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The Spatiotemporal Coupling and Coordination of Rural Labor Transfer and Agricultural Ecological Environment of Counties in Anhui

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Abstract: From the perspective of spatiotemporal evolution, this article constructs an evaluation system for the coupling coordination between labor transfer and agricultural ecological environment. The coupling coordination model is used to explore the spatiotemporal coupling coordination between rural labor transfer and agricultural ecological environment in Anhui from 2015 to 2017. The results showed that the ecological environment level in Anhui is gradually increasing and showing a trend of shifting towards southern county towns; The spatial distribution of labor force transfer shows a stable state, with each urban area as the main agglomeration area, and forming agglomeration areas in surrounding counties; From 2015 to 2017, the annual average coupling degree was close to 0.9, indicating good coordination. However, the annual average coupling coordination was on the rise, but it has been in a moderate imbalance.

Keywords: Rural Labor Transfer; Agricultural Ecological Environment; Spatiotemporal Coupling.

1. Introduction

In the report of the 19th National Congress of the Communist Party of China, Xi Jinping proposed to implement the strictest ecological environment protection system and form a green development and lifestyle. Agricultural development is closely related to the ecological environment, and strengthening agricultural greening plays a significant role in protecting the ecological environment. Anhui has a superior geographical location and abundant agricultural resources, making it a major province for grain cultivation and production. It plays a crucial role in ensuring the production and supply of agricultural products. In recent years, with the development of the economy and the improvement of agricultural production efficiency, more and more surplus rural labor force has been transferred to cities and towns. However, problems such as pesticide abuse and ecological environment pollution are inevitable in the process of rural labor transfer, which lead to problems such as poor agricultural production quality and declining agricultural environment. Therefore, coordinating the development of agricultural ecological environment in the process of rural labor transfer is the primary task of agricultural development in Anhui.

Currently, there have been many studies on the coupling and coordination between agricultural ecological environment and labor transfer. Wang Guogang et al. [1] analyzed the patterns and regulatory strategies of labor transfer in the process of urbanization in coastal areas from the perspective of time, space, form, and power. Song Yongyong et al. [2] used comprehensive evaluation index and coupling coordination model to measure the coupling between ecological environment and economy in Ningxia from 1990 to 2012, and the results showed an overall upward trend of fluctuations, achieving a positive transformation from transitional development to coordinated development. Du Ruyu et al. [3] used Henan as an example to analyze labor transfer, agricultural ecological environment, and agricultural land management from 2009 to 2016 using entropy method and coordination coupling model. They found that the coordination coupling degree was increasing, but it had not yet reached the optimal state; Kang Cuiyu et al. [4] used 25 commodity grain base counties (cities) in Jilin as examples to conduct film and television analysis from the aspects of types, factors, and trends. The results showed that the overall coordination was moderate, with the central region generally higher than the Middle East and western regions. Hou Mengyang et al. analyzed the data on labor transfer and agricultural ecological efficiency from 1978 to 2016 using threshold models and super efficiency SBM models, and found that labor transfer helps to improve agricultural ecological efficiency [5].

In summary, a series of successes have been achieved in the spatiotemporal coupling, driving force analysis, and coupling measurement of agricultural ecological environment and labor transfer, but there is still relatively weak research on the spatiotemporal evolution of coupling. Therefore, this article uses relevant data from Anhui from 2015 to 2017, and uses entropy method, coupling coordination model, and spatial visualization method to study the spatiotemporal coupling coordination between rural labor transfer and agricultural ecological environment.

Anhui includes 16 prefecture level cities and 52 counties (cities, districts). The province is vast, with the Yangtze and Huai rivers passing through it, making it one of the important grain producing areas in China. Anhui's agricultural gross domestic product ranks high in the country; Meanwhile, as a major labor force province, Anhui has a large number of rural laborers. The research area of this article is selected as the counties (cities) under the jurisdiction of Anhui, and in order to ensure consistency in administrative divisions, each urban area is considered as a county.

2. Data Sources and Research Methods

2.1. Data Source

The boundary data of Anhui Province administrative region required in this article is sourced from the Alibaba Cloud DataV website, and the base image has not been modified. Based on the completeness and accessibility of the socio-economic data, this study focuses on the spatial coupling relationship between agricultural ecology and rural labor transfer in Anhui from 2015 to 2017. The research data are all from the Anhui Provincial Statistical Yearbook from 2016 to 2018.

2.2. Research Methods

2.2.1. Entropy Method

The entropy method is an objective evaluation method for multiple indicators, which judges the degree of dispersion of a certain indicator based on the entropy value. The larger the entropy value, the greater the impact of the indicator on the comprehensive evaluation. The lower the entropy value, the opposite is true. The evaluation model of entropy method is as follows:

If there are *w* counties (cities), *n* years, and *r* indicators in the research area, then X_{nij} is the jth indicator value of county (city) *i* in the nth year. This study uses the critical value method to eliminate the impact of different indicator dimensions, and standardizes the data of each indicator, converting the indicator values to 0-1.

Firstly, eliminate the dimensional impact on the data and standardize each indicator to maintain the indicator value between 0 and 1.

For positive indicators.

$$X_{nij} = \frac{X_{nij} - X_{min}}{X_{max} - X_{min}} \tag{1}$$

For negative indicators.

$$X_{nij} = \frac{X_{max} - X_{nij}}{X_{max} - X_{min}} \tag{2}$$

Determine the P-value of each indicator.

$$P_{nij} = \frac{X_{nij}}{\sum_{i=1}^{n} X_{nij}} \tag{3}$$

Determine the entropy value of each indicator.

$$S_j = -\mathrm{k} \times \sum_{i=1}^{n} Pn_{ij} . \ln p_{nij} \tag{4}$$

$$k = -\frac{1}{\ln(n)} \tag{5}$$

Calculate the coefficient of difference.

$$G_j = 1 - S_j \tag{6}$$

Determine the weights of each indicator.

$$W_j = \frac{G_j}{\sum_{i=1}^{n} G_j} \tag{7}$$

2.2.2. Establishment of Indicator System

In order to accurately and reasonably study the development of the coupling and coordination relationship between agricultural ecological environment and rural labor transfer, referring to the indicator system proposed by Du Ruyu et al. [3], following the availability, feasibility, comprehensiveness, and scientificity of indicator establishment, and combining with the research content of this article, the indicator system and weight of rural labor transfer and agricultural ecological environment in Anhui are finally determined.

Table 1. Rural labor force transfer and agricultural ecological environment assessment indicators in Anhui

	Evaluation index	attribute	weight
Rural labour transfer	Disposable income of rural households	+	0.3543
	Percentage of non-agricultural industries/%	+	0.0236
	Non-farm labor growth/%	+	0.0354
	Ratio of non-agricultural labor to rural labor	+	0.0082
Green development of agriculture	Total mechanized power per unit of farmland/(kW/hm^2)	+	0.0897
	Amount of fertilizer per unit of farmland/(t/hm ^{2})	—	0.0261
	Amount of pesticide used per unit of farmland /(t/hm^2)	—	0.4545
	Effective irrigation rate of farmland /%	+	0.0048
	Soil erosion control area/Thousand hectares	+	0.0034

2.2.3. Coupling Coordination Model

Coupling degree refers to the degree of close relationship between two or more systems, which can also be understood as the degree of interdependence. When the various elements of the system closely cooperate and promote each other to achieve coordinated development, it is called benign coupling, or high coupling degree. On the contrary, it is malignant coupling or low coupling [7-8]. Coordination degree is a quantitative indicator of the degree of harmony and consistency between systems or internal elements in the development process, and is a measure of the quality of coordination. According to the viewpoint of synergy theory and systems theory, coupling coordination degree is an indicator of the relationship between subsystems, and coupling and cooperative scheduling can accurately reflect the synergy of various parameters between systems [10].

This article constructs a coupling coordination model between rural labor transfer and agricultural ecological environment. Transfer rural labor force. Before calculating coupling co scheduling, it is necessary to measure the comprehensive development level of the two systems, using the following calculation method:

$$U_1 = \sum_{i=1}^{n} a_i x_i \tag{8}$$

$$U_2 = \sum_{i=1}^{n} b_i y_i \tag{9}$$

Where, U_1 and U_2 represent the comprehensive evaluation levels of rural labor transfer and agricultural ecological environment, a_i and b_i represent the weights of each indicator, and x_i and y_i represent the standardized data. The calculation formula for its coupling degree model is:

$$C = \sqrt{\frac{U_1 U_2}{\left(\frac{U_1 + U_2}{2}\right)^2}} \tag{10}$$

In equation (10), the value range of C is within [0,1]. The larger the C value, the higher the coupling between rural labor transfer and agricultural ecological environment, and the lower the degree of dispersion between the two systems. Conversely, the higher the coupling is.

Due to the fact that coupling degree can only reflect the

degree relationship between subsystems, but cannot reflect the coordination degree of the overall system, a coupling coordination degree model is introduced, and its formula is as follows:

$$D = \sqrt{C \times T} \quad (11)$$

$$T = \beta U_1 + \delta U_2 \quad (12)$$

Where, T is the comprehensive evaluation index between rural labor transfer and agricultural ecological environment in Anhui Province, β and δ as an undetermined coefficient, the transfer of rural labor force, as an indirect result of agricultural green development, reflects the achievements of agricultural green construction, so it should be slightly higher than β, so β=0.4, δ= 0.6.

In order to better illustrate the degree of coupling, the coupling degree is defined in a hierarchical manner. Referring to the definition of scholar Liao Zhongbin [11], the degree and type of coupling coordination are divided into the following levels:

Table 2. Coupling coordination level classification and evaluation criteria

Coupling coordination	Coupling coordination intervals	Coupling coordination type
Dysregulated decay	[0,0.1)	Extreme dysregulation
	[0.1,0.2)	Severe dysregulation
	[0.2,0.3)	Moderate outrange
	[0.3,0.4)	Mild disorders
Overdevelopment class	[0.4,0.5)	On the verge of imbalance
	[0.5,0.6)	Barely coordinated
Coordinated development class	[0.6,0.7)	Junior coordination
	[0.7,0.8)	Intermediate coordination
	[0.8,0.9)	Well-coordinated
	[0.9,1)	Quality coordination

3. Empirical Results and Analysis

3.1. Calculation Results and Analysis of Coupling Coordination Degree of Each Subsystem

Based on the above model and method, calculate the rural labor transfer and agricultural ecological environment evaluation indices U_1 and U_2 in Anhui, as well as the comprehensive evaluation indices T, coupling degree C, and annual average coupling coordination degree D. The specific results are shown in Table 3. The average coupling degree, coupling coordination degree, and comprehensive evaluation index between labor transfer and agricultural ecological environment in various counties (cities) of Anhui Province from 2015 to 2017 are shown in Table 4.

Table 3. Efficiency evaluation index, comprehensive evaluation index, and coupling degree of each subsystem from 2015 to 2017

Year	Evaluation index of rural labor transfer (U_1)	Agro-ecological environment evaluation index (U_2)	Comprehensive evaluation index(T)	Degree of coupling(C)	Coupling coordination(D)
2015	0.057	0.086	0.069	0.880	0.206
2016	0.060	0.086	0.070	0.889	0.210
2017	0.067	0.087	0.075	0.891	0.218

3.2. The Spatiotemporal Evolution Characteristics of the Comprehensive Evaluation Index of Each Subsystem

3.2.1. The Spatiotemporal Evolution of the Comprehensive Evaluation Index of Agricultural Ecological Environment

The results indicate (Table 4) that the overall level of agricultural ecological environment in Anhui shows an upward trend, rising from 6.650 in 2015 to 6.683 in 2017, with a growth rate of 0.49%. From the increase level of each city, only Bozhou, Suzhou, Bengbu, Lu'an, Ma'anshan, Anqing and Huangshan maintained an overall increase in the level of agricultural ecological environment, with growth rates of 3%, 1.43%, 3.34%, 3.89%, 7.41%, 3.66% and 0.33% respectively. This is because the economic level of these counties and districts is good, and they have achieved good results in improving the level of agricultural mechanization and soil erosion control, and the use of pesticides and fertilizers is decreasing, leading to an overall improvement in the agricultural ecological environment. In a decreasing state, it is mainly located in the northern regions of Anhui, such as Fuyang, Bengbu, Suzhou, and Huainan. These areas are mainly plain areas and belong to the main grain production areas of Anhui Province. At the same time, the economic level cannot keep up with the cities in southern Anhui, and the improvement of agricultural mechanization is relatively poor; Moreover, the counties and districts of Bozhou, Fuyang, and Bengbu are in a gap in soil erosion control, greatly reducing the level of agricultural ecology; Due to geographical and economic limitations, farmers' levels of pesticide and fertilizer use have not decreased, ultimately leading to negative growth in the overall agricultural ecological environment.

Table 4. Changes in the level of agro-ecological environment in Anhui Province

Region	2015	2016	2017
Hefei	0.249	0.243	0.209
Huaibei	0.128	0.058	0.059
Bozhou	0.195	0.199	0.201
Suzhou	0.122	0.129	0.124
Bengbu	0.182	0.183	0.189
Fuyang	0.652	0.624	0.515
Huainan	0.110	0.103	0.102
Chuzhou	0.434	0.470	0.417
Lvan	0.500	0.514	0.519
Maonshan	0.154	0.157	0.166
Wuhu	0.278	0.271	0.271
Xuancheng	1.086	1.110	1.327
Tongling	0.142	0.132	0.133
Chizhou	0.688	0.684	0.686
Anqing	0.844	0.837	0.875
Huangshan	0.887	0.876	0.890

It can be seen from Figure 1 that the high value areas of Anhui's agricultural ecological environment in the previous two years are mainly distributed in Lu'an (Jinzhai County, Shucheng County), Mount Huangshan (Qimen County, She County, urban area and Yi County), Yuexi County in Anqing, Shitai County in Chizhou and Ningde in Xuancheng. In 2017, Jixi County, Jingde County and Xiuning County of Huangshan in Xuancheng were newly added to high-value areas. This is because Mount Huangshan and Lu'an mainly develop tourism and tea industry, local ecological protection measures are in place and the local area is mostly mountainous, and the characteristics of crops make the use of pesticides and fertilizers low; The distribution of median areas is mainly concentrated in southern Anhui and distributed around high-value areas, such as Dongzhi County in Chizhou, Qingyang County, and Jing County in Xuancheng, with a tendency to move southward; Low value areas are relatively stable in the northern Anhui region and are advancing towards the central Anhui region.

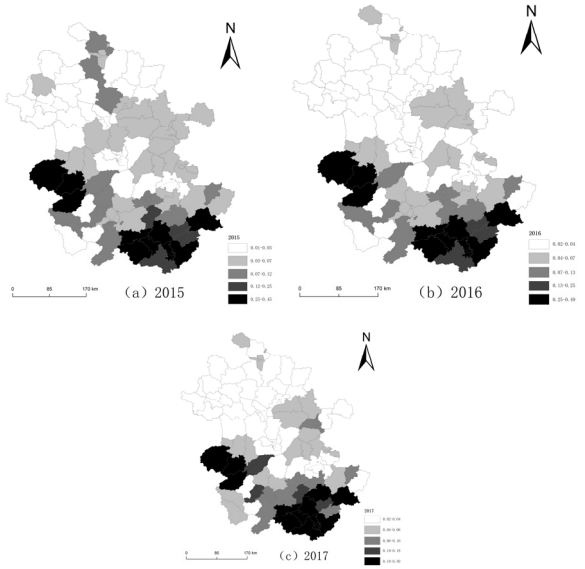

Figure 1. Spatial distribution of agro-ecological environment in Anhui County, 2015-2017

3.2.2. The Spatiotemporal Evolution of the Comprehensive Evaluation Index for Rural Labor Transfer

Table 5. Changes in rural labor transfer level in Anhui Province

Region	2015	2016	2017
Hefei	0.633	0.624	0.686
Huaibei	0.137	0.148	0.162
Bozhou	0.107	0.122	0.139
Suzhou	0.112	0.131	0.153
Bengbu	0.239	0.264	0.296
Fuyang	0.197	0.222	0.255
Huainan	0.315	0.302	0.341
Chuzhou	0.270	0.269	0.304
Lvan	0.205	0.222	0.247
Maonshan	0.367	0.403	0.443
Wuhu	0.470	0.486	0.550
Xuancheng	0.264	0.283	0.322
Tongling	0.231	0.348	0.274
Chizhou	0.219	0.135	0.215
Anqing	0.327	0.359	0.411
Huangshan	0.275	0.301	0.331

The results show (Table 5) that the overall level of rural labor transfer in Anhui shows an upward trend, from 4.368 in 2015 to 5.130 in 2017, with a growth rate of 17.45%. From the perspective of the growth rate of each city, only the overall level of rural labor transfer in Chizhou remains decreasing, with an overall decline rate of -1.93%. This is due to the large transfer of rural labor, a decrease in population size, and a small industrial economic scale in the region, which affects regional economic development and exacerbates the imbalance between urban and rural development [12]. The overall level of labor transfer in other cities has maintained a growth state, with Bozhou, Suzhou, and Fuyang having the highest growth rates of 29.34%, 36.24%, and 29.7%. With the

continuous improvement of economic level in recent years, Anhui has also formulated relevant policies to guide the return of talents. In addition, the rapid development of non-agricultural industries and the reduction of non-agricultural labor force have led to an increase in rural labor transfer.

Figure 2. Spatial distribution of rural labor transfer in Anhui County from 2015 to 2017

As shown in Figure 2, the transfer of rural labor forces forms a high-value agglomeration area centered around each urban area, Presenting a 'high in the middle and low around' pattern The distribution characteristics of ". In 2015, the level of rural labor transfer in Anhui was relatively high, with few high-value areas, mainly concentrated in Hefei, Huainan, Ma'anshan, and Tongling districts, as well as Wuhu County. With the continuous addition of low-value areas over time, the distribution of high-value areas gradually stabilized, and still maintained a spatial distribution centered around the urban area. By 2017, Hefei, Wuhu, Ma'anshan, and Tongling had formed a relatively high level of rural labor The basic pattern of rural labor force transfer has basically formed in the area of force transfer; The distribution of median areas always revolves around high-value areas, and is mainly distributed in various urban areas and surrounding counties, such as Huaibei, Fuyang, and Bengbu urban areas, as well as Feidong County, Feixi County, and Chaohu City. Low value areas are mainly distributed in county towns, with a large number of low value areas around Fuyang, Bozhou, and Huaibei.

3.3. The Spatiotemporal Evolution of the Coupling Degree and Coupling Coordination Degree of Each Subsystem

3.3.1. Evaluation of the Coupling Degree of Each Subsystem

From Figure 3, it can be seen that the coupling degree between rural labor force transfer and agricultural ecological environment in Anhui Province from 2015 to 2017 remained at 0.88 to 0.90. This is due to the changes in agricultural ecological environment caused by rural labor force transfer, which is also reflected in labor force transfer. The two interact and influence each other, and from 2015 to 2017, the coupling coordination between various subsystems was steadily increasing, indicating good coordination. The greater the coupling degree, the degree of interaction between the two systems, but it does not reflect the level of coordinated development of coupling. Therefore, coupling coordination degree is introduced to evaluate the level of mutual coordination between the two systems. As shown in Figure 3, from 2015 to 2017, the coupling and coordination between rural labor transfer and agricultural ecological environment in Anhui Province steadily increased, belonging to a moderate imbalance.

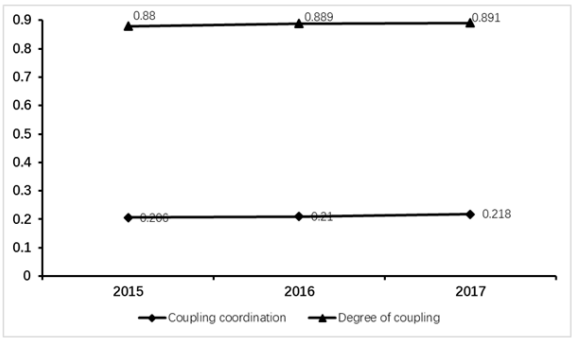

Figure 3. Coupling degree and co scheduling of rural labor force transfer and agricultural ecological environment in Anhui from 2015 to 2017

3.3.2. Spatiotemporal Evolution of Coupling Coordination Degree of Subsystems

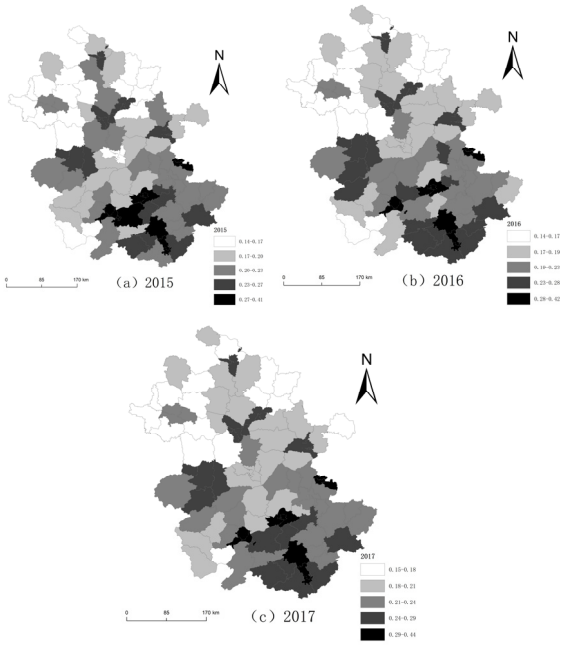

Figure 4. patial distribution of coupling and coordination between rural labor transfer and agro-ecological environment in Anhui County from 2015 to 2017

It can be seen from Figure 4 that the Degree distribution distribution of rural labor transfer and ecological environment coupling coordination in Anhui is relatively stable. High value areas are mainly distributed in developed urban areas in the province, such as Ma'anshan urban area, Wuhu urban area and Tongling urban area; Middle to high value areas are mainly distributed in southern Anhui, with a small amount distributed in northern Anhui, such as Xiuning, She County, Huoshan, etc; Low to medium value areas are mainly distributed in counties around cities in northern and central

Anhui, as well as a few counties in southern Anhui, such as Dingyuan, Huaiyuan, and Suixi. Similarly, low value areas are mainly distributed around cities in northern Anhui, such as Guoyang, Lixin and Sixian.

4. Conclusion and Suggestions

4.1. Conclusion

Based on the statistical data from Anhui from 2015 to 2017, this article constructs a coupling coordination degree model to empirically analyze the changes in the coupling coordination degree between rural labor force transfer and agricultural ecological environment in Anhui. The study found that: (1) by analyzing the ecological environment level and the spatial distribution of labor force transfer, it is found that the ecological environment level in Anhui is gradually increasing and showing a trend of transferring to southern counties, such as Dongzhi, Qingyang and Jing County, etc; The spatial distribution of labor force transfer in Anhui shows a stable state, with each urban area as the main agglomeration area, and forming agglomeration areas in surrounding counties. (2) The coupling degree between rural labor transfer and agricultural ecological environment in Anhui from 2015 to 2017 was close to 0.9, indicating a good coordination. The relationship between the two is becoming increasingly close, and the degree of dependence is also increasing. The overall coupling coordination degree is between 0.2 and 0.25. From 2015 to 2017, the coupling coordination degree in Anhui Province was moderately imbalanced, but the coupling coordination degree value has been on the rise.

4.2. Suggestions

In order to improve the coupling and coordination of rural labor transfer and agricultural ecological environment subsystems in Anhui and maintain a harmonious development state, and promote the long-term, healthy and sustainable development of Anhui's agricultural economy, the following suggestions are proposed: (1) Carry out agricultural ecological protection publicity and education to enhance the environmental protection awareness of rural residents; Strengthen technological efforts, reduce the use of pesticides, fertilizers, and thin films, and reduce agricultural pollution from the source; Establish sound rules and regulations to protect land from pollution. (2) Promote urbanization construction with county towns as an important carrier, attract rural reproductive labor force to transfer to small towns, and achieve local and nearby urbanization; Give full play to the government's functions and guiding role, promote urban-rural integration construction, and provide job opportunities for rural labor.

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