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Theoretical Study of Watershed Eco-Compensation Standards

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Abstract. Watershed eco-compensation is an effective way to solve conflicts over water allocation and ecological destruction problems in the exploitation of water resources. Despite an increasing interest in the topic, the researches has neglected the effect of water quality and lacked systematic calculation method. In this study we reviewed and analyzed the current literature and proposedatheoretical framework to improve the calculation of co-compensation standard.Considering the perspectives of the river ecosystems, forest ecosystems and wetland ecosystems, the benefit compensation standard was determined by the input-output corresponding relationship. Based on the opportunity costs related to limiting development and water conservation loss, the eco-compensation standard was calculated.In order to eliminate the defects of eco-compensation implementation, the improvement suggestions were proposed for the compensation standard calculation and implementation.

1. Introduction

With the excessive exploitation and utilization of ecosystem services and excessive pollutant discharge, watershed eco-compensation (WEC), as an economic way of environment external effect internalization and an economic promotion method for ecosystem management, obtained widely attention. Since 1970s, the eco-compensation decision process and value impact assessment had been studied in many countries. A large number of compensation study cases of ecological environmental services have been reported, but the study scope is mostly limited to the evaluation of watershed ecological services, and the calculation methods for watershed eco-compensation standards had regional characteristics.

Watershed eco-compensation standards (WECS) affect the feasibility of compensation mechanism. The essence of WECS is to determine the compensation amount, which can reflect ecological service values and environment protection input costs. Accurate calculation of water resource value is the prerequisite to determine the eco-compensation standard of the river basin. Xu and Han calculated related values of water resources with economic methods in different perspectives and levels and deduced the upper and lower limits of eco-compensation standards. Some scholars proposed new ideas for calculating the compensation standard based on the integrity of water quantity and quality, solving the defects of current economic calculation methods. The Game model by Cao, the eco-compensation standard calculation method based on water environmental capacity by Pang, and the eco-compensation standard calculation method based on water quality and total pollutant amount by Lu revealed the potential relationship between water quality and eco-compensation standards.

Promoting upstream protection activities and encouraging the downstream to pay for the upstream according to potential payment capability is the premise of eco-compensation mechanism implementation. Water quality bidding or water quality trade, as the application management tool based on market mechanisms, can provide more incentives for the ecological protectors and encourage them to protect and improve watershed ecological environment. The Indonesian case, in which the bidding mechanism was adopted in the payment, provided an example for the application of water quality tendering in eco-compensation, Jack and Kelsey selected Nyanza Province in Kenya as the experimental model to study the personal intervention effecton environmental services according to the corresponding relationship between the upstream land investment and downstream compensation. The results showed that moderate intervention might affect individual decision-making behaviours on resource protection, thus affecting the implementation of eco-compensation standard.

The consultation mechanism is an effective way to solve the conflicts in the implementation process of compensation standards. The Water Resources and Environment Regulation Fee in Costarica, consultation and non-consultation mechanisms for water allocation in southern Iran, and pollutant emission control methods based on the conflicts of the interests of stakeholders by Niksokhan indicated the importance of consultation mechanism in eco-compensation implementation. Muradianpointed out that the healthy operation of eco-compensation mechanism required the cooperation among all the parties and explained the importance of extensive system assessment. The WEC based on water quantity and quality is the key to achieve the watershed healthy and sustainable development. Some scholars considered the difference between ecological construction inputs and the obtained ecological benefits of upstream as the basis of eco-compensation standard in cross-regional areas. It is conducive to the operation of bidirectional incentive and restraint mechanisms in the upstream and downstream administrative districts. The water quality control target received or not is the main basis for determining the amount of compensation.

According to the analysis of current researches about the theory system of compensation standards, it can be found that the current studies had strong pertinence and poor generality, especially had seldom studies on the compensation standard combining regulation of water quantity and quality. Current studies on the eco-compensation standard management system and implementation mechanism have achieved some initial results, but it was usually focused on social management experience and implementation of water compensation in small river basin, ignoring the impact of natural factors on the water cycle and related aspects.

2. Theoretical Framework of Compensation Standards

In order to fully reflect the diversity of water ecological values in water scarcity area, based on the variations in water quantity and quality under natural and artificial conditions, from the perspective of the factors of eco-compensation standard calculation, water quantity and water quality control modules were respectively established in the paper. According to pollutant-holding capability of water bodies and pollutant control goals, based on government supervision and the consultation mechanism between upstream and downstream, we provided the calculation basis for WECS, as shown in Fig.1.

3. Implementation Basis of Compensation Standards

At present, most of watersheds in China are characterized by fragile ecological environment and low guarantee of minimum ecological water demand. Healthy ecological environment in the upstream is of great significance to the material production and ecological values in the downstream and even the whole watershed. According to the minimum vegetation coverage required for sand fixing (the value was temporarily determined as 20% according to the topography and vegetation characteristics in northern China as well as previous study results), basic ecological water consumption of the upstream was reserved in advance. Based on free consultation, the downstream ecological service beneficiary should compensate the upstream according to the principle of cost sharing and equivalent exchange.

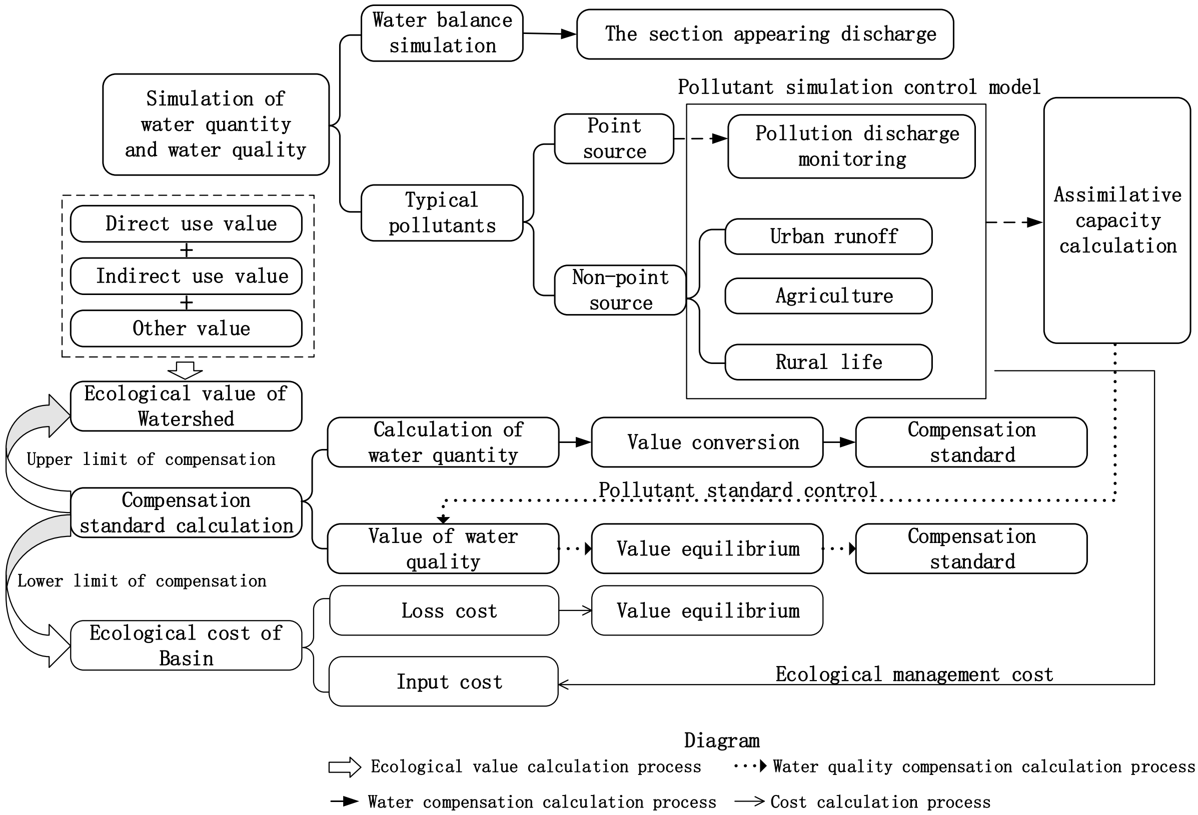

Figure 1. The watershed eco-compensation standard framework.

The discharge of wastewater from upstream reduced water quality compliance rate in the downstream to a certain extent. In the upstream, pollutant discharge (except natural pollutant) was strictly controlled and water quality qualification in boundary section was realized through water self-purification. Thus, the downstream paid corresponding compensation to the upstream according to the upstream investment in pollution reduction and the cost of maintaining water quantity for self-purification. When pollutants in watershed downstream section exceeded the required pollutant concentration, based on free consultation mechanism, the compensation standards was determined by comparing the upstream investment in pollutant reduction and the downstream development loss caused by water quantity reduction. Reclaimed water recycling in the upstream also reduced fresh water needed and increased water quantity in the downstream. Under this circumstance, the downstream should compensate the upstream for the investment in ecological protection according to the local financial situation.

3.1. Water Quantity Compensation and Water Quality Compensation

Water resources have dual attributes of water quantity and quality, which determine the function and values of water. The value of water resources has great difference in different regions, different areas and different periods. According to general monitoring level of water environment in northern China, the Class-III water pollution standard was selected as the determination basis of cross-regional compensation standard, which realizing the relationship between economic compensation and water quantity and quality of the polluted rivers.

Water quantity compensation was the key to balance initial water right allocation and to realize the comprehensive, coordinated, and sustainable development of watersheds. The compensation standard for water quality was determined according to the control standards of water function area of boundary section in watershed. In order to realize the objective of "optimal utilization of excellent water and restricted utilization of inferior water" based on the WEC and initial allocation of water rights, compensation payers should fully utilize the upstream protection achievements to promote the coordinated development in the whole watershed and support upstream ecological construction based on the economic benefits obtained through water-saving technology. In this way, the optimal allocation of water resources and maximum external positive benefits of water ecological protection might be achieved.

3.2. Compensation Standards Based on the Pollutant Treatment Level

Pollutant emissions trading took minimization of pollutant treatment cost and maximization of the ecological environment improving extent as the goal, and tried to reduce the external input during the transaction. According to the extensive applications of the joint construction and sharing theory, the optimal economic theory, and the payment willingness research method in the implementation of eco-compensation, the combination of pollutant emissions trading and eco-compensation can be realized to a certain degree. In this paper, the correlation analysis of watershed pollution treatment costs was analyzedusing the improved genetic algorithms (NSGA-II) and initial pollutant emission right allocation model (IDPA). In the multi-objective optimization model, the equalization curve between total treatment cost and fuzzy risks causing by excessive pollutant concentration was obtained with NSGA-II model. IDPA model was used to determine whether water quality was qualified under maximum pollutant emission right.

Combined with the equilibrium curve of pollutant emission and treatment, with the known of pollutant treatment level, the exceeding ratio of pollutant concentration was obtained. With the equilibrium curve of pollutant treatment cost and the exceeding ratio of pollutants, total treatment costs were calculated and the compensation standards of upstream and downstream under different pollutant treatment levels could be roughly calculated. The proposed calculation method provided the basis for water quality compensation calculation with the two-drive mechanism in watershed; it was an improvement for water quantity compensation standard.

3.3. Compensation Standard of Ecological Benefit Values

The ultimate goal of ecological compensation is to maintain the normal function of the ecosystem services by encouraging people to protect the ecological environment. In this paper, eco-compensation was considered as “input” and ecological service was considered as “output”. According to the corresponding relationship between inputs and outputs, the eco-compensation amount (ecological service value) was indirectly calculated with output value. With the combined evaluation framework of ecological products and service types, systematic classification of eco-system function could provide the basis for water ecological service value calculation, as shown in Fig.2.

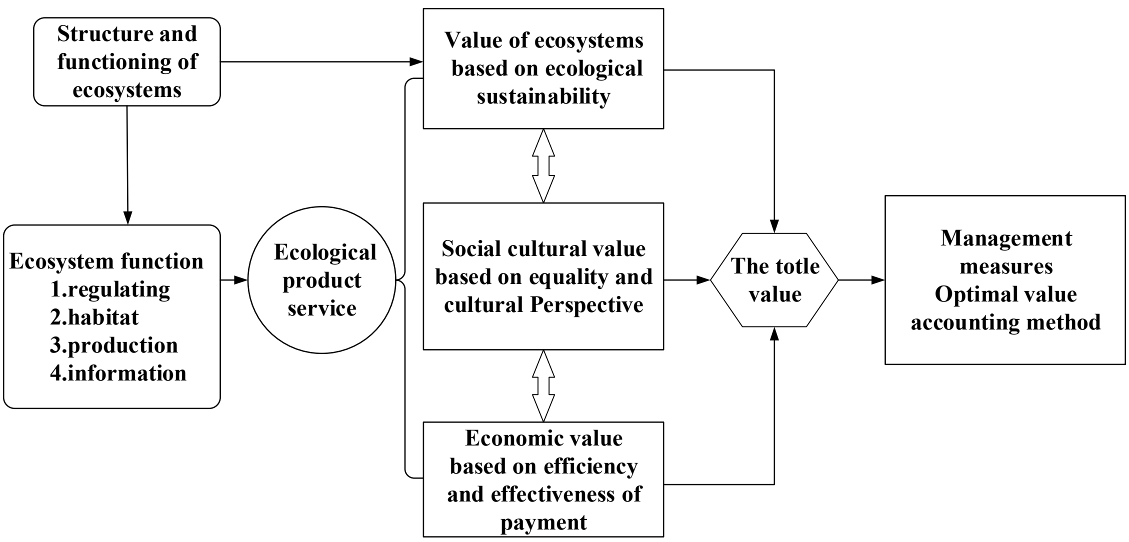

Figure 2. The evaluation framework of ecosystem functions, products and services

In the study, combined with the area statistics of different land use types, and the comparison of the advantages, disadvantages and application scopes of the calculation methods of the related values, using the market value method, the shadow pricing method, and other related methods, the direct, indirect and other values were calculated to provide the basis for precise eco-compensation.

3.4. Compensation Standard of Ecological Damage Value

Compensation standards of ecological damage should be determined through consultation according to water environment pollution treatment costs and economic loss due to water resource protection.

3.4.1. Opportunity cost of limiting development. Opportunity cost (OC) refers to the abandonedprofits when one decision is made and another decision is given up, which was used to measure the consequences of their decisions. In the upstream, in order to realize water quantity and quality control standard in the cross sections of the upstream and downstream, the development of the industries which are not conducive to water reservation and water environment protection was limited, thus limiting local economic development and living standard improvement. In order to facilitate the comparison of development indicators among various watershed areas, indirect calculation method was usually used to calculate the opportunity loss costs of upstream areas.

3.4.2. *Opportunity loss cost related to water conservation.*Afforestation in the watershed upstream plays a positive role in water conservation, soil erosion reduction, and air quality improvement. In addition to direct investment in the upstream afforestation, the downstream should compensate the opportunity costs caused by planting pattern of regional development.

In the calculation of the ecological damage compensation standard, it is difficult to accurately estimate the opportunity cost caused by the effective environmental protection activities. The upstream opportunity cost was usually determined through the effective cost analysis of watershed resources. In the process of forecasting the opportunity cost in the planning year, the carrier variation, time, and risk factors should be considered to calculate the opportunity cost based on classified calculation method.

4. Conclusions

According to the situation of water shortage and water quality deterioration in the majority of watersheds, the calculation method of cross-regional WECS was explored. Based on the clarification of the theoretical framework of eco-compensation standards, we provided the calculation basis for eco-compensation in water quantity, water quality and pollutant treatment level as well as stratified implementation details for the eco-compensation standard. Based on ecological value calculation and opportunity cost determination of different types of WEC, we provided the calculation method of ecological benefit and damage. Moreover, we provided the practical eco-compensation standard, which still required further improvement. We proposed four improvement suggestions. First, during the determination of the values of ecological services with the basic theory and methods of econometrics, the incompleteness of ecological service market, the input-output mapping relationship diversity, quantification difficulty of input factors using market price and the implicit property in service consumption should be fully considered to establish the production-consumption-value coupling transfer function of ecological services and the calculation method of eco-compensation standard of benefited ecological systems. Second, during the development of ecological damage compensation standard, microscopic decision-making behaviour of compensation objects should be fully considered to realize the precise calculation of potential efficacy of various participants with spatial distribution features of opportunity cost. Third, although water quantity, water quality and influencing factors could reflect the ecological situation, the compensation standard prepared with the above factors was not the comprehensive standard. Fourth, in the implementation process of cross-regional eco-compensation standard, the coordination of inter-region conflicts and the fairness mechanism were the main basis of verifying the reasonableness of compensation standards. In the later study, eco-compensation standards should be developed to promote the coordinated development of the whole watershed according to the synergetics, non-zero-sum games and best management practices (BMPs).

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