the Table 1, the ecological compensation criteria for the research units in the upstream areas are all positive in the counties covered by the Five Major River Basins in Jiangxi Province, indicating that these areas have ecological surpluses. Therefore, as the main body of ecological compensation, these research units should receive ecological compensation. Meanwhile, most of the research units in the Five Major River Basins in Jiangxi Province have negative ecological compensation standards, indicating that these areas have ecological losses. So these research units should be treated as payers.

5. Spatial optimization of ecological compensation standard of the Five Major River Basins in Jiangxi Province

5.1. Spatial autocorrelation Analysis of ecological compensation standards of the Five Major River Basin in Jiangxi Province

According to the above data, we use GeoDa software to conduct spatial autocorrelation research on ecological compensation standards for each research area of the Five Major River Basins in Jiangxi Province. The specific research results are shown in Table 2.

| Moran’s I | S.D. | z-value | p-value |
|-----------|------|---------|---------|
| 0.5017    | 0.0625 | 8.1807 | 0.0010 |

From the research results in Table 2, we can find that the Moran’s I index is 0.5017 and the P-value is 0.0010, which indicates that there is a positive spatial autocorrelation among the ecological compensation standards for each research unit of the Five Major River Basins in Jiangxi Province.

5.2. Spatial Hot spot Analysis of Ecological compensation Standard of the Five Major River Basins in Jiangxi Province

Based on the above research results, we use ArcGis software to carry out spatial hotspot analysis of ecological compensation standards to determine the priority of ecological compensation in the Five Major River Basins in Jiangxi Province, and provide theoretical basis for further priority of Jiangxi Province watershed ecological compensation policy. The specific research results are shown in Figure 2.

According to the spatial hot spot analysis map in Figure 2, there are both spatial cold spots and spatial hot spots for ecological compensation standards of the Five Major River Basins in Jiangxi Province. Meanwhile, it can be found from Figure 2 that Nanchang, Xinjian, Qingshanhu, Wanli, Poyang and Jinxian are located in the low-concentration areas of the ecological compensation standards for the Five Major River Basins in Jiangxi Province. The z-value of these regions are less than -2.58, indicating that these regions should be the most advanced priority payment areas for ecological compensation of the Five Major River Basins. The z-value of Zhangshu, Fengcheng, Leping, Duchang and Anyi are between -2.58 and -1.96, indicating that these regions should be the secondary priority payment areas for ecological compensation of the Five Major River Basins in Jiangxi Province. Anyuan, Huichang, Yudu and Dexing are in the high aggregation area of ecological compensation standard for the Five Major River Basins in Jiangxi Province, and the z-value of these areas are greater than 2.58, indicating that these areas should be regarded as the highest priority compensation area of the Five Major River Basins in Jiangxi Province. The z-value of Xunwu and Wuyuan are between 1.96 and 2.58, indicating that these areas should be the secondary priority compensation areas for the ecological compensation of the Five Major River Basins in Jiangxi Province.
6. Research conclusions and recommendations

In order to further improve the ecological compensation in Jiangxi Province, we put forward the following three Suggestions. Firstly, we should make clear the subject and object of the watershed ecological compensation. According to the research results in Table 1, it can be concluded that the ecological compensation standards of the most upstream areas for the Five Major River Basins in Jiangxi Province are positive. Therefore, these research areas should be regarded as the object of watershed ecological compensation. However, most of the downstream research areas of the Five Major River Basins in Jiangxi Province have negative ecological compensation standards, so these research areas should be the main subject for watershed ecological compensation. Secondly, the government should consider the spatial characteristics of the region when formulating the basin ecological compensation policy. In the process of formulating the “Measures for Ecological Compensation for River Basins in Jiangxi Province”, the Jiangxi Provincial Government did not consider the spatial characteristics of compensation standards for each study area. However, it can be found from the research results that the ecological compensation standards for the research areas of the Five Major River Basins in Jiangxi Province have obvious spatial correlation. Therefore, when further improving the ecological compensation of river basins in Jiangxi Province, we should pay more attention to the spatial characteristics of the research areas. Thirdly, we should establish the priority of watershed ecological compensation. Through this study, it is found that there are hotspots and cold spots of ecological compensation for the research areas covered by the Five Major River Basins in
Jiangxi Province, which means that in the process of implementing river basin ecological compensation, the priority of watershed ecological compensation should be formulated, so that the limited compensation funds can play the most effective role.

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