

# Assessing the Ecological-Economic Balance: Evidence from Analytic Hierarchy Modeling

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**Abstract:** Sichuan Province faces a delicate balance between economic growth and ecological sustainability, challenging resource management and environmental protection. This study quantitatively assesses how ecological occupation affects the regional economy and proposes strategies to improve this relationship for long-term stability. Using the Analytic Hierarchy Process (AHP), a decision-making framework that considers multiple criteria, this study evaluates key risk factors, including resource consumption, pollution, and ecological degradation. The land use from 2000 to 2020 shows increasing ecological occupation, rising from 905,918.06 hm<sup>2</sup> to 890,191.13 hm<sup>2</sup>, with the rate surpassing ecological carrying capacity by 114.29% in 2018. Although energy efficiency has improved, reducing unit Gross Domestic Product (GDP) energy consumption from 10 to 8 tons per 10,000 Renminbi (RMB), further efforts are needed to ensure sustainable development. The findings highlight the importance of Sichuan's prioritizing ecological protection alongside economic growth to prevent long-term environmental degradation and promote sustainable regional development.

**Keywords:** Analytical Hierarchy Process (AHP), ecological balance, economic growth, regional economy, sustainable development.

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## 1. Introduction

Amid the rapid advancement of urbanization, the tension between regional economic growth and ecological conservation has grown increasingly prominent (Zhang et al., 2023). Sichuan is in southwestern China. As an economic hub in the region, it faces dual pressures from economic growth and ecological preservation. In recent years, Sichuan Province has undergone significant changes in land use in pursuit of economic development (Lenzner et al., 2022). As industrialization and urbanization advance steadily, large areas of ecological space have been taken over by industrial and residential developments. This shift in land use directly leads to increased resource consumption and exacerbates problems such as water resource overexploitation, deforestation, and land degradation (Wu et al., 2023). Environmental pollution has also worsened due to industrial emissions and urban expansion, resulting in declining air quality, water pollution, and soil degradation.

Furthermore, ecological degradation is becoming more severe. Loss of biodiversity and diminished ecosystem services threaten local ecological balance, posing long-term challenges to sustainable development. These issues impact residents quality of life in Sichuan and pose potential threats to sustainable growth (Neimark et al., 2024; Ogura and Forwell, 2023).

In response to the issues of regional coordinated development and environmental governance under agricultural social ecosystems, especially the lack of effective research on spatial differentiated governance, Gou et al. (2025) selected the regions with severe soil erosion as the study area, and used socio-economic statistical data and remote sensing data, combined with the modified general soil erosion equation. The rate of soil erosion on the Loess Plateau has decreased over the past three decades, with an average reduction of 0.46 tons, or 2.33%, per hectare per year. Large-scale investment in ecological infrastructure enables farmers to receive ecological compensation and increases agricultural income through improved land productivity. Meresa et al. (2025) performed an archaeological botanical study on the agricultural economy of the Eastern Tigray region and its influence on social and cultural development. Through the analysis of the plant remains at the Onadi site in the Tigray region, the research found that from the mid-8th century BC to the 8th century AD, this area had both native African plants and plants introduced from Southwest Asia, and its significance changed along with the social and political changes in the region. The local agricultural economy has significant continuity, and even after the decline of the Axum Kingdom, the agricultural model remained stable. For the interaction between ecology and human activities in the

Wally Lake area, Masci et al. (2025) proposed a comprehensive research approach that combines paleoecology and historical methods. By analyzing pollen and geochemical records in the Wally Lake sediments, researchers reconstructed environmental changes over the past 2,000 years. The research results show that since the Romans occupied the area, the changes in vegetation have reflected the evolution of wetland habitats, the dynamics of mixed forests and the intensity changes of grain cultivation, grazing and horticultural activities. Frequent land use conflicts in the Yellow River section of Shandong Province have placed multiple pressures on regional economic development, farmland protection, and ecological conservation. Dong et al. (2025) utilized land use data, elevation data, and meteorological data to characterize these conflicts from 2000 to 2020. Furthermore, they simulate and predict land use conflict patterns in various scenarios in 2030. From 2000 to 2020, the degree of land use conflicts in the Yellow River section of Shandong Province generally showed a trend of alleviation, with moderate conflicts, while spatial distribution was relatively stable. The multi-scenario simulation in 2030 reveals that the mitigation effect of land use conflicts is most pronounced under the ecological protection scenario, which effectively balances the relationships among cultivated land protection, ecological security, and urban development. Thus, this is the optimal strategy for mitigating land use conflicts (Dong et al., 2025).

Existing research primarily focuses on single-dimensional economic or environmental analyses, lacking comprehensive studies on the interaction between the regional economy and the environment. Furthermore, current research has limitations in integrating macro and meso perspectives to assess how different economic activities impact the environment, making it difficult to provide a solid scientific basis for policymaking. To develop targeted prevention and optimization strategies that promote coordinated development in Sichuan, a multi-criteria decision-making model is built by applying the AHP to quantitatively evaluate how ecological occupation on types and explore how these data influence sustainable development. The innovation of this research lies not only in quantitatively assessing ecological occupation but also in linking it to multiple aspects of the regional economy, such as resource consumption, environmental pollution, and ecological degradation, through the AHP model, thereby offering a more comprehensive and systematic analysis. The goal is to provide new insights for coordinated development in Sichuan Province and other regions, fostering sustainable growth.

## 2. Methods and Materials

This study examines the factors influencing the regional economy based on ecological occupation. A multi-criteria decision-making model is developed to assess how different economic activities impact the ecological environment. Additionally, the role of ecological occupation in Sichuan's regional economy is analyzed, and its effect on sustainable development is explored. The AHP determines the relative weights of each criterion, and consistency tests are performed to ensure the scientific validity and accuracy of the results. Furthermore, relevant economic and ecological data from Sichuan Province are collected and subjected to quantitative analysis.

### 2.1. Analysis of Regional Economic Impact Factors based on Ecological Occupation

Ecological occupation represents the biologically productive land area needed to support a specific population and consumption level, including the land for resource supply and waste absorption. By analyzing the relationship between ecological occupation and Ecological Carrying Capacity (ECC), we can assess whether a region's or country's economic activities are sustainable. In regional economic analysis, ecological occupation can be viewed as an "ecological cost" that reflects how much economic activity depends on natural resources and the pressure placed on the environment. When ecological occupation exceeds its ECC, it indicates that the region's economic activities surpass the local ecosystem's sustainable capacity, potentially leading to resource depletion, environmental pollution, and ecological degradation, which threaten long-term stable development. Conversely, suppose ecological occupation is lower than the ECC. In that case, it suggests the region has ecological surplus, allowing for relatively sustainable economic activities and providing ecological space and resource reserves for future growth (Hou et al., 2022; Ma et al., 2023). The ecological occupation theory posits that regional economic output is dependent on the supply of natural resources. Natural resources, such as land, water, energy, and forests, are fundamental to economic activities (Santamaría et al., 2023). The ecological occupation model quantifies the demand for natural resources by converting resource consumption into biologically productive land area. The magnitude of ecological occupation reflects the degree to which the regional economy relies on natural resources, influencing the sustainability of economic development (Wang et al., 2022; Albert, 2023). The extent of ecological occupation depends on the combined effects of resource consumption and resource production efficiency, as shown in Eq. (1).

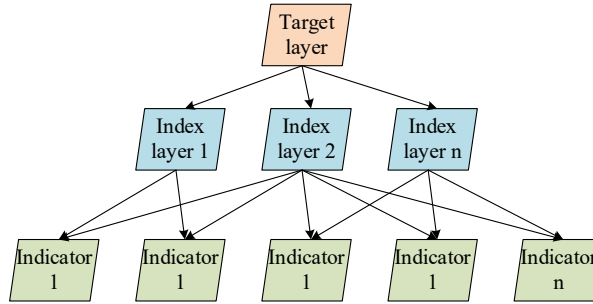
$$EF = \sum_{i=1}^n \frac{c_i}{y_i} \times f_i \quad (1)$$

In Eq. (1),  $EF$  represents ecological occupation.  $c_i$  signifies the consumption.  $y_i$  signifies the yield unit area output related to the  $i$ -th resource.  $f_i$  denotes the equilibrium coefficient of biologically productive land corresponding to the  $i$ -th resource. The increase in ecological occupation means that economic activities are exerting greater pressure on the environment. When the ecological occupation surpasses the ECC, the ecological environment will face degradation, such as land degradation, water resource pollution, and reduced biodiversity. Regions with ecological occupation below ECC have an ecological surplus, indicating that the region possesses certain advantages in resource supply and ecological environment. Ecological surplus that can provide space and potential for further economic development in the region (Nagai, 2023; Chu et al., 2022). The ECC varies from region to region. Consequently, it is imperative to accomplish reasonable allocation and optimized deployment of ecological occupation through collaborative efforts and coordination among different regions. Table 1 presents the balance factors and yield coefficients.

Table 1 illustrates that the balance factor represents the comparison of various land categories based on global average productivity, and the yield factor expresses the proportion of land productivity in a specific area relative to the global average level. In the analysis of regional economic influencing factors, the AHP method is utilized to establish a multi-criteria decision model that aims to evaluate how economic behaviors impact the ecological environment and propose targeted prevention and optimization strategies, as depicted in Fig. 1.

**Table 1.** Balance factors and yield factors across various land types

Type	Balance factor	Yield factor
Cultivated land	2.8	1.66
Built-up area	2.8	1.66
Fossil energy land	1.1	0
Forest land	1.1	0.91
Pasture	0.5	0.19
Water area	0.2	1



**Fig. 1.** Schematic diagram of hierarchical analysis

In Fig. 1, the AHP model includes a target layer, a criterion layer, and a solution layer. This model determines the relative weights of each criterion factor through expert evaluation and data analysis, then quantifies the specific impact of different economic behaviors on the environment. First, by constructing a judgment matrix and performing pairwise comparison analysis, the relative weights of each factor are calculated. In the calculation process, the sum-product approach is employed to obtain the eigenvector corresponding to the maximum eigenvalue of the judgment matrix, as shown in Eq. (2).

$$AP = \lambda_{\max} P \quad (2)$$

In Eq. (2),  $\lambda_{\max}$  denotes the maximum eigenvalue.  $P$  stands for the judgment matrix.  $A$  signifies the corresponding eigenvector. Subsequently, the normalized eigenvector represents the weights of various criterion layer factors, as displayed in Eq. (3).

$$\lambda_{\max} = \sum_{i=1}^n \frac{(AP)_i}{nA} \quad (3)$$

In Eq. (3),  $(AP)_i$  denotes the  $i$ -th element within the calculation result. To ensure the rationality of the judgment matrix, a consistency test is employed, and the consistency index is computed, as shown in Eq. (4).

$$C_1 = \frac{\lambda_{\max} - n}{n - 1} \quad (4)$$

In Eq. (4),  $n$  denotes the order of the judgment matrix  $P$ .  $C_1$  represents the consistency indicator. Through consistency testing, the model's scientific validity and precision can be guaranteed (Li and Wu, 2022). The economic influencing factors of Sichuan Province based on AHP are shown in Fig. 2.

As shown in Fig. 2, the target layer corresponds to sustainable development, while the criterion layer encompasses core risk elements, such as resource consumption, environmental pollution, and ecological degradation. The solution layer involves corresponding adjustments to economic activity and environmental improvement measures.

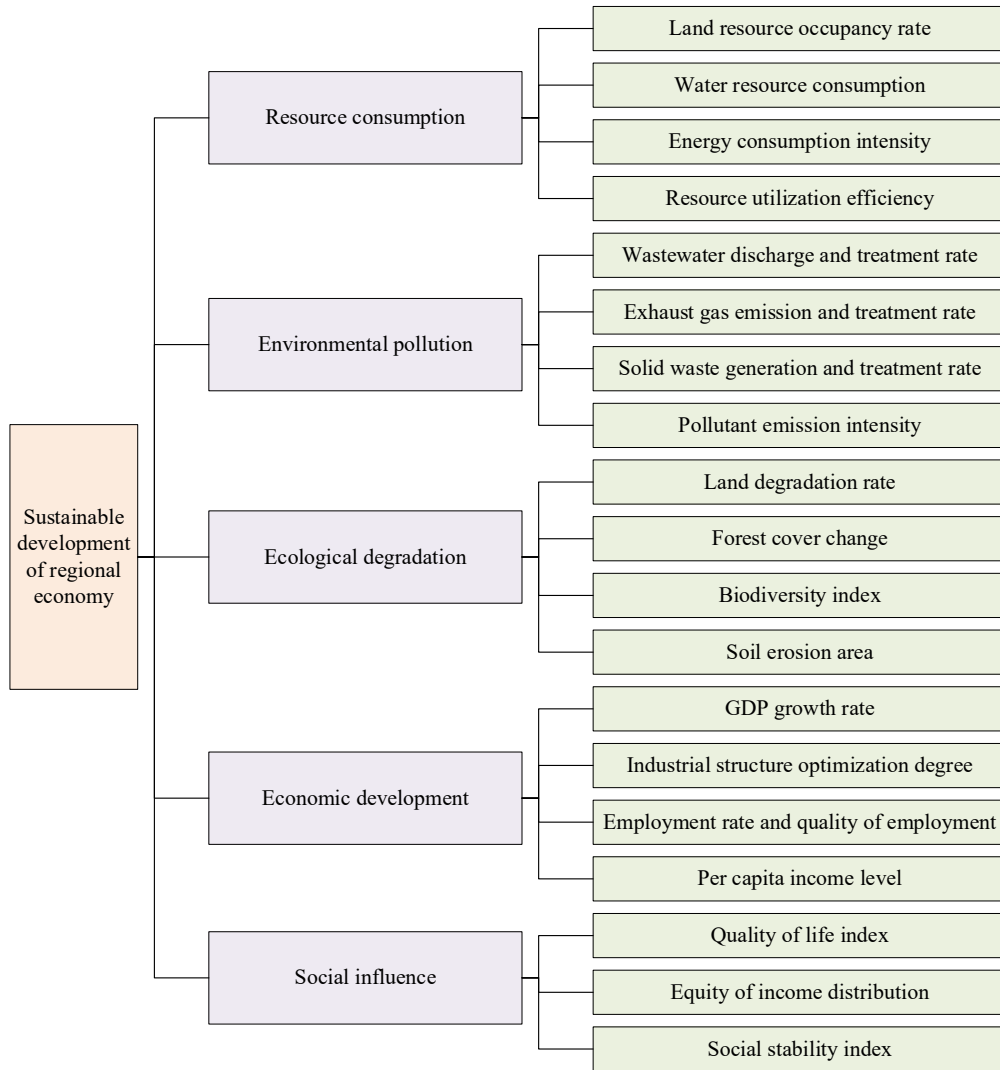


Fig. 2. Influence factors of regional economy in Sichuan Province based on AHP

For key ecological and economic indicators, such as resource consumption intensity and land degradation rate, from 2000 to 2020, the AHP weight calculation is conducted annually to reflect the dynamic changes in the influence of each factor. Integrate the annual AHP results with time-series ecological data, such as ecological occupation area and ECC, to conduct an overall comparative analysis and thereby quantify the long-term interaction relationship between ecological occupation and regional economy. The framework of the ecological-economic analysis research method in Sichuan Province is shown in Fig. 3.

In Fig. 3, data on land use, energy consumption, GDP, and pollutant emissions in Sichuan Province from 2000 to 2020 were obtained through official statistical yearbooks and remote sensing products. Based on the ecological occupation theory, determine the criterion level factors, such as resource consumption and environmental pollution, as well as the scheme level indicators. The judgment matrix is constructed through expert evaluation, the index weights are calculated using the sum-product method, and consistency checks are performed to ensure accuracy. Match the annual AHP weight results with the ecological economic data of the corresponding years to establish an association model and analyze the impact of ecological occupation on the regional economy by using coupled data to verify the rationality of the model.

## 2.2. The Role of Ecological Occupation in Sichuan Province on Regional Economy

The research analyzes the factors affecting the regional economy grounded in ecological occupation, aiming to examine its influence on Sichuan Province’s economy and explore how it impacts sustainable development. Sichuan is in the upper reaches of the Yangtze River. Chongqing borders it on the east, Guizhou on the south, the Xizang Autonomous Region on the west, and Gansu and Shaanxi on the north. The area is approximately 486,000 km<sup>2</sup>, featuring diverse landforms including plateaus, mountains, hills, and plains. Mountains and plateaus comprise a significant portion of the land, with high terrain in the west and lower terrain in the east, transitioning gradually from one to the other. Sichuan’s climate is classified as subtropical monsoon, with distinct seasons and abundant rainfall. Additionally, due to significant variations in terrain, there are notable vertical differences in climate. The province has a well-developed water system, with the Yangtze River and its

many tributaries passing through, providing ample water resources (Mai et al., 2022; Wu et al., 2023). The GDP of Sichuan from 2010 to 2020 is shown in Fig. 4.

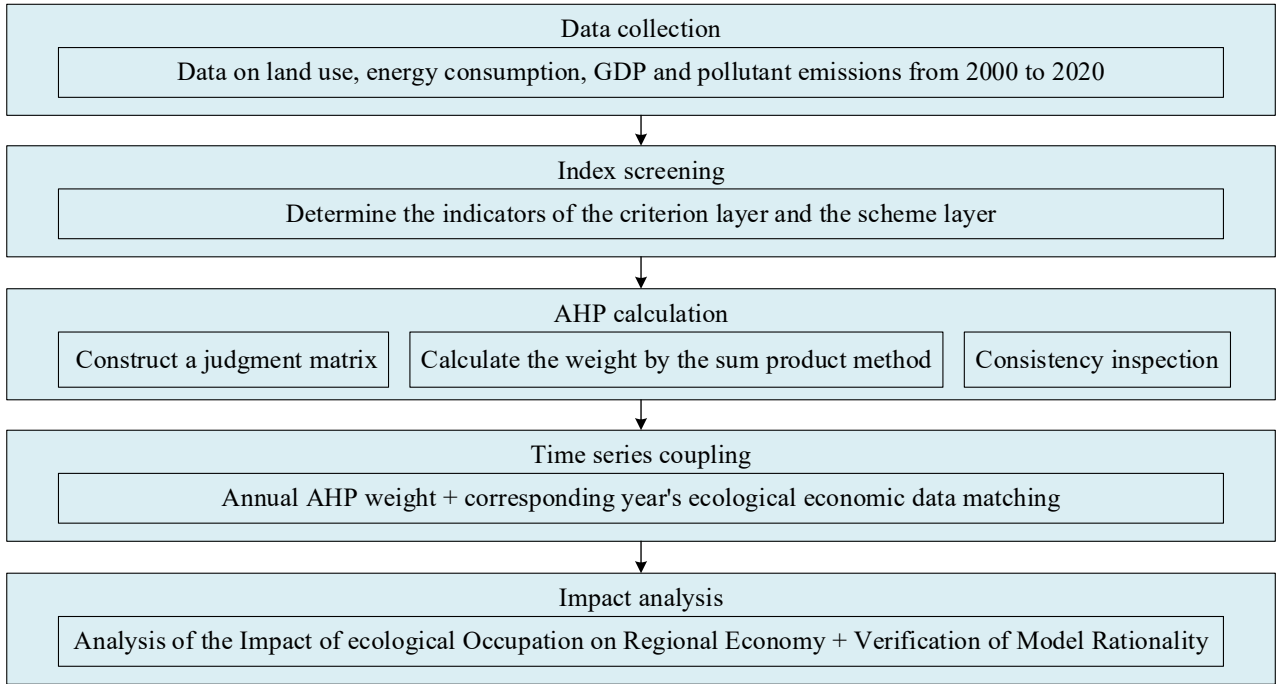


Fig. 3. Framework of research methods for ecological-economic analysis in Sichuan Province

In Fig. 4, from 2010 to 2020, the economy of Sichuan Province experienced significant growth, with GDP growing from 1689.86 billion RMB in 2010 to 4859.88 billion RMB in 2020, showing the province’s continually expanding economic scale. During this period, although Sichuan’s GDP growth rate fluctuated, it maintained an overall positive trend, with a rate of 7.5% in 2019. Even amidst macroeconomic challenges, Sichuan’s economy demonstrated strong resilience and vitality. The land classification in Sichuan Province is shown in Fig. 5.

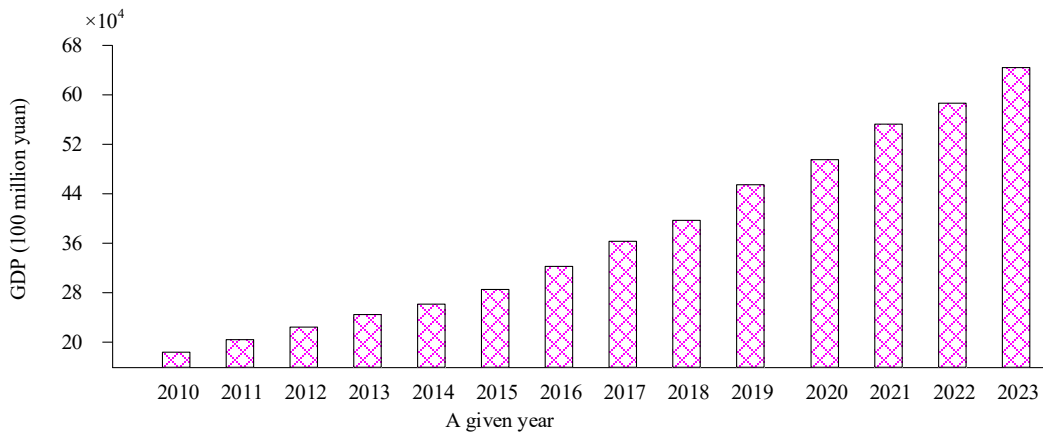


Fig. 4. GDP and GDP growth rate of Sichuan Province from 2014 to 2024

Fig. 5 illustrates the land classification details in Sichuan Province, which includes these six types: cultivated land comprises paddy fields and dry land, while forest land encompasses deciduous forests, shrublands, sparse forests, and other forest types. Grassland is categorized into high, medium, and low coverage grasslands. Water land includes canals, lakes, reservoirs, permanent glaciers, snow, and beaches. Construction land encompasses urban areas, rural residential areas, and other developed land, whereas unused land refers to bare, rocky, or gravelly land (Ke et al., 2022). Table 2 displays the ecological occupation data and structure in Sichuan.

In Table 2, the area and proportion of cultivated land have both decreased over the past three years, from 905,918.06hm<sup>2</sup> and 44.71% in 2000 to 890,191.13hm<sup>2</sup> and 43.94% in 2018. The forest land has fluctuated slightly but overall remains stable. The grassland area and proportion have shown a downward trend. The water-use land has increased somewhat. The construction land area and proportion have significantly increased, from 188,333.64hm<sup>2</sup> and 0.93% in 2,000 to 35,674.29hm<sup>2</sup> and 1.76% in 2018. The area and proportion of unused land have also increased.

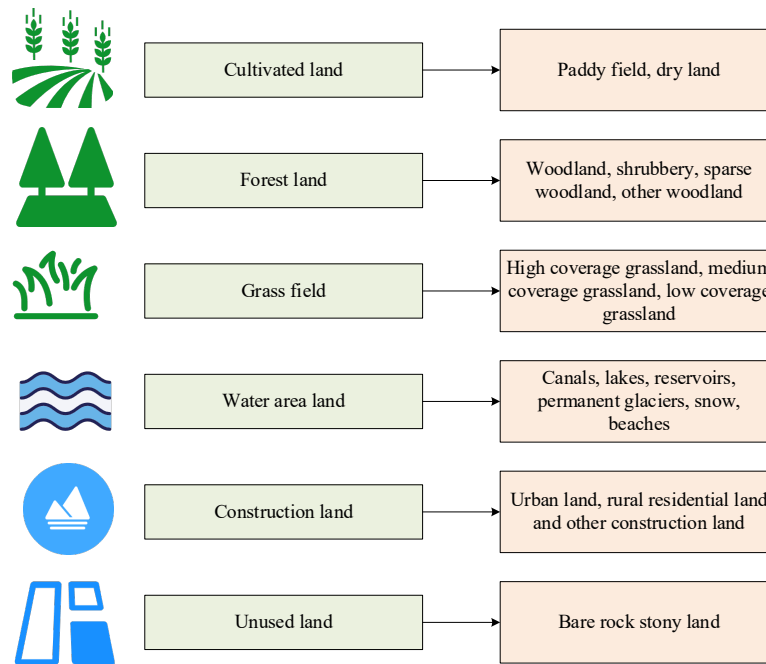


Fig. 5. Land classification in Sichuan Province

### 3. Results

This study examines the weights and scores of economic influencing factors in Sichuan Province and quantitatively assesses key risk factors, including resource consumption, ecological degradation, economic development, and social impact, using the AHP model. Additionally, it analyzes the trends in ecological occupation data and its structure and evaluates the potential influence of ecological occupation on the region’s sustainable economic development by combining time series data. By analyzing land classification in Sichuan Province, the study further uncovers the relationship between different land uses and ecological occupation, providing empirical insights into the specific role of ecological occupation in the regional economy.

#### 3.1. Analysis of Factors Influencing the Regional Economy of Sichuan

Table 3 presents the weights and scores of economic influencing factors in Sichuan. In Table 3, economic development factors, particularly GDP growth rate, employment rate, employment quality, and per capita income level, showed high weights of 0.0893, 0.0824, and 0.0839, respectively. This indicates that economic growth is a key driving force for regional sustainable development. The scores of these indicators were relatively high, at 90, 88, and 87. Sichuan Province has performed well in these areas. The weight of resource consumption and environmental pollution was low. However, the scores showed that there is still scope for improvement in these areas, especially in wastewater discharge and treatment rates, and solid waste generation and treatment rates, which were rated as 65 and 55, indicating the urgency of environmental pollution control. The weight and score of ecological degradation demonstrated the importance placed on ecological protection, with the highest score of 85 for changes in forest coverage, reflecting Sichuan Province’s achievements in ecological protection. Among the social influencing factors, the scores of residents quality of life index, employment rate, and employment quality were relatively high, at 82 and 88, respectively, indicating that social welfare is an important component of regional sustainable development. Overall, Sichuan Province has performed well in economic development and social welfare. However, further efforts are needed to reduce resource consumption and control environmental pollution to achieve more comprehensive sustainable development. Subsequently, a stability test is conducted on economic influencing factors in Sichuan Province, as presented in Table 4.

The stability of the economic influencing factors showed that the random consistency ratio for all criterion level factors was below 0.1, indicating acceptable weight consistency. The resource consumption weight change rate was 4.00%, with an average weight of 0.24, demonstrating that this factor has remained relatively stable across different iterations. The environmental pollution weight change rate was 5.00%, with an average weight of 0.19. Although slightly higher than resource consumption, it remains within an acceptable range. The ecological degradation weight change rate was 3.33%, with an average weight of 0.29, indicating the stability of this factor. The economic development weight change rate was the highest at 6.67%, but its average weight was 0.14. Despite fluctuations, its overall impact is limited. The social impact weight remained unchanged, with an average weight of 0.10, reflecting very high stability.

**Table 2.** Ecological occupation data and structure table of Sichuan Province

Land use type	2000 area /hm <sup>2</sup>	2000 ratio /%	2010 area /hm <sup>2</sup>	2010 ratio /%	2018 area /hm <sup>2</sup>	2018 ratio /%
Cultivated land	905,918.06	44.71	899,442.222	44.39	890,191.13	43.94
Forest land	754,746.62	37.25	755,757.06	37.30	755,139.40	37.27
Grassland	326,768.52	16.13	318,655.67	15.73	318,940.28	15.74
Water area	18,386.56	0.91	19,229.666	0.95	20,448.53	1.01
Construction land	188,333.64	0.93	27,543.02	1.36	35,674.29	1.76
Unused land	1,413.50	0.07	5,439.25	0.27	5,676.10	0.28

### 3.2. Analysis of the impact of ecological occupation on the regional economy in Sichuan

To demonstrate the correlation between ecological occupation and economic growth, relevant data from 2000 to 2020 are collected. Table 5 presents the results.

In Table 5, the GDP added from 1 trillion RMB in 2,000 to 2.2 trillion RMB in 2020, showing significant economic growth. However, the ecological occupation also grew from 800,000 hm<sup>2</sup> to 880,000 hm<sup>2</sup>, and the ecological occupation rate rose from 94.12% to 114.29%, indicating that the ecological occupation has exceeded the ECC. This growth pattern demonstrates a positive relationship between economic growth and ecological occupation, suggesting that it may come at the expense of the environment. While pursuing economic development, Sichuan Province must also prioritize ecological protection to prevent long-term negative impacts of ecological overload. To analyze how ecological occupation affects the industrial structure, the study gathers industrial structure data from 2000 to 2020, as presented in Table 6.

In Table 6, the proportion of the primary industry decreased from 20% in 2000 to 10% in 2020, while the secondary industry grew from 40% to 50%. The rise in ecological occupations shows a clear negative correlation with the decline in the primary industry, which may reflect the conversion of agricultural land into industrial or urban land. The tertiary industry remains relatively stable, highlighting the importance of the service sector. The increase in ecological occupations has noticeable impacts on the industrial structure of Sichuan Province, particularly on the primary industry, which could pose challenges to sustainable development and ecological balance. Table 7 presents the correlation analysis between ecological occupation and residents quality of life.

In Table 7, although the per capita income in Sichuan Province increased from 20,000 RMB in 2000 to 32,000 RMB in 2020, indicating a boost to residents economic status, the forest coverage rate and water resources quality index demonstrated a downward trend, from 35% to 31% and from 80 to 68. A clear negative correlation existed between the increase in ecological occupation and the decrease in forest coverage, as well as the decline in water resource quality index. This indicates that the increase in ecological occupation may have unfavorable effects on the living environment and the quality of residents lives. While pursuing economic growth, Sichuan Province needs to highlight ecological environment protection to ensure the continuous enhancement of resident’s quality of life. Table 8 presents the impact of ecological occupation on energy consumption.

In Table 8, from 2000 to 2020, Sichuan Province’s total energy consumption increased from 1 million tons to 1.8 million tons, whereas the energy consumption per 10,000 RMB of GDP dropped from 10 tons to 8 tons. Although the total energy consumption has increased, energy consumption per unit of GDP has declined, indicating an improvement in energy utilization efficiency. However, a positive correlation exists between the increase in ecological occupation and the rise in total energy consumption, which may reflect the increase in energy demand resulting from economic growth. While pursuing economic growth, Sichuan Province needs to further enhance energy utilization efficiency and lower energy consumption to achieve sustainable development goals.

In Table 9, from the perspective of regional sustainability, the ecological occupancy rate in Sichuan Province increased from 94.12% to 114.29% between 2000 and 2020, which was 9.88 percentage points higher than the national average ecological occupancy rate and significantly exceeded the global ecological security threshold. This indicates that the pressure on the ecosystem in Sichuan Province has exceeded the national average. Moreover, it has surpassed the fundamental threshold of ecological sustainability. In the long term, it will exacerbate problems such as land degradation and water

shortage and restrict the stability of economic growth. The Pearson correlation coefficients of ecological and economic indicators in Sichuan Province are shown in Table 10.

**Table 3.** Weight and scores of regional economic factors in Sichuan Province

Target layer	Criterion layer	Scenario level	Weights	Score
Sustainable development of regional economy	Resource consumption	Land resource occupancy rate	0.0653	75
		Water resource consumption	0.0625	70
		Energy consumption intensity	0.0545	80
		Resource utilization efficiency	0.0690	85
	Environmental pollution	Wastewater discharge and treatment rate	0.0378	65
		Exhaust gas emission and treatment rate	0.0112	60
		Solid waste generation and treatment rate	0.0475	55
		Pollutant emission intensity	0.0298	70
	Ecological degradation	Land degradation rate	0.0578	80
		Forest cover change	0.0432	85
		Biodiversity index	0.0312	75
		Soil erosion area	0.0232	70
	Economic development	GDP growth rate	0.0893	90
		Industrial structure optimization degree	0.0523	85
		Employment rate and quality of employment	0.0824	88
		Per capita income level	0.0839	87
	Social influence	Quality of life index	0.0523	82
		Equity of income distribution	0.0743	78
		Social stability index	0.0486	85

**Table 4.** Stability analysis of economic influencing factors in Sichuan Province

Criterion level factor	Initial weight	Average weight	Change rate (%)	Consistency index (CI)	Random consistency ratio (CR)
Resource consumption	0.25	0.24	4.00	0.05	0.08
Environmental pollution	0.20	0.19	5.00	0.04	0.07
Ecological degradation	0.30	0.29	3.33	0.06	0.10
Economic development	0.15	0.14	6.67	0.03	0.05
Social influence	0.10	0.10	0.00	0.02	0.03

**Table 5.** Correlation between ecological occupation and economic growth

A given year	GDP (10 billion RMB)	Ecological footprint (hm <sup>2</sup> )	Ecological capacity (hm <sup>2</sup> )	Ecological occupation rate (%)	Construction land area (10,000 hm <sup>2</sup> )	Forest coverage (%)	Soil erosion area (10,000 hm <sup>2</sup> )
2000	10.0	800,000	850,000	94.12	100.00	35.00	50.00
2002	11.0	810,000	845,000	95.86	105.00	35.20	49.00
2004	12.0	820,000	840,000	97.62	110.00	35.50	48.00
2006	13.0	830,000	835,000	99.39	115.00	35.80	47.00
2008	14.0	840,000	830,000	101.20	120.00	36.00	46.00
2010	15.0	850,000	820,000	103.66	125.00	36.20	45.00
2012	16.0	860,000	815,000	105.52	130.00	36.50	44.00
2014	17.0	870,000	805,000	108.07	135.00	36.80	43.00
2016	18.0	880,000	795,000	110.69	140.00	37.00	42.00
2018	19.0	890,000	785,000	113.37	145.00	37.20	41.00
2020	22.0	900,000	770,000	116.88	150.00	37.50	40.00

**Table 6.** The impact of ecological occupation on industrial structure

A given year	Primary industry (%)	Secondary industry (%)	Tertiary industry (%)	Industrial value added as a percentage of GDP (%)	Agricultural ecological occupation rate (%)	Industrial ecological occupation rate (%)
2000	20	40	40	35	30.0	60.0
2002	19	41	40	36	29.0	61.0
2004	18	42	40	37	28.0	62.0
2006	17	43	40	38	27.0	63.0
2008	16	44	40	39	26.0	64.0
2010	15	45	40	40	25.0	65.0
2012	14	46	40	41	24.0	66.0
2014	13	47	40	42	23.0	67.0
2016	12	48	40	43	22.0	68.0
2018	11	49	40	44	21.0	69.0
2020	10	50	40	45	20.0	70.0

**Table 7.** Correlation analysis between ecological occupation and residents' quality of life

A given year	Per capita income (RMB)	Forest coverage (%)	Water resources quality index	Ecological footprint (hm <sup>2</sup> )	Days with good air quality (days)	Urban green space (m <sup>2</sup> /person)	Domestic waste disposal rate (%)
2000	20,000	35.0	80	800,000	280	8.0	70.0
2002	21,000	34.8	79	810,000	278	8.2	72.0
2004	22,000	34.5	78	820,000	276	8.4	74.0
2006	23,000	34.2	77	830,000	274	8.6	76.0
2008	24,000	33.8	76	840,000	272	8.8	78.0
2010	25,000	33.0	75	850,000	270	9.0	80.0
2012	26,000	32.5	74	860,000	268	9.2	82.0
2014	27,000	32.0	73	870,000	266	9.4	84.0
2016	28,000	31.5	72	880,000	264	9.6	86.0
2018	29,000	31.0	71	890,000	262	9.8	88.0
2020	32,000	31.0	68	900,000	260	10.0	90.0

**Table 8.** The impact of ecological occupation on energy consumption

A given year	Total energy consumption (10,000 tons of standard coal)	Energy consumption per unit of GDP (tons of standard coal / 10,000 RMB)	Ecological footprint (hm <sup>2</sup> )	Energy mix (coal %)	Energy mix (oil %)	Energy mix (natural gas %)	Energy mix (renewable energy %)	Energy intensity improvement rate (%)
2000	100	10.0	800,000	60	20	15	5	0.0
2002	105	9.8	810,000	59	21	16	6	2.0
2004	110	9.6	820,000	58	22	17	7	4.0
2006	115	9.4	830,000	57	23	18	8	6.0
2008	120	9.2	840,000	56	24	19	9	8.0
2010	140	9.0	850,000	55	25	20	10	10.0
2012	145	8.8	860,000	54	26	21	11	12.0
2014	150	8.6	870,000	53	27	22	12	14.0
2016	155	8.4	880,000	52	28	23	13	16.0
2018	170	8.2	890,000	51	29	24	14	18.0
2020	180	8.0	900,000	50	30	25	15	20.0

**Table 9.** Comparison of Ecological Occupation Rate between Sichuan Province and the Whole Country from 2000 to 2020

Year	Ecological occupancy rate in Sichuan Province (%)	National ecological occupancy rate (%)
2000	94.12	89.50
2005	98.75	93.20
2010	103.66	97.80
2015	109.23	101.50
2020	114.29	105.00

**Table 10.** Pearson Correlation Coefficient of Ecological-Economic Indicators in Sichuan Province

Indicators	Ecologically occupied area	Proportion of secondary industry	Forest coverage rate	Energy consumption per unit of GDP
Ecologically occupied area	1.00	/	/	/
Proportion of secondary industry	0.89**	1.00	/	/
Forest coverage rate	-0.76*	-0.68*	1.00	/
Energy consumption per unit of GDP	-0.62*	-0.55	0.48	1.00

Note: \*\* stands for  $p < 0.01$ , \* stands for  $p < 0.05$ , and / stands for no significant correlation

The comparison of ecological occupation rates between Sichuan Province and the rest of the country from 2000 to 2020 is presented in Table 9.

In Table 10, through Pearson correlation analysis, it was found that the ecological occupied area was actively correlated with the proportion of the secondary industry ( $r=0.89, p<0.01$ ) and negatively correlated with the forest coverage rate ( $r=-0.76, p<0.05$ ), confirming the encroachment effect of industrial expansion on ecological space. However, the energy consumption per unit of GDP was negatively correlated with the ecological occupation rate ( $r = -0.62, p < 0.05$ ), indicating that improving energy efficiency has a specific effect on alleviating ecological pressure. However, it is insufficient to offset the increase in ecological occupation brought about by economic growth.

#### 4. Conclusion

To quantitatively assess the impact of ecological occupation on the regional economy in Sichuan Province and propose corresponding optimization strategies, a multi-criteria decision-making model based on AHP was used to analyze key factors such as resource consumption, environmental pollution, and ecological degradation. The ecological occupation rate in Sichuan increased from 94.12% in 2000 to 114.29% in 2020, surpassing the ECC, suggesting that economic growth may damage the ecological environment. Particularly in terms of energy consumption, although the energy consumption per 10,000 RMB decreased from 10 tons in 2000 to 8 tons in 2020, indicating improved energy efficiency, total energy consumption increased from 1 million tons to 1.8 million tons, reflecting increased energy demand driven by economic growth. Regarding land resource occupation, the area of cultivated land used ecologically declined from 905,918.06 hm<sup>2</sup> in 2000 to 890,191.13 hm<sup>2</sup> in 2018, a decrease of 1.61%, while the construction land increased from 188,333.64 hm<sup>2</sup> to 355,674.29 hm<sup>2</sup>, an increase of about 89.4%. This change demonstrates evolving land use patterns amid urbanization. Analyzing water resource consumption, wastewater discharge, and treatment rates shows that although treatment rates have improved, emissions are increasing at a faster pace, which could threaten sustainable water resource use. In summary, while Sichuan Province experiences economic growth, it must place greater emphasis on ecological protection and rational resource utilization to avoid long-term adverse effects caused by ecological overload.

In regional development practice, land use planning should be optimized based on ecological occupation data, such as cultivated land and construction land. Rigid ecological protection red lines should be delineated, and disorderly construction land should be strictly controlled. The proportion of cultivated land and ecological space should be maintained at a stable level. Industrial policies should be oriented towards low consumption and high output, increasing support for energy conservation and environmental protection industries, transforming and upgrading high energy-consuming industries, and incorporating the target of reducing energy consumption per unit of GDP into local assessment indicators. A cross-regional ecological compensation mechanism is established, where the ecological benefit areas share the ecological protection costs with the protected areas. Through means such as fiscal transfer payments and market-based transactions of ecological products, we balance the interests between economic development and ecological protection, which aligns with the expected requirements of coordinated regional development.

The research incorporates the weights of indicators, such as resource consumption and ecological degradation, obtained through AHP into a Geographic Information System (GIS) spatial analysis to generate an ECC distribution map, marking areas with high ecological pressure corresponding to the high-weight indicators. Meanwhile, the AHP weight was incorporated as a constraint condition to predict the ECC. Under the scenario of coordinated development, the ecological occupancy rate could be reduced to 108%, approaching the national threshold and overcoming the limitations of traditional single-method approaches. The framework constructed by the research provides replicable analysis tools for the ecologically sensitive areas in the upper reaches, solving the disconnection problem between weight calculation and spatial simulation. The proposed zonal governance plan and scenario prediction provide a quantitative basis for revising Sichuan's "14th Five-Year Plan" ecological planning. It is recommended that the land degradation rate identified by AHP be incorporated into the assessment of cities and prefectures. Quantify the relationship between ecological occupation and economic growth, verify that ecological priorities do not hinder economic development, provide empirical evidence for resolving the contradiction between protection and development, and promote the transformation of governance towards data-driven governance. The research has limitations, such as not considering social and cultural factors, and the predictive ability of the model needs to be verified. In the future, more socioeconomic data need to be supplemented to deeply explore the interaction mechanism between ecological occupation and regional economy, providing scientific support for formulating more effective ecological protection and economic development policies.

Although the research focused on Sichuan Province, the integrated framework and core conclusions constructed can be adapted and extended to global scenarios. In terms of domain application, in agriculture-dominated areas, such as paddy fields in Southeast Asia, the weight of cultivated land ecological occupation can be replaced by the coefficient of farmland ecological service value. Meanwhile, in industrial-intensive areas, such as the Ruhr region in Germany, the weight of industrial energy consumption intensity indicators can be strengthened in ecologically sensitive areas (such as the Congo Basin in Africa). The focus should remain on GIS visualization of the biodiversity index. At the national adaptation level, developing countries (such as India and Brazil) can draw on the idea of ecological compensation and economic synergy, and adjust parameters in combination with population density to alleviate the ecological pressure of urbanization. Developed countries (such as EU member states) can integrate into the carbon neutrality goal and analyze energy consumption per unit of GDP, coupled with the research on carbon emission intensity and ecological occupation. At the same time, relying on global ECC databases (such as the United Nations "Global Ecological Footprint Report"), efforts are made to promote global sustainable governance solutions.

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## Institutional Review Board Statement

Not applicable.

## Declaration of Artificial Intelligence (AI) Tools

The authors used tools solely for language editing and readability improvement. The authors reviewed and verified all content and take full responsibility for the accuracy and integrity of the manuscript.

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