Research Status and Future Prospects of Watershed Ecological Compensation based on Ecological Civilization

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Abstract. Watershed ecological compensation, as an important measure of ecological civilization construction, aims to promote ecological protection and restoration through economic means, in order to achieve coordinated development between economic development and ecological conservation. This paper provides an overview of the research progress on watershed ecological compensation under the context of ecological civilization, including the concept and significance of watershed ecological compensation. It explores the evaluation indicators and methods of watershed ecological compensation and presents future research directions in this field.

Keywords: Ecological civilization, watershed ecological compensation, evaluation indicators, research progress

1 Introduction

With the vigorous development of the global economy and continuous population growth, the impact of human activities on the natural environment is showing an increasingly significant trend. This impact not only leads to widespread destruction of ecosystems, posing a serious threat to the preservation of biodiversity but also exacerbates the overexploitation of natural resources. In such an urgent context, countries universally recognize the construction of ecological civilization as a common vision [1-8]. As a novel form of civilization, ecological civilization aims to establish a socio-ecological system that coexists harmoniously with nature, ensuring the survival and development of people and facilitating the achievement of sustainable development. Watersheds, as distinct units in natural geography, play a crucial role as a vital source of water resources [9-18]. As an emerging means of ecological conservation, the watershed ecological compensation mechanism aims to compensate for ecosystem services within the watershed, systematically promoting the restoration and protection of ecosystems, enhancing their stability and adaptability, maintaining ecosystem functions, and advancing sustainable development in the watershed [19-28]. Therefore, watershed ecological compensation is regarded as an indispensable key component in the process of constructing ecological civilization highlighting its undeniable importance [29-30]

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2 Concepts and Significance of Watershed Ecological Compensation

Watershed ecological compensation is regarded as an institutional arrangement aimed at economically compensating for the negative impacts on ecosystem services caused by economic activities within a watershed. Its purpose is to offset the adverse effects of economic activities on watershed ecosystems, protect and restore the functionality and stability of ecosystems, maintain their provision of ecosystem services, and promote the harmonious development of watershed ecology and socio-economy. In the context of ecological civilization construction, watershed ecological compensation holds significant and diverse implications. Watershed ecological compensation plays a crucial role in promoting sustainable economic development, protecting ecosystems, maintaining ecological balance, and achieving social harmony. It provides scientific support and an effective pathway for ecological civilization construction.

3 Evaluation Indicators and Methods for Watershed Ecological Compensation

3.1 Evaluation Indicators for Watershed Ecological Compensation

The main indicators for assessing the effectiveness of watershed ecological compensation include water resources quantity and water quality indicators, ecosystem services indicators, water ecosystem health indicators, socio-economic benefits indicators, stakeholder satisfaction indicators, and efficiency of fund utilization indicators. Water resources quantity and water quality indicators reflect the impact of watershed ecological compensation policies on water resource quality and sustainable utilization. These indicators include changes in total water resources before and after compensation, improvement in sustainable utilization rate, and the extent of water quality enhancement and restoration. Ecosystem services indicators are used to measure the effectiveness of watershed ecological compensation policies in protecting and restoring ecosystem services. Common indicators include wetland area, forest coverage rate, and biodiversity index, which are used to assess the improvement in ecosystem services. Water ecosystem health indicators reflect the influence of watershed ecological compensation on the structure and function of water ecosystems. These evaluation indicators can include water ecological index, water ecological landscape quality indicators, and benthic animal community structure, to evaluate the health of the water ecosystem. Socio-economic benefits indicators consider the positive impact of watershed ecological compensation policies on socio-economic development. These indicators include rural residents' income, employment opportunities, and tourism income, to reflect the influence of compensation policies on local residents and economic development. Stakeholder satisfaction indicators are used to evaluate the social acceptance and participation effectiveness of compensation policies. Common indicators include stakeholder satisfaction surveys regarding compensation policies and the level of public

participation. Efficiency of fund utilization indicators are used to evaluate the use of compensation funds, including transparency in fund utilization, efficiency evaluation reports, and project cost-effectiveness ratios, to ensure the effective utilization of compensation funds and maximize social benefits.

3.2 Methods for Watershed Ecological Compensation

Evaluation Method Based on Ecosystem Services.

The evaluation method based on ecosystem services plays a prominent role in assessing watershed ecological compensation and has distinct advantages. Firstly, this method allows for the comprehensive consideration of various functions and values of ecosystems, enabling a comprehensive assessment of the impact of compensation policies on ecosystem services. By incorporating ecosystem service factors into the evaluation scope, such as water regulation, water purification, and biodiversity maintenance, it can fully capture the protection and restoration effects of compensation policies on key ecosystem functions. Secondly, this method has the characteristic of quantifying evaluation indicators. Through the measurement, monitoring, or simulated prediction of data, it can provide specific data on the effectiveness of compensation policies, making the evaluation results more accurate and comparable. This helps to gain a deeper understanding of the substantial impact of compensation policies on the provisioning capacity of ecosystem services. Moreover, assessing the economic value of ecosystem services is crucial for revealing the contribution of compensation policies to the economy and promoting the coordination between ecological conservation and economic development. By conducting economic evaluations of ecosystem services, such as estimating the economic benefits of ecotourism and water resource utilization, it can clearly demonstrate the positive role of compensation policies in promoting sustainable economic development. This provides a scientific basis for policymakers to make informed decisions and ensures a win-win situation for both ecological conservation and economic growth.

Evaluation Method based on Cost-Benefit Analysis.

As a commonly used method in assessing watershed ecological compensation policies, the evaluation method based on cost-benefit analysis possesses prominent advantages and plays a crucial role. Firstly, this method provides a framework for quantitatively assessing the economic benefits of policies. By comparing costs and benefits, it can reveal the economic feasibility and sustainability of the policies. By explicitly establishing the relationship between cost inputs and expected benefits, decision-makers can objectively evaluate the economic effects of compensation policies, thus supporting informed decision-making. Secondly, cost-benefit analysis helps decision-makers make rational choices under limited resource conditions, aiming to optimize the effectiveness and benefits of the compensation policies to the greatest extent possible. Additionally, conducting sensitivity analysis enables the

identification of key parameters influencing the evaluation results, enabling decision-makers to better understand and address uncertainties.

4 Future Research Directions for Watershed Ecological Compensation

4.1 Improving Watershed Ecological Compensation Policies

Firstly, in-depth research and improvement of the institutional design of watershed ecological compensation policies are needed. This involves optimizing legal regulations, policy frameworks, and management mechanisms to establish a sound institutional system. By clarifying rights and responsibilities, establishing effective decision-making coordination mechanisms and supervision mechanisms, the scientific, rational, and operational aspects of compensation policies can be enhanced. Secondly, addressing the shortcomings of watershed ecological compensation standards requires the proposal of refined compensation standards that consider different ecosystem types and regional characteristics. Through in-depth research supported by data, more targeted and regionally adaptable compensation standards can be developed. This will help ensure fairness, sustainability, and the restoration and protection of ecosystems through compensation policies. Thirdly, establishing a comprehensive data support and monitoring evaluation system is crucial for supporting the implementation and effectiveness assessment of watershed ecological compensation policies. It is necessary to establish a comprehensive and accurate data collection and monitoring system to obtain reliable data on ecosystem services. At the same time, developing effective evaluation methods and indicator systems to regularly assess and monitor the implementation effects of compensation policies will enable dynamic adjustments and improvements to the policies. Fourthly, strengthening the research on the linkage between economy and ecology promotes the coordinated advancement of economic development and ecological conservation. When formulating watershed ecological compensation policies, the interrelationships and mutual influences between the economy and ecology need to be thoroughly studied. By exploring mechanisms and pathways for the synergy between economic development and ecological conservation, a virtuous cycle between economic growth and ecological restoration can be achieved. Fifthly, emphasizing regional collaboration and cross-border cooperation provides solutions for transboundary watershed ecological compensation cooperation. Transboundary watershed ecological compensation often involves multiple regions and stakeholders, requiring the establishment of effective cooperation mechanisms. This includes jointly formulating compensation standards and policy frameworks, enhancing information sharing and communication, and establishing cross-regional coordination and cooperation institutions. Through regional collaboration and cross-border cooperation, overall coordination and maximization of the effectiveness of watershed ecological compensation policies can be achieved.

4.2 Building a Watershed Ecological Compensation Evaluation System

In terms of evaluation indicators, a more refined indicator system should be gradually constructed, taking into account different ecosystem types and regional characteristics comprehensively. This should include detailed classification and quantification methods for ecosystem services, such as biodiversity indicators, water quality indicators, soil erosion indicators, and others. Additionally, it is important to consider the needs and rights of different stakeholders and establish an integrated indicator system that balances multiple dimensions, including ecology, economy, and society. In terms of evaluation methods, incorporating economic principles, quantitative methods like market valuation and replacement cost methods should be employed to conduct economic valuation of ecosystem services, quantifying their economic value. Furthermore, multi-criteria decision analysis methods, such as analytic hierarchy process and fuzzy comprehensive evaluation, should be utilized to comprehensively consider the opinions and weights of different stakeholders, in order to determine the priorities and trade-offs of compensation schemes. Regarding data collection, research should be conducted to enhance data collection and analysis techniques, exploring remote sensing technology, geographic information system (GIS) analysis, ecological modeling, and other approaches to provide the necessary data support for watershed ecological compensation evaluation. Simultaneously, a comprehensive monitoring and evaluation system should be established to track the implementation and effectiveness of compensation policies, providing scientific evidence and support for decision-making.

Therefore, through in-depth research on evaluation indicators and methods for watershed ecological compensation, the construction of a refined indicator system, the application of multidimensional evaluation methods, and the enhancement of data technology and monitoring systems, the scientific rigor and practicality of watershed ecological compensation evaluation can be improved. This will ensure the effective implementation of watershed ecological compensation policies and promote the sustainable development of ecosystems.

4.3 Promoting Watershed Ecological Compensation Practices

Firstly, establish comprehensive laws, regulations, and policy frameworks to ensure that watershed ecological compensation policies have sufficient legal basis and policy support. Through in-depth research and analysis of existing legal frameworks, fill legal gaps, eliminate regulatory conflicts, and ensure the consistency and coordination of compensation policies with other environmental protection policies. Secondly, strengthen coordination and cooperation among government departments to form a unified framework and implementation mechanism for compensation policies. Different government agencies should collaborate closely to jointly develop and implement watershed ecological compensation policies, ensuring consistency and synergy across various levels and departments. Thirdly, establish sound compensation mechanisms by clearly defining the objects, scope, methods, and standards of compensation to ensure fairness and transparency of compensation schemes. Clearly

define the objects of compensation for damaged ecosystems, specify the scope and methods of compensation, and develop scientifically reasonable compensation standards to achieve fairness in resource allocation and maximize ecological benefits. Fourthly, strengthen scientific research and data support by collecting ecosystem data and assessing the value and compensation needs of ecosystem services. Conduct in-depth research on the economic, social, and environmental benefits of ecosystem services, establish scientifically sound data collection and analysis techniques, and provide scientific evidence and decision-making support for the formulation and implementation of compensation policies. Fifthly, promote international cooperation and experience exchange by strengthening collaboration and communication with international organizations to enhance the level and effectiveness of watershed ecological management. By learning from successful experiences of other countries, undertaking collaborative projects, and engaging in cross-border exchanges, the process of watershed ecological management and protection can be accelerated, leading to sustainable development and the effective implementation of watershed ecological compensation goals.

4.4 Strengthening Integrated Watershed Ecological Management

Firstly, establish a comprehensive watershed management mechanism by developing integrated watershed management plans, establishing dedicated management agencies, and cooperation platforms to promote coordination and collaboration among different departments and stakeholders. This will help integrate resources from various parties, optimize decision-making, and advance ecological management efforts within the watershed. Secondly, promote ecological conservation and restoration work, including wetland conservation, forest protection, water body preservation, and other aspects to enhance the health of the watershed ecosystem. Through comprehensive protection measures, the integrity and sustainability of the ecosystem can be ensured. Thirdly, advance ecological restoration and rehabilitation projects by implementing restoration measures to restore the functionality and services of damaged ecosystems. This involves restoring hydrological conditions in wetlands, rebuilding damaged forest ecosystems, improving water quality in water bodies, and promoting the natural recovery capacity and ecological restoration of the watershed ecosystem. Fourthly, strengthen environmental monitoring and data support by establishing a comprehensive environmental monitoring system and utilizing advanced technologies to obtain high-quality environmental data, providing scientific evidence for decision-making. By monitoring and assessing the status and changes in the watershed ecosystem, problems can be promptly identified, and effective management and protection strategies can be formulated. Fifthly, enhance social participation and public awareness by raising public awareness about ecological compensation through educational and promotional activities, encouraging public involvement in watershed ecological management and conservation processes. This includes organizing public visits and field trips, conducting environmental education and training programs to enhance public understanding and awareness of the importance of ecological conservation. By implementing these measures in an

organized manner, the capacity for watershed ecological management and protection will be further strengthened, promoting the health and sustainable development of the watershed ecosystem.

5 Conclusions

As a key tool for ecological civilization construction, watershed ecological compensation is used to coordinate watershed ecological protection and economic development. This study conducted in-depth research and systematic analysis on the concept, significance, policies, and practices of watershed ecological compensation. The findings reveal that the implementation of watershed ecological compensation policies plays an important role in promoting ecological environmental protection, sustainable development, and improving people's well-being. Furthermore, future research can further explore related topics such as watershed ecological compensation policies, evaluation systems, practical implementation, and integrated management. It can explore the coordinated relationship between watershed ecological compensation and ecological civilization construction, sustainable development, delve into the socio-economic benefits and ecological benefits of watershed ecological compensation, and enhance the sustainability and effectiveness of watershed ecological compensation policies, thereby making a more significant contribution to ecological civilization construction and sustainable development.

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