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Study on compensation mechanism for regional ecological protection under the background of ecological civilisation

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Abstract: To improve the effect of regional ecological protection, research on the compensation mechanism for regional ecological protection under the background of ecological civilisation is proposed. Firstly, the connotation of ecological civilisation and the basic process of ecological compensation are expounded to make the whole compensation process clearer; secondly, the ecological footprint is innovatively used as the evaluation index of regional ecological protection compensation, the ecological carrying capacity is calculated, and a three-dimensional ecological footprint model (EFM) is established; Finally, introduce the principle of ecological compensation priority, establish an ecological protection compensation model, calculate the amount of ecological protection compensation, and realise regional ecological protection compensation under the background of ecological civilisation. The experimental results show that, compared with the traditional compensation methods, the compensation for ecological protection amount structure of this method is basically consistent with the actual results, and the ECC and compensation coverage have been improved.

Keywords: ecological civilisation; regional ecological protection; compensation mechanism; 3D EFM; regional evaluation indicators; carrying capacity; ECC.

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1 Introduction

The public in every era has its corresponding social responsibility, so as to promote the progress of society. Mankind is changing from the era of industrial civilisation to the ecological civilisation era. The matching public green responsibility is an important

symbol of public responsibility in the ecological civilisation era and a natural choice for building an ecological civilisation society (Kangas et al., 2021). International environmental protection experience shows that building an ecological civilised society is inseparable from public participation and public green responsibility. Facing the severe domestic ecological and environmental situation, the ecological environmental protection work of China is facing unprecedented opportunities and challenges (Vaissière et al., 2021). The eco-environmental crisis is testing the rationality, wisdom and responsibility of the Chinese government, enterprises and the public. How to scientifically build the operation mechanism of public green responsibility in China is a vital issue which should be solved urgently in constructing ecological civilisation and building a society which is resource-saving and environment-friendly (Baumgartner et al., 2020).

Compensation for ecological protection is an important institutional support for the ecological civilisation construction. Compensation for ecological protection is a public system aimed at protecting the ecological environment, promoting the harmonious development between man and nature. It takes a full consideration of development opportunity cost, ecosystem service value (ESV) and ecological protection cost, using government and market means to give reasonable compensation to ecological protectors and make adjustment of the interest relationship among ecological protection stakeholders (Yost et al., 2020; Cruz et al., 2020; Fricke et al., 2018). The narrow sense of compensation for ecological protection mainly refers to the reward for the benefits from the ecosystems and natural resources protection or the compensation for the losses due to ecosystem and natural resource destruction. The broad sense of compensation for ecological protection also includes the charges for those who cause environmental pollution.

Lai and Chen (2020) propose a mechanism of compensation for regional ecological protection on the basis of the opportunity cost method. The protected areas established are deemed as an important way to maintain biodiversity and prevent the ecological environment deterioration. The rational implementation of compensation for ecological protection is the key means to ensure the construction and management effectiveness of protected marine areas and promote the fairness of opportunities for regional economic development. From the perspective of opportunity cost compensation, the opportunity cost compensation base and regional adjustment coefficient are set respectively, and the calculation method of compensation for ecological protection standard in the reserve is constructed. Zhao et al. (2018) proposes a regional compensation for ecological protection mechanism based on watershed scale. Compensation for ecological protection is an important measure to effectively mobilise the enthusiasm of all parties and accelerate the ecological civilisation construction. Compensation for ecological protection is a vital fields of environmental protection. Starting from the ecological characteristics, this paper puts forward a regional compensation for ecological protection mechanism based on watershed scale, points out the methods to determine the scope, benchmark and mode of watershed comprehensive compensation for ecological protection, and carries out the field compensation work. Wang et al. (2020) proposes a regional compensation for ecological protection mechanism on the basis of comprehensive AHP fuzzy evaluation method. Ecological compensation plays a vitally significant role in the ecological environment improvement, and also has different degrees of influence on the society, economy, health and other aspects of the region. How to scientifically and reasonably define and evaluate the social, economic and ecological environmental impact and the degree of impact brought by compensation is of great

significance. Based on summarising the characteristics of ecological compensation, a regional compensation for ecological protection mechanism based on analytic hierarchy process (AHP)-comprehensive fuzzy evaluation method is established, and the application effect of the compensation mechanism is studied by taking the pilot of cross basin ecological compensation mechanism as the object of study.

In order to further improve the ecological compensation effect, innovative research on regional compensation for ecological protection mechanism is carried out under the background of ecological civilisation.

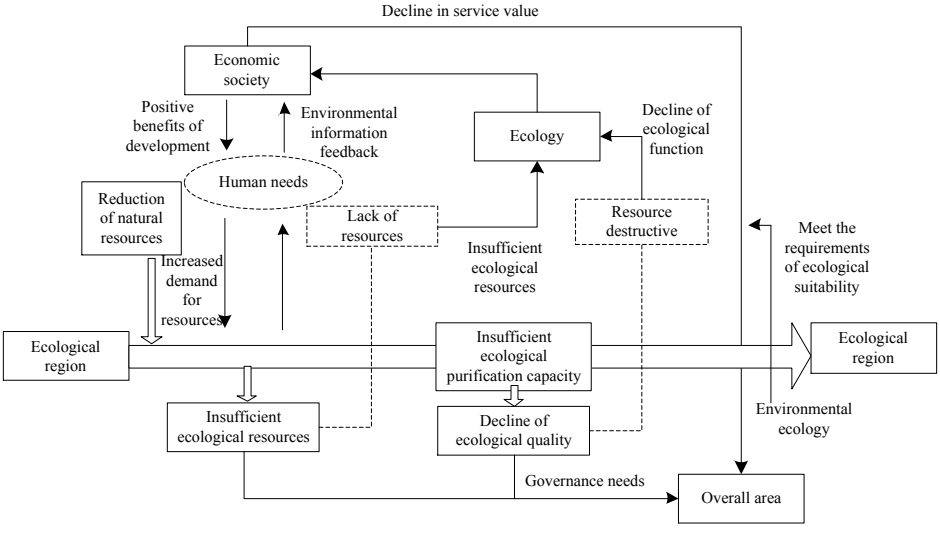
2 Connotation of ecological civilisation and basic process of ecological compensation

With the deepening of people's understanding of sustainable development, the proposal of ecological civilisation has become an inevitable result. Based on facts, human development should be the coordinated development between man and society and environment and between contemporary people and future generations. During this process, we should attach importance to both intragenerational equity, but also to intergenerational equity. Instead of focusing on the interests of contemporary people and sacrificing the interests of future generations, we must attach importance to ecological civilisation, set up the concept of ecological civilisation development and promote the ecological civilisation construction. However, to "energetically promote the ecological civilisation construction", we must first make clear what is "ecological civilisation". Ecological civilisation does not refer to the 'civilised' state of natural ecology, but refers to treating ecology in a civilised way (Hansen et al., 2018; Hyland and Bertsch, 2018; Gastineau et al., 2021). Ecology is the result of the mutual restriction of various forces and the coordination and symbiosis of various forces; Ecological civilisation is not only the man-nature relationship, but also the man-man relationship. Based on previous studies, it is concluded that ecological civilisation should first be a form of human civilisation, under the condition of respecting and maintaining nature, for the aim of achieving harmonious coexistence between man and man, between man and nature, between man and society, for the connotation of establishing sustainable production and consumption mode, and for the purpose of guiding people to embark on a sustainable and harmonious development path. Ecological civilisation focuses on people's self-consciousness and self-discipline, and lays emphasis on the interdependence, mutual promotion, coexistence and integration between man and nature. It pursues not only the harmony between man and ecology, but also the interpersonal harmony. The interpersonal harmony is the premise of the harmony between people and nature. It can be said that ecological civilisation is the result of mankind's profound reflection in the form of traditional civilisation, especially industrial civilisation. Ecological civilisation is a major progress in terms of human civilisation, and it is also the civilisation development's concept, road and mode (Ruppert et al., 2018).

Recently, the fast development of industrialisation and urbanisation has promoted the rapid regional economic development and social development. In addition to achieving economic growth, the consumption of ecological resources has increased sharply (Ranjan, 2019). Ecological deterioration and other problems are very prominent, the

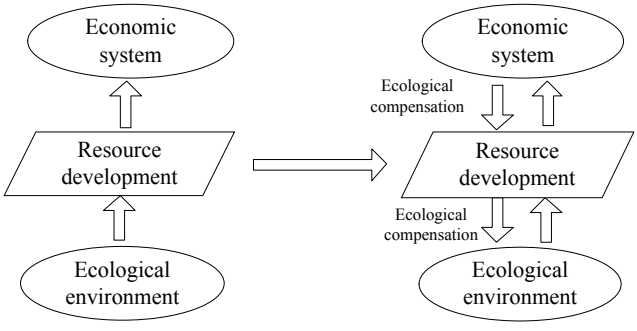
natural ecological environment is not optimistic, and the ecological environment protection situation is very severe. It has become the main bottleneck restricting the sustainable economic and social development, and seriously affects the sustainable environmental development. The rapid development of economy and society leads to a large number of pollutants, and the deterioration of environmental quality leads to the irresistible decline of ecological service function (Fedriani et al., 2020). Therefore, taking ecological protection and restoration as the goal, carrying out comprehensive management of ecological environment and restoring ecological functions is one of the main problems that must be seriously faced and solved in terms of target environmental protection. Figure 1 shows the manifestation of ecological damage.

Figure 1 Manifestations of ecological damage



As a new means of environmental management, ecological compensation regulates the relationship between various interests in ecological environmental protection for the protection and sustainable utilisation of ecosystem services, and has made extraordinary results in practical application at home and abroad. As an effective governance means, ecological compensation promotes the solution of ecological damage in economic development and social development by balancing the interest classification among resource and environment utilisation subjects in economic development and social development, so as to advance the coordinated development among regional economy, society, resources and environment (Kang et al., 2019). Taking the ecological environment as the unit, ecological compensation balances the interests of all subjects in the economic system in the process of environmental development and alleviates the contradiction of environmental use through the way of resource utilisation and environmental protection and ecological compensation. Therefore, ecological compensation currently has become an important measure for restoring and protecting the ecological environment. The ecological compensation process is shown in Figure 2.

Figure 2 Production process of ecological compensation



3 Regional compensation for ecological protection

3.1 Data sources

The major data used here include land use as well as land cover change (LUCC), NPP data, agricultural and animal husbandry production statistics and digital elevation model (DEM).

1 LUCC data came from the spatial distribution vector data of China's land use types in 2015. It was provided by the Resource and Environmental Science Data Center of the Chinese Academy of Sciences. LUCC data came from manual visual interpretation on the basis of Landsat 8 remote sensing images. The land use types consists of 6 primary categories and 25 secondary categories in terms of cultivated land, forest land, water area, grassland, construction and unused land.

2 NPP data adopted the 2013–2020 gross primary production (GPP) data which was developed based on the vegetation photosynthetic respiration model (VPM). It was calculated through the autotrophic respiration ratio, at a spatial resolution of 500 m.

3 The production data of agriculture and animal husbandry was from the regional statistical yearbooks of 2013, 2015, 2018 and 2020. The agricultural production data mainly include grain output, bean output and rapeseed output, in tons; Animal husbandry production data mainly include the year-end stock and mid year stock of large livestock and sheep, with the unit of 10000.

4 DEM data came from the 2010 Global Multi-resolution Terrain Elevation Data (gmted2010). It was provided by the United States Geological Survey (USGS) and the National Geospatial Intelligence Agency (NGA), at a resolution of 900 m.

3.2 3D EFM

Ecological footprint is a new method developed internationally in recent years for quantitative research and judging the sustainable development status of a country or region. It converts various resource and energy consumption items into 6 types of biological production areas such as cultivated land, grassland, forest land, construction land, fossil energy land and ocean (water area), and converts these biological production areas with different ecological productivity into Areas with the same ecological

productivity can be used to quantify ecological status, measure ecological footprint and ecological carrying capacity, and determine whether human beings are within the carrying capacity of their ecosystems. Ecological footprint is a quantitative index based on land area, which directly and vividly reflects the impact of human beings on the earth, and the data is relatively easy to obtain, the calculation method is highly operable and repeatable, and can be compared horizontally and vertically. It can well reveal the complementary relationship between natural capital and economic development; at the same time, the ecological footprint analysis index provides a 'fair stalk' for measuring the degree of sustainability, which can make a judgement on the two-dimensional sustainability degree in time and space. Objective measurements and comparisons provide a clear picture of how far away reality is from sustainability goals, which can help monitor the effectiveness of sustainable programmers. In addition, the ecological footprint calculation has strong reproducibility. This makes it possible to make the ecological footprint calculation process into a software package, which can promote the popularisation of the indicator and method.

Biocapacity refers to the sum of the land area of a country or region that provides all biologically productive land used by humans to meet their needs and the ability to absorb carbon dioxide, including arable land, grassland, construction land, fishing land, providing forest products, and carbon dioxide emissions required woodland.

The traditional ecological footprint model (EFM) lay emphasis on the measurement of flow capital and ignores the critical role of stock capital in regional ecosystem balance. Based on this, the 3D EFM introduces two indexes, namely footprint depth and footprint breadth, so as to characterise the human consumption degree of natural capital stock and the occupation of natural capital flow (Mackenzie, 2018).

In the correspondence between land use types and ecosystem types and values, this paper adopts cultivated land, unused land and forest land to correspond to farmland, forest and desert respectively; Take the average value of forest and grassland in the garden; Residential areas, industrial land, mining land and traffic land correspond to construction land, and the construction land's ESV is zero (Boissier et al., 2020). The calculation formula of ESV and ecosystem single service value (ESV_f) is:

$$ESV = \sum (A_K \times VC_K) \tag{1}$$

$$ESV_f = \sum (A_K \times VC_{fK}) \tag{2}$$

In the above formula, A_k represents the area of K land use types in the study area, and VC_K and VC_{fK} respectively represent land use type K's ESV and ecosystem single service value per unit area (Bennett et al., 2018).

In the calculation of ecological footprint, first calculate the per capita ecological footprint (A_i) of various consumption accounts from the two parts of biological resource consumption and energy consumption, and then convert various resource and energy consumption items into six types of bio productive land areas: cultivated land, forest land, grassland, construction land, fossil fuel land and water area, and multiply them by a corresponding equilibrium factor to summarise the regional biological productivity and ecological footprint. Calculation formula of regional per capita ecological footprint (*ef*):

$$ef = \sum r_i A_i = \sum r_i P_i / \left(Y_i \times N\right) \tag{3}$$

In the formula, r_i indicates the equilibrium factor, A_i represents the per capita ecological footprint of various consumption accounts; i indicates the consumption item type; Y_i indicates the world average output of the i consumption item of food productive land; P_i indicates the production of the i consumption item, and N indicates population (Lara et al., 2020; Simmonds et al., 2022; Bonilla-Murillo et al., 2022).

The calculation formula of the ecological footprint of the total regional population is:

$$EF_{3D} = (EF_{depth} \times EF_{size}) \times (N \times ef) \tag{4}$$

where EF_{3D} represents 3D ecological footprint; EF_{depth} is the ecological footprint depth; EF_{size} represents the breadth of the ecological footprint. Footprint depth indicates the land area multiple required theoretically for maintaining the current level of regional resource consumption. It reflects the natural capital stock consumption exceeding the ECC; footprint breadth means the area of biological productive land which is actually occupied within the range of the capacity of regional carrying. It reflects the human occupation level of natural capital flow. The calculation formula is shown below:

$$EF_{depth} = 1 + \frac{ED}{BC} = 1 + \frac{\sum_i^n \max\{EF_i - BC_i, 0\}}{\sum_{i=1}^n BC_i} \tag{5}$$

$$EF_{size} = \sum_{i=1}^{n} \min\{EF_i, BC_i\} \tag{6}$$

Among it: ED refers to ecological deficit; BC refers to the ECC. When $EF_{depth} = 1$, it indicates the flow capital just meeting the resource consumption demand; When $EF_{depth} > 1$, it indicates that at this time, the flow capital fails to meet the consumption demand and the stock capital should be consumed.

ECC refers to the total bio productive land area which can provide natural resources for the survival and development of people.

The calculation formula of regional per capita ECC is:

$$bc = \sum C_j = \sum a_j \times r_j \times y_j \tag{7}$$

In the formula, C_j represents the per capita ECC component of the consumption item j; a_j represents the biological production area per capita; r_i represents the equilibrium factor, and y_j represents the yield factor.

The calculation formula of regional total bearing capacity is:

$$BC = N \times (bc) \tag{8}$$

where N represents the total population.

Ecological deficit refers to the difference between ecological footprint per capita and ECC per capita. The formula of calculation is:

$$ED = EF_{3D} - BC = N \times (ef - bc) \tag{9}$$

In formula (9), if $ED < 0$ exists, it indicates that the regional ecological footprint exceeds the ECC it can provide, resulting in ecological deficit, and the region needs to pay

ecological compensation; If $ED > 0$, ecological surplus is obtained; otherwise, ecological surplus is obtained.

Gini coefficient is a common index often used in the world for measuring the resident income gap of a country or a region. The coefficient is between [0,1]. The closer it is to 0, the more equitable the distribution is. Based on international practices, 0.4 is usually used as the Gini coefficient's 'warning line'. The Gini coefficient's change reflects the change in regional agglomeration degree of factors such as counter export distribution, economic development and resource volume. Since the impact of population, GDP and resource volume on the distribution of ecological resources can be regarded as equally important, the three impact factors can be used as the evaluation index of ecological footprint, give weight, and calculate the comprehensive Gini coefficient to reflect the spatial balance of the ecological footprint of the studied region. The calculation formula is:

$$G_i = 1 - \sum_{i=1}^{n} (X_i - X_{i-1})(Y_i + Y_{i-1}) \tag{10}$$

$$G_t = (G_1 + G_2 + G_3)/3 \tag{11}$$

where G_i indicates the Gini coefficient; X_i indicates the cumulative percentage of influencing factor indexes; Y_i indicates the cumulative percentage of ecological footprint per capita; i indicates the sequence number of regional location. When $i = 1$, (X_{i-1}, Y_{i-1}) is deemed as (0,0), and G_t is the comprehensive Gini coefficient. Generally, Gini coefficient below 0.2 means "absolute average"; [0.2,0.3) indicates "relatively average"; [0.3,0.4) indicates "relatively reasonable"; [0.4,0.5) indicates "large degree of Agglomeration"; a value of 0.5 or above indicates that the investigated elements are highly biased in the region.

3.3 Regional compensation for ecological protection model

The ecological compensation priority is introduced to represent the priority of getting ecological compensation in various regions. It indicates the non-market value ratio of ecosystem services per unit area to per unit area GDP in a region. Since the market ESV has been converted into money in the market mechanism, only the non-market money part is taken in the determination of ecological compensation. The specific expression is as follows:

$$ECPS = VAL_N / GDP_N \tag{12}$$

In the formula, GDP_N represents the Gross Regional Product per unit area, and VAL_N represents the non-market value of ecosystem per unit area. A smaller $ECPS$ of the study area contributes to a smaller impact on its economic situation after paying ecological compensation and the more efforts it makes on taking the lead in paying ecological compensation funds.

Because the ESV is often large and difficult for payers to bear, in order to enhance the operable system, determine the areas that should pay or obtain ecological compensation, so as to realise the transformation between ESV and compensation. The specific calculation formula is:

$$E = |ef - bc| \times N \times ESV \times r_i \tag{13}$$

In the formula, E represents the ecological compensation value, r_i represents the ecological compensation correction coefficient, and ESV represents the ESV. Meanwhile, in combination with the regional economic development, the ecological compensation correction coefficient r_i is introduced. The specific expression is as follows:

$$r_i = \left(I_{ED_i} / \overline{I}_{ED}\right) \times \left(GDP_i / GDP\right) \tag{14}$$

In the formula, I_{ED_i} indicates the ecological deficit per capita of region i; $\overline{I}_{ED}$ indicates the ecological deficit per capita of the total study region; GDP_i indicates the GDP of region i, and GDP represents the GDP of the total study region.

On the basis of the 3D EFM and the actual conditions of study area, the actual amount of ecological compensation due to each region is determined through the indexes of ecological resource transformation efficiency and willingness to pay. The calculation formula of conversion efficiency of ecological resources is:

$$U_R = \frac{ef_R}{p_R} \tag{15}$$

In the formula, U_R represents the ecological footprint of 10000-yuan GDP in the study area. ef_R represents the ecological footprint per capita, and p_R represents the per capita GDP.

The calculation formula of willingness to pay index is:

$$W_R = \frac{p_R \times l_R}{\overline{p}} \tag{16}$$

$$l_R = \frac{1}{1+e^{-t}}, t = \frac{In_R}{\overline{In}} \tag{17}$$

$$InR = \frac{A \times m + B \times n}{m+n} \tag{18}$$

In the formula, W_R represents the payment willingness; l_R represents the development stage coefficient; In_R represents the per *capita* income within the region; In represents the average income per capita; A represents the disposable income per capita; m represents the total regional population; B represents the net income per capita; n represents the number of rural population.

The calculation formula of ecological service supply coefficient is:

$$\beta_R = \frac{BC_R}{\sum EC} \tag{19}$$

$$V_R = M \times \beta_R \tag{20}$$

In the formula, β_R represents the supply coefficient of ecological services, BC_R represents the total ECC, V_R represents the amount due to the supply of ecological services, and M represents the total amount of ecological services.

The calculation formula of ecological service consumption coefficient is:

$$Rec_R = \frac{U_R \times W_R}{\bar{U} \times \bar{W}} \tag{21}$$

$$\alpha_R = \frac{EF_R \times Rec_R}{\sum_{R=1}^{n} \left(EF_R \times Rec_R \right)} \tag{22}$$

$$F_R = M \times \alpha_R \tag{23}$$

In the formula, Rec_R represents the comprehensive correction coefficient; $\bar{U}$ represents the average ecological footprint of 10000 yuan GDP; $\bar{W}$ represents the average level of payment willingness; α_R represents the *coefficient* of ecological services consumption; F_R represents the amount to be given because of the ecological services consumption.

The compensation amount for ecological protection is calculated according to the above parameters:

In the formula, X_R represents the ecological compensation amount that the region should receive. If $X_R > 0$, it indicates that the ecological compensation amount in the region is net inflow; however, if $X_R < 0$, it is net outflow.

4 Experimental verification

To verify the effect of the put forward regional compensation for ecological protection method under the background of ecological civilisation in practical application, comparative verification experiments are needed.

4.1 Experimental preparation

The land use types distribution in the study area is shown in Figure 3.

Figure 3 Land use types distribution in the study area (see online version for colours)

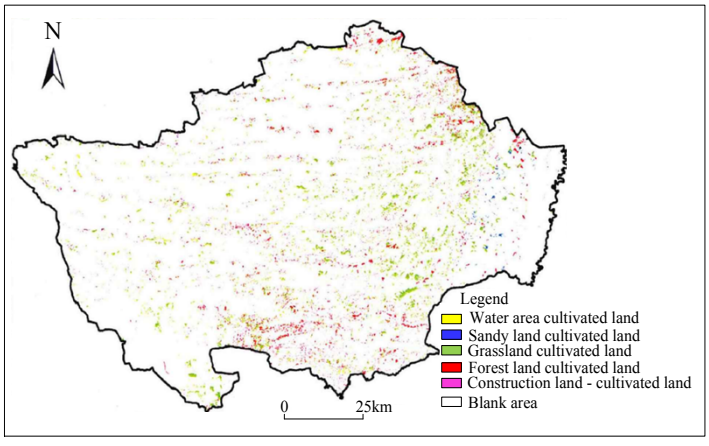


Table 1 shows the relationship *between* product consumption type and land use type in the studied area.

Table 1 Relationship between regional product consumption type and land use type

Product consumption type	*Land use type*	*Specific content*
Biological resource consumption	Cultivated land	Cotton, wheat, rice, vegetables, eggs, pork
	Grassland	Beef, mutton, other meat (poultry) and milk
	Woodland	Citrus, and other fruits like garden fruits, chestnut, tea, wood, bamboo, tung oil seeds
	Waters	Fish, crabs and shrimps, shellfish and other aquatic products (aquaculture)
Energy consumption	Fossil fuel land	Crude oil, diesel oil, raw coal, gasoline, fuel oil, coke coal, liquefied petroleum gas
	Construction land	Electric power

4.2 Analysis of experimental results

The experimental scheme is designed below: Taking the calculation accuracy of compensation for ecological protection amount, compensation for ecological protection coverage and ecological footprint carrying capacity as the experimental comparison indexes, the compensation for ecological protection effect of this method is verified.

4.2.1 Calculation accuracy of compensation for ecological protection amount

The calculation accuracy of compensation for ecological protection amount directly affects the final compensation effect, so accurate calculation of compensation amount is a key index to verify the method of compensation for ecological protection. The comparison results between the actual compensation amount required in the study area and the net compensation calculated by this method are shown in Table 2.

From the calculation accuracy comparison results of compensation for ecological protection amount shown in Table 2, it can be seen that under multiple compensation items, the calculation results of compensation for ecological protection amount in this method are very close to the actual demand results. The compensation amount of some items is the same as the actual amount, and the maximum difference is only 10000 yuan. Thus, it reflects that the calculation of this method can be used to get the real amount of compensation for ecological protection, assist relevant departments to specify a more reasonable compensation mechanism, meet the needs of regional compensation for ecological protection in all aspects, and lay a technical foundation for realising reasonable and effective ecological compensation.

4.2.2 Compensation for ecological protection coverage

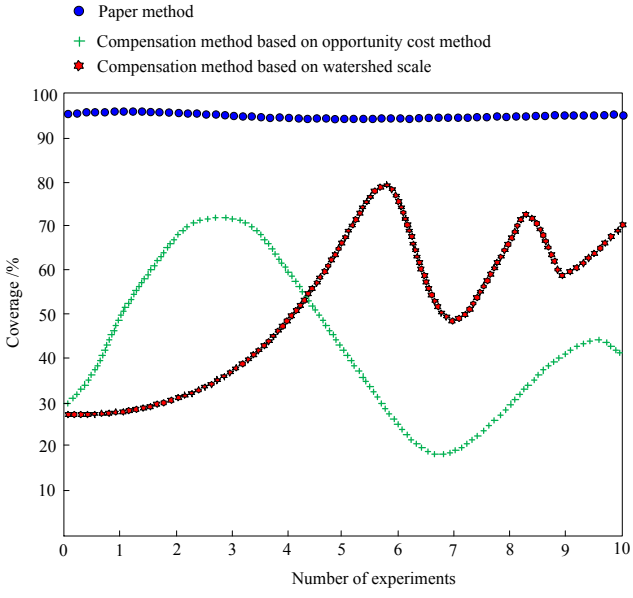
Because the scope of the area requiring compensation for ecological protection is not fixed, and the compensation needs of each area are not the same. If the coverage of compensation for ecological protection is low, it is not easy to show the value of compensation for ecological protection and the role of ecological compensation. Therefore, there are high requirements for the coverage of compensation methods. In

order to reduce the experimental error and improve the reliability of the experimental results, this method is compared with the compensation method based on opportunity cost method proposed in (Lai and Chen, 2020) and the compensation method based on watershed scale proposed in (Zhao et al., 2018). The comparison results of compensation for ecological protection coverage of the three methods are shown in Figure 4.

Table 2 Calculation accuracy results of compensation for ecological protection amount

		Compensation amount/10000 yuan	
Compensation content	*Compensation items*	*Actual results*	*Paper method*
Ecological protection and construction	Ecological governance	531.9	532.1
	Ecological governance	111.1	111.2
	Grazing prohibition compensation	312.9	312.8
	Grass animal balance	46.9	46.9
Improvement of residents' production and life	Ecological resettlement	0	0
	Production and living compensation for immigrants	95.0	95.1
	Herdsmen's production and living compensation	316.8	316.9
Basic public service capacity	Infrastructure	0	0
	Public utilities	448.2	448.1
	Industrial support	0	0
	Social security	163.1	163.2

Figure 4 Compensation coverage rate of ecological protection (see online version for colours)

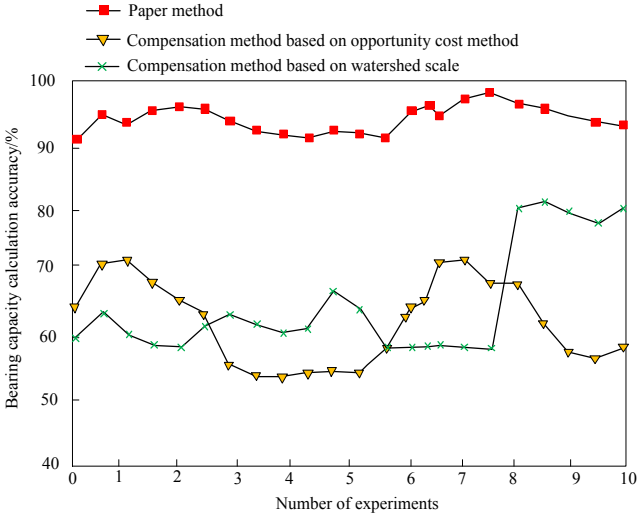


From the comparison results of compensation for ecological protection coverage shown in Figure 4, it can be seen that compared with the two comparison methods, the compensation coverage of this method is always maintained at the level of more than 90%, and the fluctuation level is small, indicating that the stability of this method is high. The ecological compensation coverage of the two comparison methods fluctuates in a large range, and the maximum coverage is less than 90%. Therefore, it shows that the compensation coverage of this method has been improved to a certain extent. This is because this paper innovatively uses the ecological footprint as the evaluation index of the ecological protection compensation mechanism, which ensures the accuracy of the compensation target; calculates the ecological carrying capacity, establishes a three-dimensional EFM, and establishes the ecological protection compensation based on the principle of priority of state compensation. model, obtain accurate compensation amount, and increase compensation coverage.

4.2.3 Calculation accuracy of ecological footprint carrying capacity

The index, ecological footprint carrying capacity, is also a key index for the evaluation of compensation for ecological protection effect, which can fully reflect the carrying capacity of the studied area. Therefore, the calculation accuracy of the three methods' ecological footprint carrying capacity is compared and verified. The calculation results of ecological footprint are shown in Figure 5.

Figure 5 Comparison of accuracy of ecological footprint bearing capacity calculation (see online version for colours)



By observing the comparison results of the calculation accuracy of ecological footprint carrying capacity which are presented in Figure 5, the calculation results of ecological footprint carrying capacity of the three methods show obvious differences. Although the results of the three methods fluctuate to a certain extent, the calculation accuracy of the method in this paper is always higher than that of other comparison methods. Therefore, it shows that this method can accurately calculate the bearing capacity of the studied area and better realise ecological compensation. This is because this paper firstly analyses the

connotation of ecological civilisation and the basic procedures of ecological compensation, which makes the compensation process clearer; and then establishes a three-dimensional EFM, which considers various influencing factors, thereby improving the calculation accuracy of ecological footprint carrying capacity.

5 Regional compensation for ecological protection mechanism

The essential connotation of 'ecological compensation' refers to the behavior that the beneficiaries of ecological service function make payment for the ecological service function providers. It mainly aims for adjusting the interest relationship between ecological protection stakeholders and alleviating the relationship between regional economic development and environmental protection through "compensation", so as to improve, maintain and restore ecosystem services. For regional compensation for ecological protection, the following countermeasures are put forward:

1 *Improve the policy mechanism of compensation for ecological protection*

The implementation of the integration of special financial funds and the concentration of limited financial funds on projects that are urgently needed but have a funding gap meet the current economic situation and the needs of social development, and can improve the use efficiency of financial funds. Therefore, by combing the existing compensation for ecological protection policies, clarifying the existing regional investment in compensation for ecological protection and identifying the problems existing in the process of policy implementation will help to clarify the source and scale of compensation for ecological protection funds, drive the improvement of compensation for ecological protection mechanism and ensure the ecological civilisation construction.

2 *Strengthen top-level design of compensation for ecological protection policy*

Integrate existing policies and regulations, enhance the pertinence and effectiveness of policies, continuously promote the organic integration of individual compensation policies, form compensation for ecological protection policies and regulations led by comprehensive departments, and guide compensation for ecological protection from single element compensation to regional main functions. The comprehensive compensation transformation of positioning ensures that the output capacity of ecological products in the compensated area continues to increase, promotes ecological construction as well as integrated environmental management with compensation for ecological protection, forms a positive interaction with ecological construction and integrated environmental management, and ensures "lucid waters and lush mountains", it will be converted into "Golden Mountains and Silver Mountains" as soon as possible to effectively boost the harmonious development between man and nature.

3 *Construct a long-term mechanism for compensation for ecological protection*

It is a long-term task of establishing and improving the compensation for ecological protection policy. It is suggested to continue to enhance the transfer payment compensation for major ecological functional areas and gradually improve their basic public service level; For some major projects, it is suggested to properly integrate

channels and extend the subsidy period to ensure the smooth transfer of relevant residents. Set up an evaluation system for the effect of compensation for ecological protection and improve the performance evaluation mechanism of compensation for ecological protection. Governments and management departments at all levels prepare annual reports on the implementation of compensation for ecological protection, focusing on whether the objectives, tasks and funds of compensation for ecological protection are issued synchronously, whether the fund distribution is standardised, whether the fund management is strict, whether the subsidy objects are reasonable and whether the funds are in place. In combination with the medium-term rolling budget preparation carried out by the Ministry of finance, conduct a mid-term evaluation on the ecological compensation policy implementation effect, increase the compensation budget funds for places with good protection results, and gradually improve the incentive and restraint mechanism of compensation for ecological protection.

4 *Accelerate the implementation of horizontal compensation for ecological protection*

We will accelerate the pilot of horizontal compensation for ecological protection. For some important ecological functional areas that are not covered in the national key ecological functional areas but have regional significance, we will encourage beneficiary areas and protected areas to carry out horizontal compensation for ecological protection by financial subsidies, counterpart support and industrial transfer, and both sides will share ecological protection funds. It is suggested that the superior government should coordinate and determine the compensation scheme, and the third party should evaluate the compensation effect. For provinces with better implementation of objectives and tasks, the central finance should give appropriate rewards. Encourage the private sector to participate in the provision of public goods and services, and promote the integration of social funds into compensation for ecological protection projects.

6 Conclusion

In the new era and stage of ecological civilisation construction, all provinces and local cities are vigorously exploring means and methods of ecological civilisation construction. The ecological civilisation construction is the organic unity of concept consciousness, theoretical form and practical form. It is an all-round change in the history of human civilisation. It is an innovation and exploration from value to culture, from economy to politics. In the context of ecological civilisation, this paper proposes a new compensation method for regional ecological protection. Analyse the connotation of ecological civilisation and the basic procedures of ecological compensation, and construct the entire compensation process; innovatively use the ecological footprint as an evaluation index of the ecological protection compensation mechanism, calculate the ecological carrying capacity, and establish a three-dimensional EFM; based on the principle of ecological compensation priority, establish an ecological protection compensation model, calculate the amount of ecological protection compensation, and realise regional ecological protection compensation. According to experimental results, this method can accurately calculate the specific amount of different compensation items, and is basically consistent with the actual compensation amount. Therefore, it shows that this method can provide effective technical support for compensation for ecological protection.

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