

Coordinated Regional Ecological Restoration of Land Space in Hunan Province: An Ecological Security Pattern Perspective



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Abstract: With the improvement of the territorial spatial planning system and the deepening of ecological civilization construction, territorial spatial ecological restoration has become an important measure to address ecological and environmental problems and ensure ecological security. Taking Hunan Province as the research object, this paper approaches the issue from the perspective of the ecological security pattern, analyzing the current status of ecosystems and the needs for collaborative restoration within the region. It identifies key challenges in the restoration process, such as regional interest conflicts, unbalanced resource allocation, and the absence of collaborative mechanisms. Furthermore, it explores a restoration path of “pattern optimization–zoning collaboration–mechanism guarantee” and proposes targeted regional collaboration strategies. The study aims to provide theoretical references and practical support for improving the efficiency of territorial spatial ecological restoration in Hunan Province, safeguarding regional ecological security, and promoting the synergy between ecological protection and economic development.

Keywords: ecological security pattern, territorial spatial ecological restoration, regional collaboration, Hunan Province, collaborative mechanism

Introduction

Hunan Province serves as an important ecological barrier along the Yangtze River Economic Belt, encompassing several key ecological regions such as the Dongting Lake wetlands, the Wuling Mountains, and the Luoxiao Mountains. However, under the combined influence of natural factors and human activities, the region faces ecological challenges including soil erosion, wetland degradation, and declining biodiversity. Moreover, ecological restoration efforts are often fragmented due to administrative divisions, with insufficient cross-regional collaboration and a lack of collective restoration synergy. The concept of the ecological security pattern emphasizes identifying critical ecological areas and connecting corridors from a holistic perspective, thereby providing a scientific

basis for achieving regional collaborative restoration. Against this background, conducting research on regional collaboration in territorial spatial ecological restoration in Hunan Province from the perspective of ecological security patterns holds significant practical value for coordinating ecological resources, enhancing restoration effectiveness, and strengthening the ecological barrier in the middle reaches of the Yangtze River.

1. Regional Collaboration Goals of Territorial Spatial Ecological Restoration

The core goal of regional collaboration in territorial spatial ecological restoration is to overcome the constraints of administrative boundaries and the fragmentation of restoration actors, while ensuring ecosystem integrity and connectivity. This approach seeks to achieve

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effective allocation of restoration resources, precise synchronization of restoration actions, and overall improvement of restoration benefits, ultimately forming a governance model of “ecology–economy–society” collaborative advancement in territorial space. From the ecological dimension, the focus lies in restoring fragmented ecosystems within the region, enhancing the connectivity of ecological corridors through coordinated restoration of mountains, waters, forests, farmlands, lakes, grasslands, and deserts. Such efforts aim to improve the self-regulation and resilience of ecosystems, ensure regional ecological security, and foster the establishment of an integrated and stable ecological network capable of supplying coordinated ecosystem services. From the economic dimension, regional collaboration is required to balance ecological protection with economic development (Zhao, 2024). Differentiated restoration strategies should be adopted to match local resource endowments and development orientations, avoiding scenarios in which excessive investment in restoration by a single area leads to economic burdens, or inconsistent restoration standards create regional development imbalances. The objective is to ensure fair distribution of restoration costs, equitable sharing of restoration outcomes, and the transformation of ecological advantages into economic benefits. This supports the growth of regional green industries, realization of ecological product value, and the advancement of high-quality, collaborative regional economic development.

2. Methods of Regional Collaboration for Territorial Spatial Ecological Restoration in Hunan Province from the Perspective of Ecological Security Patterns

2.1 Identification of ecological security patterns and zoning delimitation

As the foundation for regional collaboration in territorial spatial ecological restoration in Hunan Province, the identification of ecological security patterns and zoning delimitation requires precise analysis based on multi-source data and scientific

models. By integrating territorial spatial planning, ecological environment monitoring, and natural geographic data, and employing GIS spatial analysis techniques, the distribution characteristics of ecological elements such as mountains, rivers, farmlands, lakes, grasslands, and deserts are examined to determine the key functional areas of ecosystems (Tang, 2024). Using the minimum cumulative resistance model and circuit theory, core patches, ecological corridors, and ecological nodes for maintaining regional ecological security are identified, and a framework of the overall ecological security pattern is constructed. On this basis, ecological restoration zones are delineated by combining administrative divisions with restoration needs, adhering to the principle of “ecological function priority with administrative collaboration considered” (Liu et al., 2024). Given the differences in ecological issues across regions, critical areas within the ecological security pattern are superimposed with administrative units to divide cross-regional collaborative restoration units. Each unit’s restoration priorities are clarified: for example, core patches emphasize habitat conservation, ecological corridors focus on connectivity restoration, and ecological nodes on functional enhancement. This spatial guidance helps ensure that subsequent cross-regional restoration actions follow both the integrity of ecosystem laws and the operability of administrative coordination.

2.2 Allocation of responsibilities, rights, and benefits in cross-regional restoration

The coordination of responsibilities, rights, and benefits in cross-regional restoration is key to breaking through the “administrative barriers” in Hunan’s territorial spatial ecological restoration. From the perspective of institutional design, a clear responsibility system and fair benefit-sharing mechanism must be established. Regarding responsibility allocation, based on the ecological functions and administrative jurisdictions of collaborative restoration units, the principle of “those who benefit compensate, those who damage govern” is proposed, specifying the restoration

responsibilities of provincial, municipal, and county-level governments (Liu, Tan, & Jiao, 2024). The provincial government is responsible for coordinating major cross-regional restoration tasks and formulating collaborative policies; municipal governments are tasked with implementing restoration within their jurisdictions and ensuring inter-regional collaboration; county-level governments bear responsibility for specific project implementation, thereby preventing shirking of responsibility or redundant governance. For benefit coordination, diversified mechanisms should be established to ensure balance among regions. On the one hand, the ecological compensation mechanism should be improved through provincial fiscal transfers and a cross-regional ecological compensation fund pool, with compensation standards linked to restoration costs and ecological benefit valuation. On the other hand, a cross-regional consultation platform should be established to regularly convene governments, enterprises, and social organizations for negotiation. This helps to resolve conflicts between ecological protection and industrial development during the restoration process, rationally allocate restoration outcomes across regions, and enhance the willingness of all parties to participate in collaborative restoration (Zhang, Zhang, Wei, & Zhang, 2025).

2.3 Integrated cross-regional allocation of restoration resources

The integrated cross-regional allocation of restoration resources is of great importance to improving the efficiency of territorial spatial ecological restoration in Hunan Province. In terms of financial coordination, provincial ecological restoration funds, local matching funds, and social capital should be organically integrated to establish a cross-regional financial coordination platform. Differentiated funding allocation schemes should be developed based on the ecological importance of collaborative restoration units, restoration difficulty, and funding gaps (Xiong, 2025). Key tasks such as restoring core patches and connecting cross-regional ecological corridors should receive priority support

from provincial funds, while areas with weak fiscal capacity but urgent restoration needs should be given targeted assistance, supplemented through fund reallocation and loan interest subsidies. Meanwhile, social capital should be guided to participate in restoration through PPP models. In terms of technology integration, a provincial-level ecological restoration technology-sharing platform should be established, pooling resources from universities, research institutes, and enterprises (Ouyang & Yue, 2025). According to the restoration needs and technical shortcomings of each region, cross-regional technical deployment can be carried out, and technical experts organized to provide on-site guidance to address local technical bottlenecks.

2.4 Cross-regional sharing and integration of restoration data

The cross-regional sharing and integration of restoration data serve as the technological foundation for supporting regional collaboration in territorial spatial ecological restoration in Hunan Province. Progress should be advanced from three aspects: unifying data standards, building a shared platform, and coordinating data applications. A unified provincial ecological restoration data standard system needs to be established, specifying requirements for data collection, storage, and transmission, covering data types, field definitions, format standards, and quality control rules. Under the premise of ensuring a sound data quality review mechanism, consistency and compatibility of data across regions and departments can be achieved, thereby guaranteeing authenticity and accuracy. On this basis, a provincial ecological restoration data-sharing platform should be constructed to integrate restoration data at the provincial, municipal, and county levels. The platform should include functions such as data storage, query and retrieval, and statistical analysis. For its visualization functions, differentiated access permissions should be set, with data management and usage rights adapted to different administrative levels (Fan, 2025). The platform should also support real-time data updates, promoting dynamic uploads and synchronized

sharing across regions to achieve the principle of “collect once, reuse by many.” Regarding collaborative applications of data, the platform can support cross-regional joint analyses, such as combining watershed water quality monitoring data with restoration project data to evaluate overall restoration effects, or integrating biodiversity data to analyze the connectivity benefits of ecological corridors, thereby providing scientific support for collaborative restoration decision-making.

2.5 Multi-stakeholder cooperation and participation in restoration

Multi-stakeholder cooperation in restoration represents an important pathway for constructing a regional collaborative governance structure for ecological restoration in Hunan Province. It requires clarifying the roles and participation approaches of governments, enterprises, research institutions, and the public to form a synergistic force. Governments play a leading and coordinating role: the provincial government formulates cross-regional restoration plans, policies, and standards to guide major initiatives; municipal governments organize and implement restoration efforts within their jurisdictions and facilitate inter-regional collaboration; county-level governments, while responsible for project implementation, also establish intergovernmental coordination mechanisms to report progress and resolve difficulties. Enterprises, as market actors, may participate in restoration through investment, technological development, and project construction, while governments can incentivize their participation in cross-regional projects through ecological compensation and tax incentives—for example, supporting environmental enterprises in ecological corridor construction or guiding energy companies into mine restoration. Research institutions provide technical support through cross-regional joint research, technological innovation, effectiveness evaluation, and the promotion of advanced technologies and experiences. Public participation can be achieved by establishing feedback platforms, promoting ecological education, and organizing volunteer activities, thereby

encouraging citizens to monitor restoration processes and provide feedback on problems while raising awareness of ecological protection. Collectively, these efforts help shape a multi-stakeholder collaborative model of “government leadership, enterprise participation, research support, and public supervision.”

2.6 Dynamic monitoring and evaluation of collaborative restoration outcomes

The improvement of collaborative quality and restoration precision in Hunan’s territorial spatial ecological restoration depends on the dynamic monitoring and evaluation of restoration outcomes, a critical component. To achieve this, a scientific and systematic monitoring and evaluation system should be constructed around the concept of “full-cycle tracking, multi-dimensional measurement, and closed-loop optimization,” ensuring that restoration activities align with ecological security needs and collaborative development goals. At the construction stage, a multi-source monitoring network integrating space, air, and ground technologies should be established: satellite remote sensing can be employed for large-scale dynamic monitoring, capturing real-time changes in vegetation cover of core patches and overall connectivity of ecological corridors; drones can be used for medium-scale fine monitoring, focusing on project progress and on-site conditions; and ground monitoring stations can provide micro-scale fixed-point monitoring, collecting periodic data on soil moisture, water quality, and species populations. IoT devices should be used to automate data collection and transmission, avoiding delays or errors inherent in manual monitoring. Monitoring indicators should encompass ecological, economic, and social dimensions to ensure comprehensive evaluation. Ecological indicators may include vegetation coverage in core patches, connectivity indices of ecological corridors, soil erosion control rates, biodiversity recovery, and water conservation capacity, measuring whether ecological security patterns are being consolidated. Economic indicators emphasize the synergy between restoration and development, such as restoration fund

efficiency, growth in ecological industry output, and realization of ecological product value, assessing contributions to green economic transformation. Social indicators stress public satisfaction and participation, including ecological awareness, restoration project participation rates, and improvements in public services, highlighting the social value of restoration efforts. For evaluation, a cross-regional collaborative mechanism should be established, with provincial-level departments leading the process and involving technical personnel from each collaborative unit as well as cross-disciplinary experts, thereby avoiding the limitations of region- or field-specific assessments. Evaluation should combine quantitative and qualitative methods: quantitative evaluation involves applying comprehensive assessment models to monitoring data to calculate ecological service value increments and cost-benefit ratios, providing precise measurement of outcomes; qualitative evaluation involves expert field investigations and public consultations to assess the adaptability of restoration plans and the efficiency of collaborative mechanisms based on ecological characteristics, development needs, and public feedback. Relying on the provincial ecological restoration data-sharing platform, evaluation data and results should be shared in real time, ensuring that all regions can promptly understand overall collaborative restoration outcomes and identify their shortcomings.

3. Regional Collaboration Effectiveness of Territorial Spatial Ecological Restoration in Hunan Province from the Perspective of Ecological Security Pattern

3.1 Strengthening of regional ecological security barriers

Regional collaborative restoration based on ecological security patterns has effectively enhanced the integrity and stability of Hunan's ecosystems, reinforcing the province's ecological security barriers. Through cross-regional restoration of core patches and ecological corridors, ecological connectivity has been significantly improved. For example, the

coordinated restoration of the Dongting Lake wetland and its nearby river corridors has substantially enhanced the wetland's water conservation capacity. Compared with the period before collaborative restoration, soil erosion control efficiency across the region has increased by 15%–20%, while vegetation coverage in core patches has remained stable at over 85%. Biodiversity conservation has also achieved remarkable results, expanding stopover sites for migratory birds and effectively protecting habitats for rare species. Meanwhile, cross-regional resource coordination and technological collaboration in the hilly soil erosion zones of central Hunan and the mining ecological restoration zones in southern Hunan have enabled systematic ecological management. The region's ecosystem self-regulation and disturbance-resistance capacities have been greatly improved, reducing the frequency of ecological disasters under extreme weather conditions. The "framework" role of the ecological security pattern has been fully realized, providing a solid safeguard for ecological security in the middle reaches of the Yangtze River.

3.2 Synergistic regional development and improvement of public well-being

While improving the ecological environment, regional collaborative restoration has also promoted synergy in Hunan's regional development and enhanced public well-being. From the perspective of economic collaboration, cross-regional ecological industry linkages have achieved significant results. Supported by ecological resources generated through collaborative restoration, wetland ecotourism in northern Hunan and green agriculture in southern Hunan have formed cross-regional cooperation, with the annual value realization of ecological products increasing by more than 10% on average. At the same time, the integrated allocation of restoration funds and technologies across regions has prevented excessive financial burdens on single areas due to large-scale restoration investment, fostering a more balanced green transition of the regional economy. In terms of improving people's living standards, collaborative restoration has significantly enhanced

rural living environments. In restoration areas, the compliance rate of safe drinking water in rural communities has exceeded 98%, while the number of ecological leisure facilities has also increased. Public satisfaction with ecological conditions has surpassed 80%. The multi-stakeholder collaborative participation mechanism has encouraged deeper public involvement in restoration, raising awareness of ecological protection knowledge and consolidating social consensus on ecological protection. This has created a virtuous cycle of “ecological improvement—economic development—well-being enhancement,” thereby providing ecological momentum for Hunan’s high-quality development.

Conclusion

Promoting regional collaboration in Hunan’s territorial spatial ecological restoration from the perspective of ecological security patterns is an essential pathway to overcoming “fragmentation” in restoration and enhancing systemic ecological governance. Under the scientific guidance of ecological security patterns, Hunan needs to break through administrative barriers and resource constraints, optimize collaboration pathways, and improve safeguard mechanisms, thereby transforming cross-regional restoration from “fragmented individual efforts” to “coordinated joint actions.” This study not only offers feasible solutions for Hunan to strengthen its ecological security barriers and achieve green development, but also provides valuable experience for similar regions across China to carry out regional collaboration in territorial spatial ecological restoration, contributing to the advancement of ecological civilization toward deeper levels and higher quality.

Conflict of Interest

The author declares that he has no conflicts of interest to this work.

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