Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 2349-2362
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

Exploring the Coordinated Development of Ecological Environment and Economy in Jiangxi Province, China

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Abstract:

This study constructed a set of indexes to evaluate the coordination levels of ecological environment and economy using entropy weight method and adopted the 11 cities of Jiangxi Province, China as a case. The results show that: (1) There was a general increasing trend in the levels of economic development of the 11 cities of Jiangxi from 2004 to 2018 characterized by low fluctuation, slow growth, and favorable stability. (2) The comprehensive evaluation of the ecological environment from 2004 to 2018 showed downward fluctuating trends followed by gradual upward trends with slow growth and poor stability. However, most cities have experienced decreasing levels of ecological environment in recent years. (3) The coordinated development of ecological environment and economy remained stable with rising fluctuations from 2004 to 2018. Although coupling moved toward a generally sound and coordinated state, several cities experienced downward trends. Coupling coordination levels also manifested as moderate imbalance, mild imbalance, imbalance, coordination, and basic coordination. The coupling coordination degrees of different cities were characterized by high-value-centered clustered development with a moderate coupling coordination degree and clear differences in spatial distribution. Meanwhile, the factors constraining coupling and coordinated developments of different cities included the lagging economy and the lagging ecological environment. The present study demonstrated that Jiangxi should adhere to the principles of green development, actively develop advantageous industries, and attach great importance to the governance of the ecological environment.

***Keywords**: Ecological environment, Economy, Coupling coordination model, Jiangxi.*

I. INTRODUCTION

The ecological environment and economy influence and restrict each other, and their coordinated development has a profound impact on the sustainability of long-term regional development. Rapid economic development has resulted in a series of ecological problems, including resource constraints, serious environmental pollution, and ecosystem degradation, which have constrained regional economic development. Studies on the interaction and coordination between ecological environment and economic development have become increasingly important given the need for realizing green sustainable development and for constructing a prosperous society [1]. There have been various studies on the relationship between ecological environment and economic development. A typical example is the Environmental Kuznets Curve (EKC) hypothesis, which states that the relationship between ecological environment and economic development follows a ∩-shaped trend [2]. Subsequently, many studies have attempted to provide theoretical or policy explanations for EKC from different perspectives. These studies have also confirmed the relationship between economic growth and environmental quality described by the evolutionary EKC hypothesis in different countries or regions through empirical studies [3-5]. There have been recent studies on the relationship [6-7] between economic development and the ecological environment, the influencing factors [8], evaluation of the coupling coordination [9-10], the regulation path [11], and other aspects. Among those studies, many models have been proposed to evaluate the coupling coordination between economic development and the ecological environment, such as the coupling coordination degree model [12-13], principal component analysis model [14], grey relation model [15], pressure-state-response (PSR) model [16], structural equation model [17], and scissors difference analysis [18] etc. There have been some studies on the degree and evolution of coordinated development of ecological environment and economy [19] by combining the static coupling coordination degree model and dynamic coupling process analysis. These studies have been of great significance for revealing the coordinated relationship between ecological environment and economy. However, many past studies were based on subjective indexes, and there remains a need for further study based on objective indicators [8,15].

Jiangxi Province acts as an important ecological buffer zone in southern China and a national ecological civilization pilot zone. However, Jiangxi is currently facing two major interrelated challenges: economic development and protection of ecological environment. Therefore, studies on the coordinated development of ecological environment and economy in this region are of significance from both research and practical standpoints. The present study aimed to explore the coordinated development of ecological environment and economy via coupling coordination degree model and propose suggestions for realizing coordinated development of ecological environment and economy in Jiangxi.

II. STUDY AREA AND DATA SOURCES

2.1 Study Area

The 11 cities of Jiangxi Province collectively achieved a GDP of 2,475.75 billion yuan in 2019, up 8.0% on the previous year. The added value of the tertiary industry of Jiangxi Province was 1,176.01 billion yuan, up 9.0% on the previous year. The industrial structure of Jiangxi Province is recognized as reasonable and its optimization and upgrade have achieved remarkable results. The total investment in protection of ecological environment in Jiangxi exceeded 80 billion yuan in 2019, representing an average annual growth of 15.6%. Consequently, the area of green land in the province increased by 2,400 ha, representing a proportional increase of 43.69%. The increase in area of green land included the construction of 701 green parks with a cumulative area of 7,558.92 ha and a per-capita green park area of 14.86 m^2, as well as the construction of 543 km of green roads and green corridors in urban areas. In

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addition, the area of protected wetlands reached 541,000 ha, with 59.45% of wetlands protected. Consequently, Jiangxi currently hosts 190, 182, and 99 natural reserves, forest parks, and wetland parks, respectively, ranking among the highest in China.

2.2 Data Sources

The present study focused on the period of 2004 to 2018. Data on ecological environment and economy were obtained mainly from the China Statistical Yearbook, Jiangxi Statistical Yearbook, Jiangxi Statistical Bulletin on National Economic and Social Development, and Jiangxi Statistical Bulletin on Water Resources for the period 2005 to 2019.

III. RESEARCH METHOD

3.1 Construction of the Evaluation Index System

The comprehensive index system of ecological environment and economy in the current study is composed of an economic system and an ecological environment system. The present study developed the index system by comprehensively considering the availability of data from previous studies [1,8], following a systematic process, representativeness, and operability. First, the current study selected 38 indexes of ecological environment and economy through a literature review. Representative indexes were then selected through a questionnaire survey. Finally, 27 indexes of the coordinated development of ecological environment and economy were identified to construct a scientific evaluation index system for Jiangxi, see TABLE I. Within the index system, 14 indexes were related to the economic development system and 13 indexes were related to the ecological environment system.

The various indexes showed positive and negative orientations and different dimensions and dimensional units. Therefore, the present study used the range method to standardize the various indexes. The processing methods were as follows:

$$\text{Positive indicator: } Xij = \frac{\mathrm{xij} - \min(\mathrm{xij})}{\max(\mathrm{xij}) - \min(\mathrm{xij})} \tag{1}$$

$$\text{Negative indicator: } Xij = \frac{\max(xij) - xij}{\max(xij) - \min(xij)} \tag{2}$$

In Eq. (1) and Eq. (2), xij is the original value of the jth index in the ith city, $\max(xij)$ and $\min(xij)$ are the maximum and minimum values of the jth index respectively, and Xij is the corresponding standardized value with a range of [0, 1].

The present study conducted translation processing for the standardized data to eliminate the influence of the value 0 after standardization, making $bij = Xij + 0.001$. On this basis, the entropy weight method was used to determine the weight of each index:

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$$pij = bij / \sum_{i=1}^{m} bij \tag{3}$$

$$ej = -\frac{1}{lnm} \sum_{i=1}^{m} pij * lnpij \tag{4}$$

$$wj = \frac{1-ej}{\sum_{j=1}^{n} 1-ej} \tag{5}$$

In Eq. (3) to Eq. (5), ej is the information entropy of the jth index, $1-ej$ is the coefficient of variation of the jth index, m is the number of evaluated objects, n is the number of indexes, and wj is the weight of the jth index.

Table I. Evaluation indexes of ecological environment and economy

Object	Criterion	Index	Unit	Attribute
Economy	Scale	Regional GDP	100 million CNY	+
		Fiscal revenue	10 thousand CNY	+
		Fixed asset investment	10 thousand CNY	+
		Retail sales of consumer goods	10 thousand CNY	+
		Savings deposits of urban and rural residents	10 thousand CNY	+
	Structure	Proportion of tertiary industry output value in GDP	%	+
		Added value of industrial enterprises above designated size	10 thousand CNY	+
		Proportion of tertiary industry working population	%	+
	Benefit	Per-capita disposable income of urban residents	CNY	+
		Per-capita net income of rural residents	CNY	+
		Number of employed people	10 thousand	+

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		Number of hospital beds for 10,000 people	/	+
		Proportion of government revenue in GDP	%	+
		Per-capita GDP	CNY	+
Ecological environment	Resource	Garden green space area	hectare	+
		Per-capita park green space area	m^2	+
		Water supply	100 million m^3	+
		Park green space area	hectare	+
		Total amount of water resources	100 million m^3	+
	Pressure	Industrial wastewater emission	10 thousand tons	-
		Urban sewage emission	10 thousand m^3	-
		Industrial sulfur dioxide emission	Ton	-
		Per-capita daily domestic water consumption of urban residents	liter	-
		Usage of agricultural plastic film	ton	-
	Protection	Capacity of wastewater treatment facilities	10 thousand tons per day	+
		Volume of domestic garbage	10 thousand tons	+
		Green coverage rate of urban areas	%	+

3.2 Coupling Coordination Degree Model

Coupling is a concept that originates from physics and is used to analyze the phenomenon under which two or more systems coordinate within their interaction. However, coupling cannot accurately and objectively reflect the integrated level of coordinated development between systems. Therefore, the present study used the coupling coordination degree to measure the degree of interaction between ecological environment and economy:

$$C=\left\{\frac{f(X)\times f(Y)}{[f(X)+f(Y)][f(X)+f(Y)]}\right\}^{\frac{1}{2}} \quad (6)$$

$$T=\alpha f(X)+\beta f(Y) \quad (7)$$

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$$D = \sqrt{C \times T} \tag{8}$$

In Eq. (6) to Eq. (8), C is the degree of coupling with a range of [0, 1], with the value of C *proportional to* the degree of coupling and the interconnectedness of the systems, $f(X)$ and $f(Y)$ are the indexes of economic development and ecological environment, respectively, k is the adjustment coefficient (assigned a value of 2), T is the comprehensive evaluation index of ecological environment and economy system, and α and β are undetermined coefficients. Since economic development and ecological environment are assigned equal importance, $\alpha = \beta = 0.5$. D is coupling coordination degree, with a value proportional to the level of coordinated development of economy and environment ($0 \leq D \leq 1$). The category of coupling coordination was determined according to previous studies [20], see TABLE II.

TABLE II. Category of coupling coordination degree

coupling coordination degree	Category of coupling coordination	coupling coordination degree	Type of coupling coordination
0–0.09	Extreme imbalance	0.5–0.59	Coordination
0.1–0.19	Serious imbalance	0.6–0.69	Basic coordination
0.2–0.29	Moderate imbalance	0.7–0.79	Moderate coordination
0.3–0.39	Mild imbalance	0.8–0.89	Good coordination
0.4–0.49	Imbalance	0.9–1	High quality coordination

IV. RESULTS AND ANALYSIS

4.1 Analysis of the Comprehensive Evaluation

4.1.1 Comprehensive Evaluation of Economic Development

As shown in Fig. 1, the overall economic development levels of all cities in Jiangxi Province from 2004 to 2018 showed favorable upward trends with small fluctuations, relatively slow growth rates, and good stability. A large gap between Nanchang and the other cities remained by the end of 2018, indicating that Nanchang showed a large lead in overall level of economic development. Nanchang showed the highest level of economic development every year during the study period, with an evaluation value of 0.81 in 2004 increasing to 0.917 in 2018. The fastest increase of Nanchang's economic development was during 2004–2005, after which the rate of increase was relatively low. Ganzhou showed the second highest overall level of economic development, showing a stable growth over the past 15 years. Jiujiang and

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Shangrao were ranked third and fourth, respectively. The economic levels of Fuzhou and Yingtan were relatively low, mainly coming last and second-last among the cities.

Nanchang experienced huge economic advantages as the capital city of Jiangxi Province with the government attaching great importance to the economic development of Nanchang and constantly implementing reform measures and positive countermeasures. The level of economic development of Ganzhou followed closely that of Nanchang. The levels of development of the remaining cities were relatively similar, ranging between 0.1-0.4.

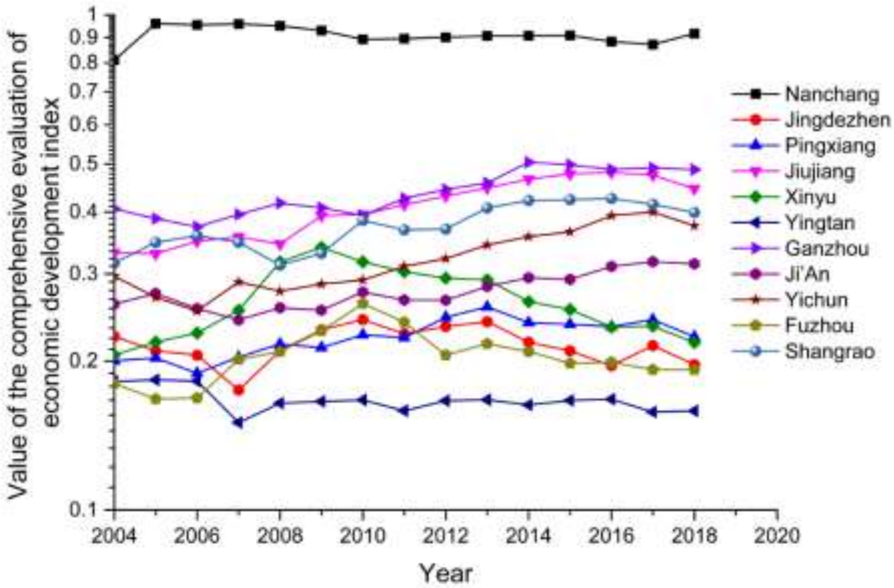

Fig. 1: Comprehensive evaluation of economic development in Jiangxi Province

4.1.2 Comprehensive Evaluation of Ecological Environment

As shown in Fig. 2, the comprehensive evaluation of the ecological environment of cities in Jiangxi Province from 2004 to 2018 showed gradually increasing trends after a fluctuating decreasing trend, characterized by a slow development speed and poor stability. The levels of the ecological environment of most cities have gradually decreased in recent years.

Nanchang, Jiujiang, Ganzhou, and Yingtan showed relatively low levels of development of ecological environment from 2004 to 2018. More specifically, the development level of ecological environment of Nanchang exceeded that of the other cities, with this gap gradually narrowing. The value of the ecological environment evaluation index increased from 0.638 in 2004 to 0.647 in 2018. Yingtan showed a relatively low level of ecological environment development with values of 0.226 in 2004 increasing to 0.236 in 2018.

Most cities showed relatively low levels of comprehensive development of the ecological environment. For example, the ecological environment evaluation index values of Jingdezhen, Pingxiang, Xinyu,

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Yingtan, JiAn, Yichun and Fuzhou were below 0.5 from 2004 to 2018. Although the level of ecological environment evaluation index of each city showed variations over time, each city showed an inverted U-shaped Environment Kuznets Curve trend in development of the ecological environment. The ecological environments of these cities experienced damage during the period prior to the study period due to the extensive economic growth mode, resulting in declines in the ecological environment evaluation index. However, subsequent adjustments of economic structure and the continuous strengthening of environmental protection efforts resulted in increases in the quality of the ecological environment and a concurrent fluctuating increases in the ecological environment evaluation index. Subsequent to the implementation of measures to protect the ecological environment, there were moderate increases in the levels of ecological environment in Jiangxi Province. This result can be attributed to protection and restoration of the ecological environment being a long-term project that requires large investments in human and material resources. Since many governments and companies still regard efforts to protect the ecological environment to be counterproductive to economic development, the levels of development of the ecological environment in the 11 cities in Jiangxi Province remain low.

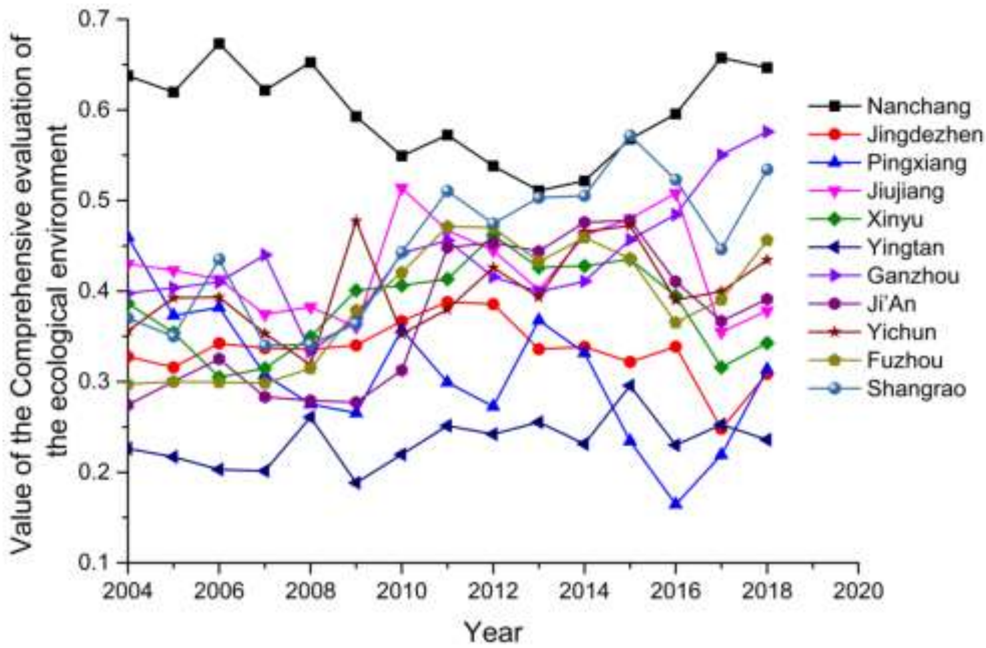

Fig. 2: Comprehensive evaluation of ecological environment in Jiangxi Province

4.2 Temporal and Spatial Analysis of the Coordinated Development

4.2.1 Temporal evolution of the coordinated development

The spatiotemporal evolution of the coordinated development between ecological environment and economy reflects its complexity. As shown in Fig. 3, the present study analyzed the temporal changes in the of coupling coordination degrees from 2004 to 2018 to reveal the characteristics of changes to the stages of coordinated development between ecological environment and economic development in Jiangxi

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Province.

In general, the results indicated a development pattern moving towards benign coordination with gradual growth, although some cities showed relative downward trends. Nanchang, Ganzhou, and JiAn showed the highest increases in coupling coordination degrees. More specifically, the coupling coordination degree of Nanchang increased from coordination to basic coordination, that of Ganzhou increased from imbalance to coordination, and that of Ji'An increased from mild imbalance to imbalance. At the same time, the coupling coordination degree of Xinyu decreased from imbalance to mild imbalance from 2004 to 2018. Jingdezhen, Pingxiang, Yingtan, and Fuzhou all fell within the category mild imbalance, whereas those of Jiujiang, Yichun, and Shangrao fell within the category imbalance.

Nanchang was the only city to reach a coordinated state in 2004 with the highest level of 0.599. Cities that fell within the mild imbalance category were Jingdezhen, Pingxiang, Xinyu, Yingtan, JiAn, and Fuzhou, while Jiujiang, Ganzhou, Yichun, and Shangrao fell within the imbalance category. In 2018, Nanchang and Ganzhou fell within the basic coordination and coordination categories, respectively. Jingdezhen, Pingxiang, Yingtan, and Fuzhou fell within the mild imbalance category, whereas Jiujiang, Yichun, and Shangrao fell within the imbalance category. Although Nanchang and Ganzhou fell within the coordinated category, their levels of coordinated development do not exceed 0.7, indicating the need for further improvement. While the levels of economic development of the cities gradually increased, the levels of the ecological environment showed fluctuating trends during this period.

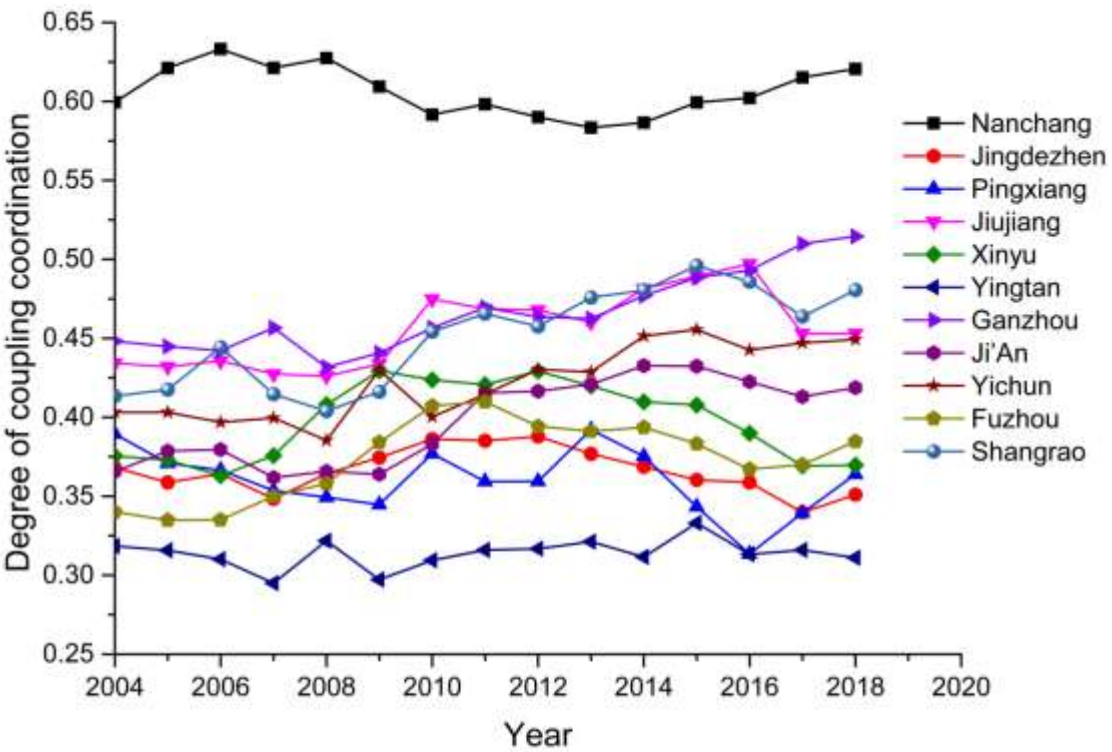

Fig. 3: Temporal evolution of the coordinated development

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4.2.2 Spatial evolution of the coordinated development

As shown in Fig. 4, the present study visualized the level of coupling coordination between ecological environment and economic development in Jiangxi Province in 2004, 2011, and 2018 using ArcGIS10.2 software. This allowed the changes in the coupling coordination degree between ecological environment and economic development to be further revealed.

The coupling coordination degree of ecological environment and economic development in 2004 could be placed into three levels: mild imbalance, imbalance and coordination. Areas showing mild imbalance were mainly distributed in Jingdezhen, Pingxiang, Xinyu, Yingtan, JiAn, and Fuzhou, whereas those showing imbalance were mainly distributed in Jiujiang, Ganzhou, Yichun, and Shangrao. Areas showing coordination were only noted in Nanchang.

In 2011, there were slight changes in the spatial distribution pattern. More specifically, the number of cities falling within the imbalance state increased and the spatial distribution pattern of areas showing mild imbalance changed from aggregation to dispersion. In other words, the coupling coordination degrees of Xinyu, JiAn, and Fuzhou evolved into an imbalance state. In general, the difference in spatial distribution of the coupling coordination degree of ecological environment and economic development in Jiangxi Province gradually narrowed and the overall degree of regional coupling coordination was relatively low.

The coupling coordination degree between environment and economy in Jiangxi Province in 2018 evolved into four levels: mild imbalance, imbalance, coordination and basic coordination. Compared with 2011, the coupling coordination degrees of Xinyu and Fuzhou returned to mild imbalance and the number of cities in the imbalance state was further reduced. Ganzhou transitioned from an imbalance state to a coordinated state and Nanchang transitioned from a coordination state to a basic coordination state.

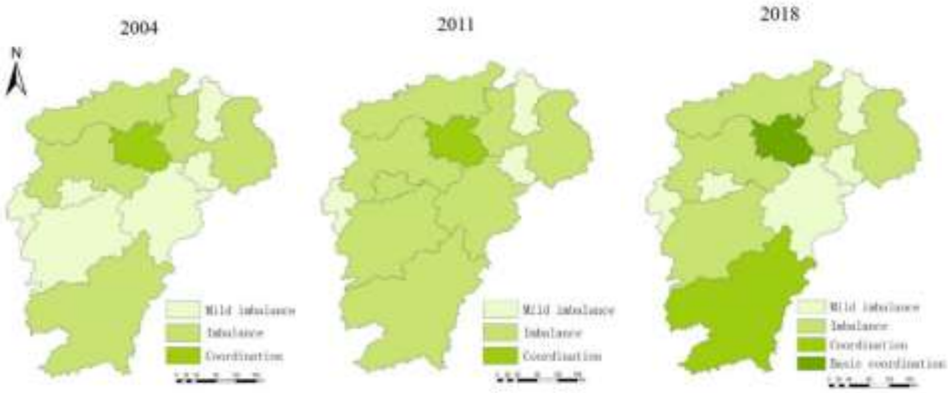

Fig. 4: Spatial distribution of the coupling coordination degree

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In general, the coupling coordination degrees of the 11 cities showed high-value-centered clustered development with relatively low coupling coordination degrees and clear differences in spatial distribution. Only Nanchang and Ganzhou were in a coordinated state by 2018. Since Nanchang is the capital city of Jiangxi Province, it received a good foundation of economic development, characterized by developed secondary and tertiary industries, developed infrastructure, convenient transportation, and a high level of economic development. The strong economic development of Nanchang has provided economic support for the maintenance of the ecological environment. Meanwhile, policy support by government and a focus on the ecological environment has resulted in good synchronization between environment and economy, translating to a high coupling coordination degree.

TABLE III shows the mean evaluation values of ecological environment and economic development and coupling coordination degrees. The results showed that the factors restricting the coupling and coordinated development could be divided into two types. The first type was the "economy lagging" type including Jingdezhen, Pingxiang, Jiujiang, Xinyu, Yingtan, JiAn, Yichun, Fuzhou and Shangrao. Within these cities, the contribution of ecological environment to economic development exceeded that of economic development to ecological environment. The second type was the "ecological environment lagging" type, including Nanchang and Ganzhou. Within these cities, the contribution of economic development to ecological environment exceeded that of ecological environment to economic development.

TABLE III. Mean values of ecological environment, economy and coupling coordination degree

District	Evaluation value of economic development	Evaluation value of ecological environment	Comprehensive evaluation value	coupling coordination degree	Category	Major restraining factor
Nanchang	0.910	0.597	0.753	0.607	Basic coordination	Ecological environment lagging
Jingdezhen	0.217	0.335	0.276	0.367	Mild imbalance	Economy lagging
Pingxiang	0.224	0.308	0.266	0.360	Mild imbalance	Economy lagging
Jiujiang	0.409	0.426	0.417	0.456	Imbalance	Economy lagging
Xinyu	0.266	0.382	0.324	0.398	Mild imbalance	Economy lagging
Yingtan	0.168	0.234	0.201	0.314	Mild imbalance	Economy lagging
Ganzhou	0.438	0.436	0.437	0.466	Imbalance	Ecological environment

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						lagging
JiAn	0.278	0.368	0.323	0.398	Mild imbalance	Economy lagging
Yichun	0.322	0.400	0.361	0.422	Imbalance	Economy lagging
Fuzhou	0.205	0.386	0.295	0.374	Mild imbalance	Economy lagging
Shangrao	0.375	0.447	0.411	0.451	Imbalance	Economy lagging

V. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The present study constructed the evaluation index system and adopted the entropy weight method and coupling coordination degree model to analyze the levels of coupling and coordinated development of economy and environment of the 11 cities of Jiangxi Province in 2004-2018. The following conclusions can be drawn:

First, the levels of economic development of different cities of Jiangxi Province generally showed clear rising trends with small fluctuations, gradual growth rates, and good stability. Nanchang showed an overall higher level of economic development, resulting in a considerable gap between Nanchang and the other cities by 2018.

Second, The results of the comprehensive evaluation of the ecological environment of the cities of Jiangxi Province showed a trend of an initial fluctuating decline followed by a gradual rise, characterized by slow development and poor stability. The levels of ecological development in most cities have gradually decreased in recent years.

Third, The coupling coordination development of ecological environment and economy of different cities of Jiangxi Province during 2004-2018 was characterized by an increasing trend with fluctuations and stability with a low growth rate. However, some cities showed downward trends. Five levels of coupling coordination were identified: moderate imbalance, mild imbalance, imbalance, coordination and basic coordination. The coupling coordination degrees of different cities featured high-value-centered clustered development with moderate coupling coordination degrees and clear differences in spatial distribution. Only Nanchang and Ganzhou were in a coordinated state by 2018. Meanwhile, there were differences in the factors restraining the coordinated development. Nanchang and Ganzhou were the "ecological environment lagging" type, whereas the other 9 cities were the "economy lagging" type.

5.2 Recommendations

First, adhere to green development. Jiangxi Province is currently experiencing a critical period of accelerated economic development. Since economic development should be sustainable, there should be a focus on green development. Economic growth and protection of ecological environment should be promoted in a holistic way to obtain optimal trade-offs. Meanwhile, the technological innovation of enterprises can be fully mobilized to drive the innovative development of ecological and environmental conservation industry. The advantages of Nanchang as a provincial capital city should be fully exploited to actively promote integration between Nanchang and Jiujiang and between Nanchang and Fuzhou to drive the development of neighboring cities.

Second, actively develop competitive industries. Jiangxi is a province with a scenic ecological environment and many tourist attractions. The natural assets of Jiangxi are considerable and should be branded and marketed. Realizing the coordinated development of the ecological environment and economy requires full use of its industrial advantages while sustainably make use of environmental resources. In addition, the ecological environment advantages of Jiangxi and the considerable national supporting policy can be translated into industrial advantages to promote economic development.

Third, attach great importance to governance of ecological environment: The rapid economic development of cities of Jiangxi has had inevitable effects on ecological environment. The results of the present study showed that the level of the ecological environment fluctuated with slow development and poor stability. Therefore, there should be sufficient focus on the negative impacts resulting from a low level of ecological environment. Green development should be promoted in Jiangxi and the policy of the "transformation of green mountains into gold and silver mountains" should be accelerated. More specifically, further efforts should be made to combat pollution, set out planning boundaries, promote innovation in systems and mechanisms, properly manage the conservation and restoration of the ecological environment, and promote the modernization of governance of the ecological environment.

ACKNOWLEDGEMENTS

This research was funded by the Humanities and Social Sciences Project of Education Ministry of the People's Republic of China (Grant No. 20YJA630023) and the Science and Technology Project of Jiangxi Provincial Department of Education (Grant No. GJJ170997).

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