Research on the Coupling and Coordinated Relationship between Economy and Ecological Environment in Qinghai Province

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Abstract: Qinghai Province, as the source of the Yellow River and a key ecological barrier, has a relatively low economic development level. Promoting high-quality economic growth within ecological limits is essential. Based on 2011-2021 economic and social data, this study constructs an evaluation index system for coordinated economic-ecological development and analyzes its progress. The results show a gradual improvement in coordination, but challenges such as ecological fragility, resource exploitation conflicts, and industrial imbalances persist. The study suggests scientifically informed planning, balancing conservation and development, leveraging resource endowments to foster emerging industries, and building an ecological agro-pastoral economy to drive sustainable growth.

Keywords: economic development; ecological environment; regional high-quality development; coupling coordination

1. Introduction

In recent years, China's national strategies have placed increasing emphasis on the concept that "lucid waters and lush mountains are invaluable assets", promoting ecological protection and a path of green development. This philosophy, known as the "Two Mountains Theory", has become a central guiding principle for advancing ecological conservation efforts [1]. As the source region of the Yellow River, Qinghai Province holds substantial ecological responsibilities; however, it continues to face challenges in achieving economic development at the same pace. Attaining high-quality growth with ecological sustainability as a priority requires a deeper understanding of the dynamic relationship between economic advancement and ecological protection [2].

Drawing on the specific conditions of Qinghai Province, this study proposes targeted strategies to foster coordinated economic and ecological development [3]. These recommendations are intended to support the formation of a synergistic development model aligned with the strategic goals of the Yangtze River Economic Belt and the Yellow River Economic Belt. This approach emphasizes Qinghai's vital role in the upper reaches of the Yellow River and aims to contribute to reducing regional development disparities between eastern and western China [4].

Previous studies using ecological footprint models have revealed a growing mismatch between ecological supply and economic demand, resulting in low levels of coupling coordination. Other research based on composite index systems has shown that the degree of coordination between economic and ecological systems in western regions — including Qinghai — has generally improved over time, shifting from patterns characterized by economic dominance or ecological lag. Additional findings indicate that the overall coordination level between ecological, economic, and social systems varies significantly across regions, with eastern areas typically showing higher levels of integration than western counterparts.

While these studies offer valuable quantitative insights into coordination characteristics, they often fall short in analyzing the root causes behind the persistent coordination challenges [5]. Therefore, this research utilizes data from 2011 to 2021 to construct a high-quality development evaluation index system tailored to Qinghai Province. Through empirical analysis, it examines the interplay between economic and ecological systems, identifies key constraints, and provides policy suggestions to support balanced and sustainable regional development.

2. Overview of the Study Area

2.1. Overview of Ecological Protection in Qinghai Province

As the "source of the Three Rivers" (Yangtze, Yellow, and Lancang Rivers), Qinghai is one of China's most important water conservation areas. The province has a wetland area of 8.14 million hectares and a total water resource volume of 96.19 billion cubic meters. It contains numerous rivers and lakes, with many rivers having basin areas exceeding 1,000 square kilometers [6]. In recent years, Qinghai has implemented various ecological protection measures for its grasslands, forests, and other ecosystems. These efforts have led to a gradual increase in the overall vegetation coverage of forests and grasslands, effectively reducing land desertification and helping prevent ecosystem degradation in the Yellow River headwater region. As a result, the province's ecological service functions have been significantly enhanced, reinforcing its role as a high carbon sequestration surplus area.

Furthermore, the improvement of ecological services has contributed to significant progress in biodiversity conservation. Populations of iconic plateau wildlife species, such as the Tibetan antelope, snow leopard, and Tibetan wild ass, have been steadily increasing, suggesting notable progress in biodiversity conservation.

2.2. Overview of Economic Development in Qinghai Province

Due to its geographical and historical conditions, Qinghai's economic development remains relatively weak. In 2021, its GDP was 334.66-billion-yuan, accounting for only 0.29% of the national total, the lowest among Yellow River Basin provinces. However, the province's economy has shown steady growth, with a GDP increase of 11.19% from the previous year and an average annual growth rate of 9.38% over the past decade. Similarly, per capita GDP grew by 11.02% in 2021, with a decade-long average growth rate of 8.87%. Compared to 2011, both total and per capita GDP more than doubled, indicating continuous economic improvement. Despite this progress, Qinghai's 2021 per capita GDP was only 56,400 yuan, significantly below the national average of 81,000 yuan. This reflects ongoing economic growth and improved living standards but also highlights the gap between Qinghai and other regions. Moving forward, the province must improve the structure and efficiency of its economy through reform, innovation, and industrial upgrading.

3. Data Sources and Research Methods

This study uses data from the Qinghai Statistical Yearbook and China Statistical Yearbook to analyze the coordination between economic and ecological development in Qinghai Province. An index system is constructed, and the entropy weight method and coupling coordination degree model are applied.

3.1. Index System Construction

Based on existing research literature, the index system is designed to ensure scientific rigor, feasibility, a systematic approach, and representativeness. Considering data availability for Qinghai's economy and ecology, nine indicators are selected for both the economic and ecological subsystems (Table 1).

Table 1. Evaluation Index System for High-Quality Coordinated Economic and Ecological Development in Qinghai Province.

	Primary Indicators	Secondary Indicators	Attribute	Weight
Economic Development	Economic Scale	GDP	+	0.1078
		Total Retail Sales of Consumer Goods (Billion Yuan)	+	0.0855
		Total Import and Export Volume (Billion Yuan)	+	0.1186
	Economic Structure	Primary Industry GDP Share (%)	-	0.1280
		Secondary Industry GDP Share (%)	+	0.1301
		Tertiary Industry GDP Share (%)	+	0.1445
	Living Standards	Per Capita Disposable Income of Urban Residents (Yuan)	+	0.1000
		Per Capita Disposable Income of Rural Residents (Yuan)	+	0.1012
		Per Capita Consumption Expenditure (Yuan)	+	0.0844
Ecological Environment	Status	Forest Coverage Rate (%)	+	0.1177
		Wetland Area (10,000 hectares)	+	0.0744
		Per Capita Water Resources (Cubic meters)	+	0.0956
	Pressure	Fertilizer Use in Agriculture (10,000 tons)	-	0.1434
		Total SO$_2$ Emissions (10,000 tons)	-	0.1979
		Total Industrial Water Consumption (Billion cubic meters)	-	0.0437
	Protection	Harmless Disposal of Domestic Waste (10,000 tons)	+	0.1365
		Green Coverage Rate in Built-up Areas (%)	+	0.0904
		Afforestation Area in the Year (10,000 hectares)	+	0.1004

3.2. Determination of Indicator Weights

1) Data Standardization Processing

For positive indicators：$X'_{ij} = \frac{X_{ij} - X_{min}}{X_{max} - X_{min}}(X_{min} \leq X_{ij} \leq X_{max})$

For negative indicators：$X'_{ij} = \frac{X_{max} - X_{ij}}{X_{max} - X_{min}}(X_{min} \leq X_{ij} \leq X_{max}）$

X_{ij} represents the j-th indicator of the i-th year before data processing；X'_{ij} is the normalized value；X_{max} and X_{min} are the minimum and maximum values of the indicator across all observations.

2) Calculation of the Proportion of the j-th Indicator in Year i

$$P_{ij} = \frac{X'_{ij}}{\sum_{i=1}^{m} X'_{ij}}$$

3) Calculation of the Entropy Value of the j-th Indicator

$e_j = -k \sum_{i=1}^{m} X'_{ij} \ln(X'_{ij}) \ \ k > 0, \ \ k = \frac{1}{lnm}$

4) Calculation of the Variation Coefficient for the j-th Indicator

$$g_j = 1 - e_j$$

5) Calculation of Indicator Weights

$$\omega_j = g_j / \sum_{j=1}^{m} g_j$$

3.3. Comprehensive Development Index

$$F(X) = \sum_{i=1}^{m} \omega_j \times X'_{ij}$$

The closer the comprehensive development index is to 1, the better the development of the economic or ecological system. A higher index value indicates a more favorable economic development level or ecological environment quality.

3.4. Calculation of Coupling Degree and Coupling Coordination Degree

The Coupling Coordination Degree reflects the extent of coordinated development between different systems during their interaction and indicates the quality of their coupling state [7]. The specific formula is as follows:

$$D = \sqrt{C \cdot T}$$

$$C = 2 \cdot \sqrt{\frac{U_1 \cdot U_2}{(U_1 + U_2)^2}}$$

$$T = a \cdot U_1 + b \cdot U_2$$

D represents the Coupling Coordination Degree, *C* represents the Coupling Degree, *T* is the Comprehensive Coordination Index; The economic system development level is denoted as U_1, and the ecological system development level as U_2. That both *a* and *b* represent weights, and considering that the two systems have equal influence on the development level, the values are selected as *a* = *b* = 0.5. According to the value of D, the coupling coordination degree is classified as follows [7]: (0, 0.4) is low-level coordinated coupling; (0.4, 0.5) is moderate coordinated coupling; (0.5, 0.8) is high coordinated coupling; (0.8, 1) is extremely high coordinated coupling.

4. Results

Based on Figure 1, the comprehensive economic development index of Qinghai Province exhibited a steady upward trend from 2011 to 2021, indicating a favorable economic growth trajectory. In contrast, the ecological environment development index lagged behind in 2011, followed by a turning point with an inverted "V" shape between 2013 and 2015. After 2015, the ecological environment index experienced significant growth, reaching a peak in 2020 before declining slightly in 2021. Overall, the relationship between economic development and ecological environment exhibits distinct phase transitions. Between 2011 and 2016, the growth rate of the economic development index significantly exceeded that of the ecological environment index, suggesting that economic growth outpaced ecological improvements. However, in 2016, the two indices intersected, marking a turning point where the ecological environment development index began to surpass economic development, with the gap between ecological and economic development indices

continuing to widen. This trend suggests meaningful progress in Qinghai's ecological governance efforts during this period.

Figure 1. Comprehensive Development Index of Economy and Ecology in Qinghai from 2011 to 2021 (a).

According to Figure 2, the coupling degree underwent a significant shift from low to high between 2012 and 2014. Over time, the coupling degree between the two systems gradually approached 1, indicating an increasingly strong interaction and interdependence. In terms of coupling coordination, the two systems were in a state of low coordination coupling from 2011 to 2013, transitioning to a highly coordinated coupling state between 2014 and 2017. After 2017, the coupling coordination index progressively approached 1, reflecting an increasing level of synergistic development between the two systems. Overall, these findings suggest that Qinghai Province has achieved remarkable progress in ecological protection in recent years, leading to rapid improvements in the ecological environment. However, economic development has been relatively slow. Although the province's economy has grown annually, it still lags significantly behind other provinces in the Yellow River Basin. This indicates that the coordination between economic development and ecological protection in Qinghai Province requires further improvement and enhancement.
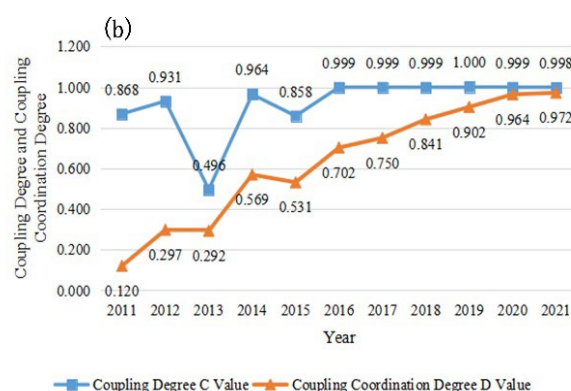
Figure 2. Economy and Ecology in Qinghai from 2011 to 2021 Coupling Coordination Degree (b).

5. Constraints Analysis

5.1. Ecological Vulnerability

Ecological vulnerability serves as a key constraint on the coordinated development of the economy and ecology in Qinghai Province. As a typical ecologically vulnerable re-

gion, Qinghai's historical development has been constrained by harsh environmental conditions, posing significant challenges to economic growth. Located in the northeastern part of the Qinghai-Tibet Plateau, the province features complex terrain with diverse landforms, characterized by an intricate network of mountains and ravines. The region suffers from poor soil quality, severe water and soil erosion, desertification, and rocky desertification, all of which limit land productivity and economic activities. These environmental constraints have long restricted human livelihoods and economic development.

In recent years, Qinghai has received strong national support for ecological protection projects, leading to notable progress in environmental restoration. However, the comprehensive protection of critical ecosystems — such as rivers, lakes, grasslands, and wetlands — remains inadequate. A stable and healthy ecological pattern — characterized by resilient ecosystems and balanced land use — has yet to be fully established. Additionally, the region's weak natural self-recovery capacity and insufficient protective measures further exacerbate ecological vulnerability. This deterioration threatens the stability of forest and grassland ecosystems, increasing environmental fragility and restricting the sustainable development of agriculture and animal husbandry. To achieve a higher level of coordinated development between economy and ecology, it is crucial to enhance ecological restoration efforts, implement systematic environmental governance, and promote sustainable agricultural and pastoral practices. Strengthening regional ecological resilience will be essential for ensuring long-term economic stability and environmental sustainability in Qinghai Province.

5.2. Conflict Between Resource Exploitation and Ecological Protection

The Muli Coal Mine case in Haixi Prefecture, Qinghai Province, exemplifies the conflict between resource exploitation and ecological conservation. Situated at the headwaters of a major tributary of the Yellow River, this mining area lies within a nationally designated key ecological function zone. While its abundant coal resources have significantly contributed to local economic development, excessive pursuit of economic benefits by enterprises — without regard for ecological carrying capacity — has led to large-scale illegal mining, causing severe degradation of alpine grassland and wetland ecosystems. This has intensified the contradiction between resource development and ecological protection.

This case highlights the necessity of prioritizing ecological conservation when planning and executing resource development projects. Strict adherence to sustainable development principles is essential to prevent the sacrifice of the environment for short-term economic gains. It is crucial to move beyond the traditional perception of "conflict between protection and development" and instead seek a green balance between economic growth and ecological preservation. Strengthening environmental regulations, enforcing sustainable mining practices, and promoting eco-friendly resource utilization strategies are key measures to resolve this conflict and achieve harmonious development between economy and environment.

5.3. Unbalanced Industrial Structure

Qinghai Province's industrial structure is predominantly centered on resource extraction, energy production, and heavy chemical industries. However, the high energy consumption of these industries poses significant challenges to industrial upgrading and high-quality development.

A key constraint to the expansion of clean energy in Qinghai is underdeveloped market mechanisms. Despite the province's vast potential for solar and wind energy, the utilization rate remains only around 1%, significantly below the national average. Low electricity purchase prices have weakened investment incentives for enterprises, limiting the further expansion of the renewable energy market [8].

Additionally, the province's agricultural and pastoral sectors face long-standing bottlenecks. Agricultural and livestock product processing remains at a rudimentary stage,

with products often sold after minimal processing, failing to fully capitalize on their potential value. The absence of leading enterprises to drive industry growth, coupled with delayed brand development, has led to weak market competitiveness. Addressing these structural constraints will be crucial for Qinghai to achieve sustainable economic development and enhance its position in emerging industries [9].

6. Countermeasures and Suggestions

6.1. Scientific Planning with Equal Emphasis on Protection and Governance

In the context of the new era, a well-structured ecological protection mechanism is crucial for achieving the coordinated development of the economy and the environment. Strengthening top-level planning is necessary to define ecological protection red lines and bottom lines, ensuring the effective conservation of key ecosystems. Establishing a diversified ecological compensation mechanism can incentivize broad participation in conservation efforts, fostering a positive interaction between ecological protection and economic development. Additionally, enhancing ecological culture and raising public awareness will provide social impetus for building an environmentally conscious society, in line with the principles of ecological civilization. Through scientific planning, supported by a robust ecological protection framework and guided by ecological civilization principles, Qinghai can safeguard its natural resources for future generations while achieving sustainable economic growth.

6.2. Leveraging Resource Advantages to Develop Emerging Industries

Building upon Qinghai's unique resource endowments and fostering competitive industries is a viable pathway to harmonizing economic and environmental development. The establishment of a dedicated Qinghai Salt Lake Industry Fund and the consolidation of key enterprises will strengthen innovation and drive the sustainable development of salt lake resources, ensuring a win-win outcome for both ecological and economic benefits. At the same time, advancing the construction of large-scale national wind and solar energy projects will help position Qinghai as a leading national clean energy hub. Additionally, optimizing the layout of eco-tourism, developing distinctive tourism routes and products, and fostering leading cultural tourism enterprises through a coordinated governance model involving provincial, local, and enterprise-level collaboration will promote the industrialization of ecological resources and the ecological transformation of industries.

6.3. Establishing an Ecological Agro-Pastoral Economic System

An ecological agro-pastoral economic system prioritizes environmental conservation, resource recycling, and industrial integration to achieve sustainable agricultural and livestock development while unifying economic, ecological, and social benefits. The government should utilize media platforms and implement an "Internet + Ecological Agro-Pastoral Industry" model to streamline product sales channels for farmers and herders, while ensuring quality assurance and market credibility through effective regulation. By incorporating elements of Qinghai's by incorporating Qinghai's rich cultural heritage into agricultural branding into agricultural branding, promoting pollution-free, organic, and green-certified products, and strengthening trademark registration efforts will enhance the value and competitiveness of highland agricultural and livestock products. Furthermore, establishing a well-structured highland agro-pastoral product system will drive qualitative transformation in Qinghai's agricultural sector, promoting a sustainable and resilient agro-pastoral economy.

By implementing these strategies, Qinghai can achieve a balanced and sustainable economic development model that aligns with ecological preservation, ensuring long-term prosperity for both the environment and the economy.

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