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Research on the Coordinated Development of Ecological Security and Rural Revitalization in the Zhaotong Section of the Chishui River Basin

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Abstract: *As an important ecological barrier in the upper reaches of the Yangtze River, the Zhaotong section of the Chishui River Basin plays a pivotal role in the coordinated development of ecological security and rural revitalization, serving as a key component in implementing the strategy of "ecological priority and green development". This study focuses on the towns and townships of Zhenxiong County and Weixing County, employing methods including questionnaire surveys, on-site interviews, and data analysis to examine the synergistic effects of ecological conservation and rural development. The findings reveal that rural revitalization in this region is constrained by ecological conditions; however, the development of green industries can effectively support ecological restoration, thereby achieving a win-win outcome in terms of both economic and ecological benefits. Based on these findings, this paper proposes targeted policy recommendations and constructs a multi-stakeholder governance mechanism involving the government, market, and local communities. It also advocates for enhanced cross-regional ecological compensation and the promotion of eco-labeled agricultural products and other green industries, aiming to foster positive interactions between cross-regional ecological protection and rural revitalization. This study provides both theoretical and practical references for achieving rural revitalization within the Zhaotong section of the Chishui River Basin under the framework of ecological security.*

Keywords: *Chishui River Basin; Ecological Security; Rural Revitalization; Collaborative Governance Mechanism; Transboundary Ecological Compensation*

1.Introduction

With the in-depth implementation of China's Rural Revitalization Strategy, rural ecological security faces increasingly stringent demands. The Chishui River Basin (Zhaotong section), a crucial ecological buffer zone in China, plays a vital role in the stability and sustainable development of southwestern China's ecosystems. However, due to its complex topography, variable climate, slow economic growth, and an undiversified industrial structure, the region has been grappling with severe ecological issues such as soil erosion, water pollution, and loss of biodiversity, which have significantly impacted local agricultural productivity and residents' quality of life.In response, Yunnan Province has proactively formulated the 'Chishui River Basin (Yunnan Section) Protection, Management, and High-Quality Development Plan'. This plan proposes a conservation and management framework of 'One Belt, Three Waters, and Four Zones' to foster the synergistic advancement of ecological protection and economic development. By addressing prominent ecological problems and enhancing ecological foundational functions, the plan aims to provide a robust material foundation for rural revitalization.

This study centers on the Chishui River Basin (Zhaotong Section), delving into the synergistic development of regional ecological security and rural revitalization. It analyzes the intrinsic links between the two in terms of objectives, pathways, and enabling conditions, clarifies their synergistic logic, and reveals the extent of achieving ecological security and rural revitalization. Guided by green development principles, the study proposes actionable pathways for synergistic optimization, offering

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theoretical support and practical guidance for regional ecological governance and economic development. By integrating empirical analysis and policy recommendations, it outlines specific strategies for establishing a development model that prioritizes ecology and green growth. The research not only enhances rural ecological security in the Chishui River Basin but also provides crucial references for achieving the modernization goal of coexistence between humanity and nature. Furthermore, by promoting harmonious coexistence between regional ecology and economy, this study contributes new theoretical perspectives and practical insights to Yunnan Province's "3815" Strategy. It supports the implementation of the rural revitalization strategy in the Chishui River Basin (Zhaotong Section), achieving an organic integration of ecological beauty, industrial prosperity, and public well-being.

2. Current Situation Investigation and General Overview

2.1 Basic Characteristics and Background of the Study Area

To comprehensively elucidate the coordinated development of ecological security and rural revitalization, this study primarily focuses on the ecological security and rural revitalization status in the Zhaotong section of the Chishui River Basin, specifically Zhenxiong County and Weixian County. It examines key aspects such as ecological environment quality, risk source identification, and residents' awareness of ecological security, and further analyzes the interactive relationship, existing challenges, and influencing factors between these two developmental dimensions.A total of 120 questionnaires were distributed, of which 115 were recovered, and 111 were deemed valid, resulting in an effective response rate of 92.5%. We employed SPSS to perform descriptive statistics, correlation analysis, and difference analysis in order to systematically identify current issues and their influencing factors.

2.2 Overview of the Study Area

2.2.1 Location Overview

The Chishui River originates from Chishuiyuan Town, Zhaotong City, Yunnan Province. As the headwater region of a first-level tributary in the upper reaches of the Yangtze River, it is the only such tributary that remains undammed and retains its natural hydrological regime. The river is widely recognized as the "Hero River," "Wine River," and "Ecological River." Geomorphologically, the region exhibits a typical karst plateau mountain landscape. It is geographically situated between 104°44′E and 107°1′E, as well as 27°15′N and 28°50′N. The main stem of the river extends for 525 kilometers, of which the Zhaotong section—including the watersheds of Zhenxiong County and Weixing County—spans 97 kilometers, accounting for 100% of the river's length within Yunnan Province. The river experiences a total drop of 1,588 meters, resulting in a distinctive alternation of "U"- and "V"-shaped river valley landforms.

2.2.2 Natural Background Overview

The Zhaotong section of the Chishui River Basin serves as a crucial ecological barrier in the upper reaches of the Yangtze River. It lies within the transitional zone between the Yunnan-Guizhou Plateau and the Sichuan Basin, characterized predominantly by mountainous and canyon-like terrain, with higher elevations in the northwest and lower ones in the southeast. The average elevation is approximately 1,200 meters, with a significant relative elevation difference, resulting in a complex and diverse topographical landscape. The region is endowed with abundant water resources, with an average annual precipitation ranging from 800 to 1,200 millimeters. Influenced by a monsoon climate, rainfall is primarily concentrated between June and September, ensuring a substantial water supply to the main stem and tributaries of the Chishui River, thereby providing a reliable foundation for industrial and agricultural activities as well as for the sustainable functioning of the basin's ecosystem. The basin exhibits a diverse range of soil types, predominantly yellow and purple soils, with moderate fertility levels. Vegetation coverage within the basin maintains a relatively stable rate of approximately 30%, dominated by subtropical evergreen broad-leaved forests and mixed coniferous-broadleaved forests, with supplementary contributions from bamboo forests, shrublands, and herbaceous vegetation. Despite the region's strong natural ecological foundation, the Zhaotong section of the Chishui River Basin currently faces numerous challenges in terms of ecological conservation and sustainable management.

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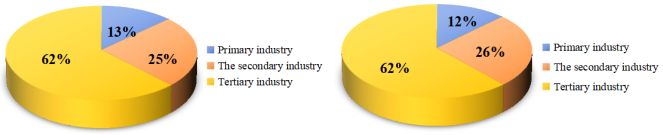
2.2.3 Socioeconomic and Economic Development Overview

In the development of the three major industries in the two counties of the study area in 2024, the tertiary industry holds a dominant position(Figure 1). This trend reflects the local governments' ongoing efforts to promote regional economic growth through continuous innovation in industrial development models, effective pollution control, and regulated enterprise expansion, all aimed at ensuring ecologically sustainable and secure regional development.



(a) Zhenxiong Proportion of GDP (%) *(b) Weixin Proportion of GDP (%)*

Figure 1 Proportion of the Three Major Industries in the Study Area in 2024

Note: All data are derived from the 2024 Statistical Bulletins on National Economic and Social Development of Zhenxiong County and Weixing County.

As indicated in the government work report (Table 1), the socio-economic development of Xiongxian County and Weixing County in 2024 demonstrates a positive trajectory. Compared to 2023, there has been an overall increase in total production value and per capita disposable income, reflecting a growing upward trend. Therefore, both counties have utilized their respective advantages to promote coordinated urban-rural development and industrial integration, thereby enhancing the overall quality of economic growth.

Table 1 National Economic Development Situation in the Study Area in 2024

Indicator	Zhenxiong County			Weixing County		
	2023	2024	Growth Rate	2023	2024	Growth Rate
GDP (10,000 RMB)	3427612	3590178	4.8	112000	1168100	4.3
GDP Per Capita (10,000 RMB)	2.6382	2.8081	6.5	3.3000	3.4963	5.9
Urbanization Rate (%)	29.92	30.72	0.8	44.12	44.61	1.1
Per Capita Disposable Income of Urban Residents(10.000 RMB)	3.3290	3.4821	3.2	3.2627	3.3997	4.2
Per Capita Disposable income of Rural Residents(10,000 RMB)	1.4846	1.5841	91	1.4242	1.5210	6.8

Note: All data are extracted from the 2024 Statistical Bulletins on National Economic and Social Development of Zhenxiong County and Weixin County.

2.3 Current Status and Challenges of Coordinated Development

2.3.1 Current Status of Integrated Development

While safeguarding the ecological environment of the Chishui River Basin, Zhaotong City has actively advanced the rural revitalization strategy. Through measures such as pollution source control and restoration of the aquatic ecosystem, the water quality of the Chishui River has significantly improved, and biodiversity has been effectively preserved, thereby providing a healthier living environment for local residents. In terms of inter-provincial cooperation, the provinces of Yunnan, Guizhou, and Sichuan jointly signed the "Horizontal Ecological Compensation Agreement for the Chishui River Basin," establishing a cross-regional ecological compensation mechanism that facilitates a fair and reasonable sharing of the costs associated with ecological protection. This mechanism has initially overcome administrative barriers through initiatives such as financial transfers and joint law enforcement. At the local implementation level, Zhaotong City has issued the "Regulations on the Protection of the Chishui River Basin" and implemented the River Chief System. In Zhenxiong County, the River Chief System has been fully extended to the village level. Meanwhile, Zhaotong City has leveraged its abundant natural resources to develop distinctive agricultural industries, which have not only increased farmers' incomes but also promoted rural economic development. Furthermore, the government has advanced rural revitalization by improving infrastructure and enhancing the quality of education and healthcare services. Overall, governments at all levels have initially established a "five-in-one" collaborative framework encompassing inter-provincial compensation, local legislation, basin-wide governance, industrial development feedback, and shared progress in people's livelihoods.

2.3.2 Challenges in Synergistic Development

(1) The issue of spatial mismatch is particularly pronounced. First, due to terrain limitations, corn yield on slopes is low, and steep inclines increase runoff, carrying more nitrogen and phosphorus into rivers. Additionally, farmers face barriers in adopting alternative crops. Inadequate cold chain logistics

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infrastructure and an underdeveloped industrial chain reduce farmers' motivation to transition to alternative agricultural practices[1]. Third, slope land management initiatives remain fragmented. The 14 square kilometers of enclosed management implemented in 2023 account for only 9.4% of the total area requiring ecological restoration.

(2) The coordination between government and market mechanisms remains inadequate. First, the environmental compensation standard is insufficient, covering only 32% of enterprises' direct environmental protection costs. As a result, 86% of enterprises are unwilling to invest in pollution control infrastructure, as the annual operating costs of wastewater treatment facilities significantly exceed the compensation provided. Second, the incentive framework is limited and lacks market-based instruments such as carbon trading and green credit systems. Consequently, the return on investment in environmental protection for some enterprises is less than 5%. Third, regulatory enforcement is inadequate. The penalties imposed on non-compliant enterprises amount to only 12% of their average daily revenue[2], making the cost of non-compliance substantially lower than that of pollution control.

(3) The community participation mechanism is not well established. First, the dissemination of policy information is inefficient. Most farmers rely on village loudspeakers to access relevant policy updates, while critical decision-making meetings are primarily held at the township level, limiting farmers' access to detailed policy content. Second, the distribution of benefits is inequitable. In certain regions, ecological compensation policies have not been effectively implemented, and compensation standards have remained unchanged for many years, negatively affecting farmers' interests. Third, there is a lack of sufficient capacity-building initiatives. Statistical data indicate that only 11% of villages have environmental protection supervisors, and the success rate of farmers in safeguarding their rights and lodging complaints remains low. This model of "representative participation" restricts genuine farmer involvement in ecological projects.

3. The Synergistic and Interdependent Relationship between Ecological Security and Rural Revitalization

Based on the Social-Ecological System (SES)[3]framework, this study develops a conceptual diagram illustrating the interactive relationship between ecological security and rural revitalization (Figure 2).

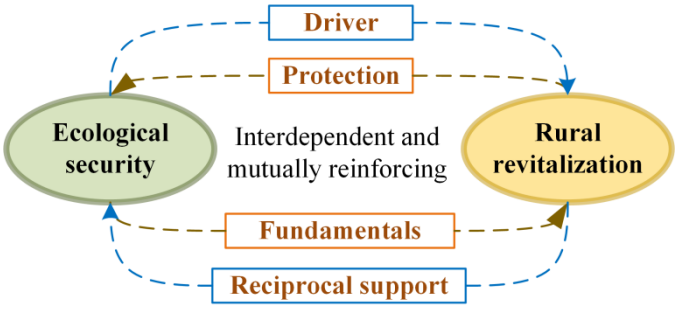

Figure 2: The Synergistic and Reciprocal Interaction between Ecological Security and Rural Revitalization

3.1 Ecological security serves as both the foundation and driving force for rural revitalization

A favorable ecological environment constitutes the fundamental basis for rural development. The Chishui River Basin, characterized by its diverse vegetation, clean water resources, and stable ecological systems, provides essential support for rural survival and sustainable development. High-quality ecological conditions are crucial for the growth of distinctive agriculture, such as the cultivation of region-specific fruits and medicinal plants, which depend on unpolluted soil and water as well as a favorable climate. Ecological security ensures the environmental integrity and quality of agricultural products, meets growing market demand for eco-friendly produce, and supplies unique resources for the revitalization of rural industries. Furthermore, ecological security contributes to the improvement of the rural soft environment. A clean and attractive living environment is essential for creating habitable and productive rural communities. Fresh air and a beautiful natural setting help attract talent and promote population return, thereby injecting vitality into rural development. A stable ecosystem also mitigates the risks associated with natural disasters, reduces development costs, and

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ensures the steady advancement of rural construction. From a broader social development perspective, ecological protection fosters the coordinated development of industries, human capital, and the environment, enabling rural revitalization to be built firmly upon a foundation of ecological sustainability.

3.2 Rural revitalization is the guarantee of ecological security and contributes to ecological security

Rural revitalization continuously enhances ecological security by promoting industrial upgrading and fostering a transformative shift in development paradigms. The economic benefits derived from eco-tourism and green agriculture allow villagers to directly perceive the market value embedded in ecological conservation, thereby transitioning from "passive protection" to "active stewardship." Additionally, the construction of environmental infrastructure and the refinement of ecological compensation mechanisms within rural revitalization efforts provide essential financial and technical support for ecological restoration, facilitating the recovery and stabilization of ecosystems within the river basin. Simultaneously, rural revitalization encourages the return of skilled individuals, who bring valuable experience and innovative approaches in ecological governance, thereby strengthening the collective economy and increasing investment capacity in environmental protection. As residents' ecological awareness grows, it drives the greening of both production methods and lifestyles. This dynamic creates a positive feedback loop that establishes a "development–protection" closed cycle, transforming ecological security from a solely government-led responsibility into a collaborative societal effort. Consequently, rural revitalization continuously optimizes ecological security, achieving a virtuous cycle of mutual reinforcement and coordinated advancement between rural development and ecological protection, jointly reinforcing the dual foundation for sustainable development in the Zhaotong section of the Chishui River Basin.

In conclusion, ecological security and rural revitalization in the Zhaotong section of the Chishui River Basin are mutually reinforcing and interdependent, forming an integrated and coordinated relationship. Ecological security constitutes the foundation for rural revitalization, while rural revitalization, in turn, sustains and enhances ecological security.

4. Analysis of Practical Cases on the Syllnergetic Promotion of Ecological Security and Rural Revitalization

4.1 The "Rice-Fish Coexistence" Model in Heishui Town

Heishu Town is located in the southeastern part of Zhenxiong County, Zhaotong City, Yunnan Province. It lies at the intersection of Sichuan, Yunnan, and Guizhou provinces. The terrain rises in the south and gradually slopes downward toward the north, with a relatively gentle gradient in the central area. As such, it serves as the "eastern gateway" for Zhenxiong County in its efforts to connect with the outside world. With the advancement of rural revitalization, Heishu Town has actively implemented the "rice-fish coexistence" model in accordance with local conditions, achieving dual benefits in ecological conservation and increased farmer income. The 200-acre demonstration base completed in 2023 demonstrates that this model has effectively reduced pesticide use by 62% and fertilizer application by 45% through the natural behavior of fish consuming pests and weeds[4]. While maintaining a stable rice yield of 450 kilograms per mu, the model has generated an additional fish output value of 3,000 yuan per mu, resulting in an average annual income increase of 5,000 yuan per participating household.The ecological improvements have facilitated the recovery of local endemic fish resources. Monitoring data from 2023 indicate that the number of fish species increased by five compared to the previous year, with a 22% rise in the biodiversity index. In parallel, the model has been enhanced through the construction of 8 kilometers of ecological ditches and four ecological retention ponds, establishing a three-tier purification system comprising "rice fields – ditches – ecological ponds." This system has successfully reduced agricultural non-point source pollution entering the river by more than 60%, positioning it as a demonstration model for ecological agriculture within the Chishui River Basin.

In conclusion, the "rice-fish symbiosis" model in Heishu Town has realized a mutually reinforcing relationship between ecological conservation and economic development. It provides practical experience for the coordinated advancement of ecological security and rural revitalization in the Chishui River Basin (Zhaotong section), demonstrating significant potential for replication and promotion.

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4.2 Carbon Trading Practices in Zaxi Town

Zaxi Town is located in the central-southern region of Weixin County, Zhaotong City, Yunnan Province. It lies at the tri-provincial junction of Yunnan, Guizhou, and Sichuan, on the northern foothills of the Wumeng Mountains and adjacent to the Chishui River. Historically, it has served as a commercial corridor connecting the three provinces and is famously described as the place where "a rooster's crow can be heard across three provinces." Through the implementation of initiatives such as the "vegetation restoration of steep slopes with sparse tree and shrub cover" and the "near-natural transformation of artificial forests," Zaxi Town completed the establishment of 978,700 mu of soil and water conservation forests by the end of the planning period. Monitoring data indicates a significant enhancement in soil carbon sequestration capacity within the project area. The extent of soil erosion in key river basins, such as the Shikan River, has decreased by 41.26%, while the area affected by severe rocky desertification has been reduced by 30%.By promoting the production line for biomass charcoal-based fertilizer, the comprehensive utilization rate of straw has reached 85%, and the annual cost of agricultural waste treatment has been reduced by approximately 480,000 yuan[5]. A "four-unified" service system (unified testing, distribution, supply, and application) has been established, covering all 14 administrative village[6] s in Zaxi Town. Through the implementation of a cross-basin ecological compensation mechanism, an average of 1.5 million yuan in ecological transfer payment funds has been secured annually to support the construction of a 6.15-kilometer riverbank ecological isolation belt. [7]Therefore, the economic benefits derived from carbon trading in Weixin County have become evident, establishing a virtuous cycle in which ecological conservation and economic development mutually reinforce each other. This initiative has effectively facilitated the implementation of the rural revitalization strategy and has explored a sustainable development model for the Zhaotong section of the Chishui River Basin, characterized by ecological integrity, industrial prosperity, and improved livelihoods.

5. Strategies and Recommendations for Promoting Coordinated Development of Ecological Security and Rural Revitalization in the Zhaotong Section of the Chishui River Basin

To effectively promote a collaborative mechanism involving the government, market, community, and public within the basin, strategies of ecological restoration, ecological compensation, environmental protection, and green development will be implemented to achieve regional economic prosperity, modern governance, ecological sustainability, improved public well-being, and social harmony. The development direction will follow the collaborative development mechanism model (Figure 3), aiming to enhance the positive interaction between ecological security and rural revitalization and to drive the sustainable integration of regional ecological, economic, and social benefits.

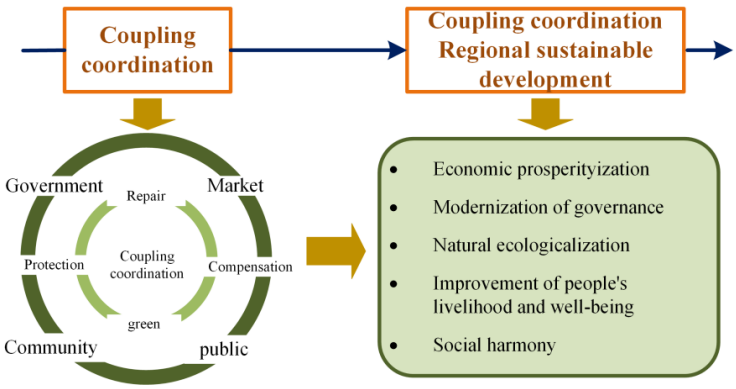

Figure 3: Model of the Synergistic Development Mechanism

5.1 Strengthen ecological conservation and restoration, and improve the ecological compensation mechanism

In the realm of ecological conservation, it is essential to rigorously implement water source protection and soil and water conservation initiatives. Priority should be given to the establishment of ecological buffer zones aimed at intercepting non-point source pollution. Concurrently, efforts must be intensified to advance the conversion of farmland into forest and restore wetlands, while establishing

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an integrated management framework for mountains, rivers, forests, farmlands, lakes, grasslands, and deserts. Ecological restoration projects should be designed and executed in accordance with local conditions. In key soil erosion areas, such as sloped terrains in the middle and lower reaches, a combination of small-scale water conservancy infrastructure and vegetation recovery strategies should be employed to elevate forest coverage to above 60%. To enhance ecological compensation mechanisms, it is recommended to establish a cross-provincial horizontal compensation system[8], implement fiscal transfer payments to upstream conservation zones, and innovate the "flying land economy" model[9], enabling ecological protection areas to co-develop industrial parks in economically developed regions. Furthermore, the "polluter pays" principle should be enforced, with ecological resource fees imposed on enterprises with high water consumption. Third-party evaluations should be conducted to ensure the effective and transparent use of funds. Through ecological certification systems, the value-added potential of agricultural products can be enhanced, thereby fostering a sustainable cycle of "protection - compensation - development" and ultimately achieving the objective of increasing the basin's annual ecological service value by 15%.

5.2 Utilize Regional Resource Endowments to Promote the Development of Green Industries

The development of green industries in the Chishui River Basin should be grounded in regional resource endowments, with the objective of constructing a sustainable ecological industrial system. Priority should be given to advancing highland-characteristic ecological agriculture, promoting certification of organic agricultural products and protection of geographical indications, and implementing the integrated model of "soil testing and formula fertilization combined with organic fertilizer substitution" to transform more than 30% of the cultivated land in the basin into ecologically managed farmland. Leveraging the presence of 17 fish species endemic to the upper reaches of the Yangtze River, an ecological aquaculture industrial clustershould be established, with the promotion of circular farming models such as "rice-fish coexistence." Concurrently, cultural resources such as the red revolutionary heritage and Miao ethnic traditions within the basin should be integrated to develop a tourism framework encompassing and with a focus on cultivating emerging business forms such as forest-based wellness programs and ecological study tours. The under-forest economy should be expanded through the establishment of specialized bases for Chinese medicinal materials and edible fungi, while green financial instruments, including carbon credit trading, should be developed. By leveraging the value-added benefits generated along the industrial chain to support ecological conservation, the objectives of achieving an annual green industry growth rate exceeding 10% and creating more than 50,000 jobs should be realized.

5.3 Establishment of a Cross-Regional Collaborative Governance Platform

The construction of a cross-regional collaborative governance platform for the Chishui River Basin necessitates the establishment of a tri-provincial coordination mechanism. The initial step involves setting up a "Yunnan-Guizhou-Sichuan Tri-Provincial Joint Conference" system, led by provincial authorities, to form a basin protection coordination group and establish specialized working groups focused on water quality monitoring, ecological compensation, and joint law enforcement. A key priority is the development of a digital twin platform[10] for the basin, integrating critical data from 17 towns, 132 water quality monitoring stations, and monitoring points in rare fish conservation areas, enabling intelligent functions such as simulation of pollutant dispersion and early warning of ecological risks. Concurrently, it is essential to enhance the cross-provincial joint law enforcement framework and establish an information-sharing system for a "blacklist" of violations, including illegal discharges and fishing activities. Cross-provincial joint inspections should be conducted at least four times annually, ensuring mutual recognition of violation data among the three provinces and coordinated enforcement actions. The ultimate objective is to fully establish a smart governance system covering the entire river basin by 2030, achieving a 50% increase in inter-provincial collaboration efficiency and maintaining a 100% compliance rate for water quality at transboundary sections[11].

6. Conclusion

The development of the Chishui River Basin (Zhaotong section) exemplifies the idea that "lucid waters and lush mountains are invaluable assets". This paper deeply analyzes the synergistic relationship between ecological security and rural revitalization in this area, uncovering their mutually reinforcing interaction mechanism. Ecological security underpins rural revitalization, offering essential

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support. Soil and water conservation and ecological restoration enhance the regional ecological environment, driving economic and ecological progress. Rural revitalization, in turn, boosts ecological security. Increased income leads to more investment in conservation and raises environmental awareness, creating a positive feedback loop between ecology and development. This study lays a foundation for the sustainable development of the Chishui River Basin (Zhaotong section) and offers a reference for other ecologically fragile regions. It aids in exploring a modernization path where humans and nature coexist harmoniously.

Acknowledgements

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