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Research on Coupling Coordination Evaluation of Sustainable Land Use and Economic Development: A Case Study of Guangdong Province, China

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중국 광동성의 지속가능한 토지이용 및 경제발전 결합조화 발전평가에 관한 연구

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Abstract Sustainable land use is an essential part of the regional natural ecosystem. Likewise, economic development is needed for national prosperity, societal progress, and the high living standards of people. However, some regions blindly pursue economic development and ignore sustainable land use, reducing the level of sustainable land use and hindering economic development. Hence, exploring the coupling coordination between sustainable land use and economic development is conducive to the overall economic development and land protection in any region. Hence, this study collected data on the land use and economic development in Guangdong Province, China for 2008 and 2019 and established the evaluation index system of sustainable land use and economic development for the province. Further, a coupling coordination model of sustainable land use and economic development was established to measure and analyze the level of coupling and coordination between sustainable land use and the land use subsystems, and economic development in the province, respectively. The results of the measurement and analysis were as follows. The sustainable land use and regional economic evaluation values of the province changed during 2018 - 2019. In addition, the respective coupling coordination levels of the two sustainable land use subsystems maintained an upward trend during the period. Meantime, the contribution of the overall development of the two subsystems to their respective coupling coordination degree had been increasing during the period. In particular, this coupling coordination degree had changed from a low to a good coupling coordination stage. Hence, the construction of environmental facilities should further be improved to realize the ecologically, economically, and socially sustainable development of land resources in the province. In particular, the province should promote the optimization of industrial structure and develop tertiary and high-tech industries to coordinate sustainable land use and economic development in the province.

요 약 토지에 대한 지속적인 활용은 지역 자연 생태계의 중요한 부분이며, 경제발전은 국가의 번영, 사회 발전, 국민의 생활 수준 향상을 위해 필요한 것이다. 일부 지역은 경제발전을 맹목적으로 추구하며 지속이 가능한 토지이용은 무시해 지속이 가능한 토지이용 수준을 떨어뜨리고 경제발전을 저해한다. 따라서 양자의 결합 조화 관계를 연구하는 것이 경제발전과 토지 보호에 도움이 된다. 본 연구는 연구성과를 바탕으로 2008~2019년 데이터를 활용하고, 토지에 대한 지속적인 활용과 그 서브시스템(subsystem)과 경제발전의 결합 조화 관계를 분석 및 논의했다. 결과에 따라 광둥성 토지에 대한 지속적인 활용은 지역경제의 평가치 변화 정도와 달리 모두 상승세를 유지하고 있는 것으로 나타났다. 또한 2008년 이후 두 서브시스템의 전체적인 발전 수준은 결합 조화에 기여하는 바 있다. 결합 조화 정도도 낮은 단계에서 높은 단계로 변화하고 있다. 이에 기반하여 광둥성 토지에 대한 지속적인 활용과 경제 수준 조화롭게 발전시키기 위해 광둥성 환경시설을 더욱 정비하고 토지자원의 생태·경제·사회 지속적인 발전을 실현해 나가며 산업구조 최적화를 강력히 추진하여 3차 산업과 첨단 기술 산업의 발전을 촉진해야 한다.

Keywords : Sustainable Land Use, Economic Development, Entropy Weight Method, Coupling Coordination Degree, Guangdong Province

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1. Introduction

In the regional natural ecosystem and social-economic development process, sustainable land use is one of the hot issues in the study of man-land relationships[1,2]. As an essential carrier of population, resources, infrastructure, investment, technology, land development intensity, and utilization efficiency are closely related to local economic development pattern evolution[3]. With the continuous development of industrialization and urbanization, industry and population are gathering in cities on a large scale. However, China's reserve land resources are seriously insufficient, and land is a non-renewable resource. As a result, agricultural land is largely converted into non-agricultural land, and the contradiction between man and land is becoming increasingly acute[4]. With the development of the economy and the continuous expansion of urban agglomerations, the rapid growth of the regional economic aggregate often poses more significant challenges to the sustainable use of land, which is likely to lead to the degradation of cultivated land quality, the reduction of biodiversity, and the shortage of land resources. A variety of land issues threaten the stability of sustainable land use in China to a certain extent[5].

The relevant studies on sustainable land use at home and abroad mainly focus on the following. Most studies show that sustainable land use and socioeconomic development interact with each other. Fischer et al. (2001) concluded through investigation and analysis that the process of land use change is directly related to the economic decisions made by the government, which can promote the development of urban high-tech industries and improve land use efficiency[6]. Hadeel et al. (2009) confirmed that the main driving force of land use and cover change in Basra province was the rapid development of the urban economy and the migration of the rural population[7]. Weilanda (2011) pointed out that the key to achieving sustainable and healthy social and economic development lies in the sustainable use of land, which should be considered from the aspects of society, economy, ecology, etc., and to balance the relationship between people, resources and the environment[8]. With the development of China's economy, the conflict between economic development and the limitation of land resources has gradually emerged. How to rationally utilize land resources, promote sustainable land use, and help economic development has attracted extensive attention from domestic scholars. Li Xiaoshu (2015) believes that sustainable land use can alleviate the contradiction between man and land in China and promote the development of cities and the economic growth of rural areas to achieve the sustainable development of the whole society[9]. Chen Juan et al. (2019) believe that the rapid expansion of urban construction land area is the direct inducement for transforming land use patterns. Therefore, in economic development, land use efficiency should be improved by optimizing the land use structure to ensure sustainable economic development[10]. To sum up, the existing research mainly focuses on the study of land resources and regional economic development, focusing on the impact of land use on economic development. In contrast, the research on the coupling and coordination relationship between economic development and sustainable land use is relatively lacking. And the less in-depth exploration of the coupling mechanism between the two is from the economically developed regions.

At the beginning of the reform and opening up, Guangdong Province's economic strength ranked seventh in the country, and its per capita GDP ranked first in the country in the early 1990s. By 1999, it was 11,739 yuan, 179.3% of the national average. The fastest growing

province. How to maintain the high-quality growth of the regional economy in Guangdong Province and at the same time give full play to the value of land resources to achieve sustainable utilization of land resources has important strategic significance not only for Guangdong Province, but also for the formulation of development strategies for all provinces across the country. Because of this, this study starts from multiple levels, constructs a coupling and coordinated evaluation index system of sustainable land use and economic development in Guangdong Province, and calculates and analyzes the development level and internal coupling relationship between the two systems of sustainable land use and economic development in Guangdong Province. It is expected to provide a helpful reference for Guangdong Province to promote comprehensive, efficient, and sustainable land use development and economic development.

2. Study area and data source

2.1 Study area

The region of Guangdong Province is located between latitudes 20°13′ N and 25°31′ N, and longitudes 109°39′ E and 117°19′ E and has an area of about 196,342 km^2 (Fig. 1)[11]. Guangdong Province is situated in the southernmost part of China, and is a main economic hub of the country. The study area shared its eastern boundary with Fujian Province, northern boundary with Jiangxi and Hunan Provinces, western boundary with Guangxi, and a southern boundary with the South China Sea[12]. The geography of the study area is characterized by plains, plateaus, mountains, hills, and rivers. Its climate is categorized by hot, humid summers and cold, windy, dry winters. The mean annual precipitation and temperature are 1500~2000 mm and 22 ℃, respectively[13,14]. The availability of infrastructure has been supported by government and local authorities since the opening of the economic reform policy in 1978 and has successfully enjoyed economic prosperity. This has made Guangdong Province the international, cultural, and political communication center of China. This region has experienced an increase in population, socio-economic development, and changes in land use land cover over the past three decades. The significant surge in the urban area has predominantly come from the conversion of farmland into built-up regions[12]. The increase in population is mainly the result of immigration. Guangdong Province accommodates ever more unsatisfactory, jam-packed transportation systems and consequent environmental pollution[15].

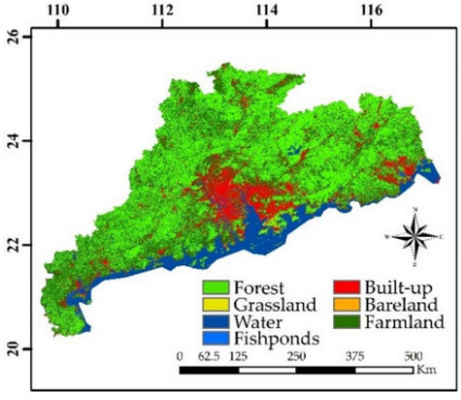

Fig. 1. Land use status of Guangdong Province

2.2 Data source

Establishing a correct evaluation index system is the premise and basis for obtaining scientific and objective evaluation results. Therefore, if you want to objectively evaluate the coupling and coordination relationship between the two and put forward correct countermeasures and suggestions, you must first establish a scientific, systematic, and suitable evaluation index system. This study selects 2008~2019 as the research period covered by the research. The relevant

indicators are mainly from the 2008~2019 Guangdong Provincial Statistical Yearbook, the Statistical Bulletin, and the "China Urban Statistical Yearbook," which are quoted from the National Bureau of Statistics website, Guangdong Provincial Bureau of Statistics, Economic Big social database and EPS database platform.

3. Index selection and Methodology

3.1 Data processing

Data of different indicators may have different units and characteristics. Therefore, to eliminate the influence of dimension, magnitude, and positive and negative orientation, the numeric data needs pre-process before using[16]. A standardization method of the data range was used to pre-processing the original data. After transformation, all the indicators' values were transformed into normalized values with a numerical range from 0 to 1[17]. To mitigate the impact of different dimensions or orders of magnitude of indices, first, we performed dimensionless processing of the data. We divide the indices into two categories, positive index and negative index[18], according to their effect on the system and standardized the data by following:

$$X^{'ij} = \frac{X_{ij} - \min(X_{ij})}{\max(X_{ij}) - \min(X_{ij})}, \quad \text{(Positive indicator)}$$
$$X'_{ij} = \frac{\max(X_{ij}) - X_{ij}}{\max(X_{ij}) - \min(X_{ij})}, \quad \text{(Negative indicator)} \qquad (1)$$

Where $X^{'ij}$ is the value of indicator X_{ij} processed by the extremum method, X_{ij} is the actual value of indicator i in the year j, $\max(X_{ij})$ is the maximum actual value of indicator i in the year j, and $\min(X_{ij})$ is the minimum actual value of indicator i in the year j.

3.2 Index system of sustainable land use and economic development

This study thoroughly analyzes the connotation of sustainable land use, and this study compares and analyzes the evaluation indicators in previous studies, then an initial evaluation indicator system is established. The indicators should be rationally selected in this study to ensure the accuracy of the evaluation results. The rationality of the evaluation index selection directly affects the coupling coordination evaluation results of sustainable land use and economic development.

Because sustainable land use and economic development are two different systems with different contents, definitions, and index systems, the research scope of the two systems is extensive, and there are many influencing factors. This study illustrates the interaction between the two systems and selects indicators from systematic, coordinated development and sustainable development perspectives. Based on the indicator system of sustainable land use constructed by Sun[1], this study selects 12 indicators from three aspects of ecological sustainability, economic sustainability, and social sustainability to evaluate the level of sustainable land use in Guangdong Province. Meantime, combined with the objective situation of Guangdong Province's economic development, this study draws lessons from the economic development index system constructed by Wei et al. (2019)[4], and evaluates the level of Guangdong province's economic development from four indicators: GDP, government revenue, investment in fixed assets, and total retail sales of consumer goods. Based on the scientific, systematic, representative, and accessible nature of indicators and data, this study selected 16 indicators to construct the indicator system of sustainable land use and economic development by referring to previous studies, as shown in Table 1.

Table 1. The evaluation index system of sustainable land use and economic development

Item	Primary index	Secondary index	Weight
Sustainable land use	Ecological sustainability (0.366581)	Urban green coverage ratio (%)	0.081527
		Wastewater discharge (100 million tons)	0.099449
		Fertilizer application rates (100 million tons)	0.062916
		Grain sown area (ha)	0.122689
	Economic sustainability (0.346056)	Grain yield per unit area (kg/ha)	0.043188
		GDP (100 million yuan/10000 km^2)	0.085046
		Net income ((100 million yuan/10000 km^2)	0.082025
		The proportion of the tertiary industry (%)	0.135798
	Social sustainability (0.287363)	Green area per capita (m^2)	0.059843
		Road area per capita (m^2)	0.036458
		Urban construction land (km^2)	0.115171
		Population density (people/per km^2)	0.075890
Economic development	Economic level (1)	GDP (100 million yuan)	0.253668
		Government revenue (100 million yuan)	0.250776
		Investment in fixed assets (100 million yuan)	0.260080
		Total retail sales of consumer goods (100 million yuan)	0.235476

3.3 Index weighting

For an evaluation system, the weight of the evaluation index is the basis of evaluation results. In evaluating indicators, the method to determine the weight of indicators is the key to whether the evaluation results are convincing. The weight directly affects the accuracy of the final evaluation results, and the different methods to calculate the weight will make the evaluation results other to a certain extent. By analyzing the index weighting approaches of previous studies, we discover that existing literature mainly utilizes analytic hierarchy process (AHP) and the Delphi method, which are relatively subjective and can compromise the accuracy of the results[18]. The entropy weight method is an objective weighting method. According to the dispersion of each index, the entropy weight of each index is calculated by using information entropy. Then the entropy weight is modified to some extent according to each index to get the more objective index weight[17]. Therefore, we leveraged the entropy weight method as the weighting method of the index system.

Assuming that there are n evaluation indicators, m years. Then the matrix $R=(X_{ij})_{m\times n}$ can be obtained according to the original data, where X_{ij} is the normalized value of the i-th year to the j-th indicator. The steps are as follows:

(1) Calculate the proportion of the indicators:

$$P_{ij}=X_{ij}^{'}/\sum_{j=1}^{m}X_{ij}^{'} \tag{2}$$

(2) Calculate the entropy of the indicators:

$$E_j=-\frac{1}{\ln m}\sum_{j=1}^{m}P_{ij}\ln P_{ij} \tag{3}$$

(3) Calculate the weight of the indicators:

$$w_j=\frac{1-E_j}{\sum_{i=1}^{n}(1-E_j)} \tag{4}$$

Where E is the entropy for each indicator, m is the number of samples, and w refers to the indicator weight. The weights of each indicator

in Table 1 are determined by the entropy weight method in this study.

3.4 Coupling coordination degree model

Coupling refers to the phenomenon that different systems evolve to a stable dynamic equilibrium state by interacting with each other according to specific laws[19]. In this study, sustainable land use and economic development are regarded as two systems, the interaction and influence of the two systems. Based on the coupling theory, it can be defined as the coupling of sustainable land use and economic development[20].

We built the coupling coordination degree model using the following steps:

(1) Calculate the comprehensive evaluation value of sustainable land use and economic development systems:

$$u_1 = \sum_{j=1}^{n} a_j x_j \tag{5}$$

$$u_2 = \sum_{j=1}^{n} b_j y_j \tag{6}$$

Where u_1, u_2 is the comprehensive evaluation value of sustainable land use and economic development system, respectively. a_j, b_j are the index weight of each indicator.

(2) Calculate the coupling coordination degree of the sustainable land use and economic development systems:

$$C_2 = 2\sqrt{\frac{u_1 \cdot u_2}{(u_1+u_2)^2}} \tag{7}$$

Where C_2 is the coupling degree of the three systems, $C_2 \in [0,1]$, u_1 is the evaluation value of sustainable land use subsystem, u_2 is the evaluation value of economic development.

Coupling is the degree to which systems interact, ignoring the internal elements of the system and their relationships with each other. The smaller the coupling degree is, the less coordinated the two systems are. It can be used to measure the coordinated development of sustainable land use and economic development and is conducive to promoting the coordinated development of the system at a deeper level. However, sustainable land use and economic development are two constantly changing systems[21]. The coupling degree can only explain the coordination of the two systems but not the level of both. Therefore, even if the coupling degree is very high, it cannot indicate the high degree of development of the two systems. Therefore, it is necessary to use the coupling coordination model to evaluate the coordination degree of the interactive development of sustainable land use and economic development of Guangdong Province. The calculation formula of the coupling coordination degree is as follows.

$$T = \alpha u_1 + \beta u_2 \tag{8}$$

$$D = \sqrt{C \cdot T} \tag{9}$$

Where T is for the comprehensive evaluation value among the sustainable land use, and economic development, respectively. α and β are the contributions of the sustainable land use and economic development systems, respectively. In the particular case of Guangdong Province, we determined the values of α and β according to the actual calculation result of the sustainable land use and economic development and $\alpha = 0.5$ and $\beta = 0.5$. D is the coupling coordination degree of sustainable land use and economic development, and $D \in [0,1]$. According to the coupling coordination degree, considering the previous study[22], we divided the coupling coordination degree in to 4 stage and 10 categories, as shown in Table 2.

Table 2. Discriminating standards of the coupling coordination degree

Stage	D-value	Category
Low coupling coordination	0.00~0.09	Extremely uncoordinated
	0.10~0.19	Seriously uncoordinated
	0.20~0.29	Moderately uncoordinated
	0.30~0.39	Slightly uncoordinated
Moderate coupling coordination	0.40~0.49	At the edge of being uncoordinated
	0.50~0.59	Barely coordinated
Good coupling coordination	0.60~0.69	Slightly coordinated
	0.70~0.79	Moderately coordinated
High quality coupling coordination	0.80~0.89	Well coordinated
	0.90~1.00	Perfectly coordinated

4. The results of empirical analysis

4.1 The evaluation value analysis of two subsystems in Guangdong Province

According to the above steps, the data processing results can be obtained in Table 3 u_1 means the evaluation value of sustainable land use subsystem, u_2 means the evaluation value of economic development subsystem. In order to see the development and change more intuitively, the evaluation values are drawn in Fig. 2 Combining Table 3 and Fig. 2 we can see the evaluation value of Guangdong Province's sustainable land use and economic development from 2008 to 2019. The evaluation value of sustainable land use increased from 0.358903 in 2008 to 0.756011 in 2019.

The growth rate was fast in 2008~2009, and decreased slightly in 2009~2014. However, it gradually increased from 2014 to 2019, and rose rapidly after 2017. The three subsystems of sustainable land use in Guangdong province, ecological sustainability, economic sustainability, and social sustainability, have changed to different degrees during the study period. The ecological sustainability index decreased from 0.282949 to 0.200246. The economic sustainability index increased from 0.000035 to 0.346091. The social sustainability index rose from 0.075919 to 0.209674. Among the three indexes, the sustainable use index of land economy develops well on the whole, which also reflects the characteristics of Guangdong province as a strong economic province in China, but the cost is the loss of the natural environment. And the economic development level in Guangdong Province had developed the fastest among the two subsystems, increasing from 0.0001 in 2008 to 1 in 2019.

According to the different evaluation value of the two subsystems of sustainable land use and economic development in Guangdong Province, these two subsystems are divided into different types: $u_1 > u_2$, the stage of sustainable land use development ahead of time. $u_2 > u_1$, the stage of economic development ahead of time. As shown in Fig. 2 from 2008 to 2013, the evaluation value of sustainable land use was higher than that of economic development in Guangdong Province. The coupling coordination degree of the two subsystems had also changed from 0.042365 to 0.384396. It shows that the sustainable land use ahead of time can well drive the overall growth of the regional economy. After 2013, the evaluation value of regional economic development was higher than that of sustainable land use. It shows that the regional economic development ahead of time can well drive the overall growth of the sustainable land use. It was also similar to Li's research result: in the early

Table 3. Measurement results of sustainable land use level and economic development level in Guangdong Province from 2008 to 2019

Year	Ecological sustainability	Economic sustainability	Social sustainability	Sustainable land use (u_1)	Economic development (u_2)
2008	0.282949	0.000035	0.075919	0.358903	0.000100
2009	0.271213	0.026134	0.132827	0.430175	0.049974
2010	0.241405	0.048258	0.115808	0.405471	0.133683
2011	0.187521	0.084726	0.091590	0.363837	0.217245
2012	0.149312	0.104957	0.112813	0.367081	0.281779
2013	0.121732	0.109152	0.102799	0.333683	0.371266
2014	0.072488	0.141465	0.123457	0.337410	0.456258
2015	0.083359	0.198663	0.161335	0.443357	0.575105
2016	0.078277	0.190318	0.164066	0.432661	0.674743
2017	0.131071	0.221908	0.142360	0.495338	0.792841
2018	0.142909	0.320555	0.158742	0.622205	0.898557
2019	0.200246	0.346091	0.209674	0.756011	1.000000

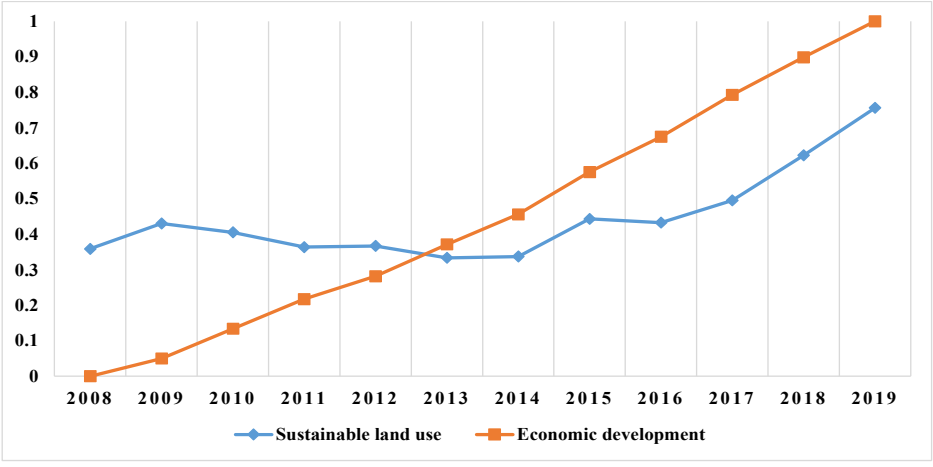

Fig. 2. Sustainable land use and economic development evaluation value in Guangdong Province from 2008 to 2019

stage of economic development, growth mainly depends on land resources and other original inputs. With the development of the economic level to a particular stage and the maturity of technological achievements, economic growth will react to resource input[23].

4.2 The comprehensive evaluation value analysis of two subsystems in Guangdong Province

The comprehensive evaluation value of the coupling coordination model describes the contribution degree of the overall development level of the two subsystems to the coupling coordination degree. If the comprehensive evaluation value is larger, the development of each subsystem will contribute more to the coupling coordination degree. Conversely, the smaller the composite index, the smaller the contribution[24]. In this study, the comprehensive evaluation index of sustainable land use and economic development describes the contribution of sustainable land use and economic development to the coupling coordination degree of the two systems in

Table 4. The comprehensive evaluation values of sustainable land use and economic development

Year	Sustainable land use (u_1)	Economic development (u_2)	Comprehensive evaluation values (T)
2008	0.358903	0.000100	0.179501
2009	0.430175	0.049974	0.240074
2010	0.405471	0.133683	0.269577
2011	0.363837	0.217245	0.290541
2012	0.367081	0.281779	0.324430
2013	0.333683	0.371266	0.352474
2014	0.337410	0.456258	0.396834
2015	0.443357	0.575105	0.509231
2016	0.432661	0.674743	0.553702
2017	0.495338	0.792841	0.644089
2018	0.622205	0.898557	0.760381
2019	0.756011	1.000000	0.878006

Table 5. The coupling coordination degree (D) of sustainable land use and economic development

Year	Coupling degree (C)	Coupling coordination (D)	Category
2008	0.009999	0.042365	Extremely uncoordinated
2009	0.211596	0.225386	Moderately uncoordinated
2010	0.317075	0.292363	Moderately uncoordinated
2011	0.368816	0.327347	Slightly uncoordinated
2012	0.399264	0.359907	Slightly uncoordinated
2013	0.419209	0.384396	Slightly uncoordinated
2014	0.440418	0.418058	At the edge of being uncoordinated
2015	0.500355	0.504773	Barely coordinated
2016	0.513441	0.533191	Barely coordinated
2017	0.552148	0.59635	Barely coordinated
2018	0.606330	0.679001	Slightly coordinated
2019	0.656146	0.759012	Moderately coordinated

Guangdong Province.

The comprehensive evaluation value is calculated according to Eq. 8. The specific results are shown in Table 4 The comprehensive evaluation value (T) of sustainable land use and economic development in Guangdong province shows a growing trend, and the comprehensive evaluation value increased from 0.179501 in 2008 to 0.878006 in 2019, indicating that the contribution of the overall development of the two subsystems to their coupling coordination degree has been increasing since 2008.

4.3 The coupling coordination degree analysis of two subsystems in Guangdong Province

The coupling degree and coupling coordination degree are calculated according to Eq. 7 and 9. The coupling coordination levels of sustainable land use, and economic development in Guangdong Province from 2008 to 2019 are classified according to the classification standards of coupling coordination levels in Table 2. The specific results are shown in Table 5.

The coupling degree can describe the strength and weakness of the system coupling effect[25]. In this study, the coupling degree represents the

strength and weakness of the coupling effect between sustainable land use and economic development in Guangdong Province. During the study period, the coupling degree of sustainable land use and economic development in Guangdong province shows an increasing trend every year, from 0.009999 in 2008 to 0.656146 in 2019. It shows that the two systems of sustainable land use and economic development in Guangdong province are constantly running in harmony to ensure the sustainable use of land resources and stable economic development.

Table 5 shows that the coupling coordination degree among the two subsystems of sustainable land use and economic development in Guangdong Province from 2008 to 2019 had steadily improved. The coupling coordination degree has also changed from imbalance to coordination. In 2008, the evaluation indexes of the two subsystems were low, and the coupling coordination degree was in the stage of Low coupling coordination. From 2009 to 2013, the degree increased from 0.225386 in 2009 to 0.384396 in 2013, the coupling coordination degree began to shift to the slightly uncoordinated stage. From 2014 to 2018, The coupling coordination degree of the two subsystems rose to a new stage from 0.418058 to 0.679001. In 2019, the coupling coordination degree increased slightly and was in the stage of good coupling coordination.

5. Conclusions and policy implications

This study uses the coupling coordination degree model to measure the coordinated development of the two subsystems of sustainable land use, and economic development in Guangdong Province to distinguish the coupling coordination relationship of the two subsystems. The research results can provide a decision-making reference for the collaborative development of the sustainable land use and economic development in Guangdong Province. The conclusions can also be used for reference for similar research methods, and the main conclusions of this study are as follows: (1) From 2008 to 2019, Guangdong Province's sustainable land use and regional economic evaluation values changed differently. The levels of sustainable land use and economic development maintained an upward trend. The evaluation values of the two subsystems had increased from 0.358903 and 0.0001 in 2008 to 0.756011 and 1 in 2019, respectively. As for the three subsystems of sustainable land use, among the three indexes, the sustainable use index of land economy develops well, reflecting the characteristics of Guangdong province as a solid economic province in China, but the cost is the loss of the natural environment. Meantime, in the early stage of development, sustainable land use can drive the economic growth of Guangdong Province. Economic development will react to sustainable land use based on economic accumulation to a certain extent. (2) The comprehensive evaluation value (T) of sustainable land use and economic development in Guangdong province shows a growing trend, and the comprehensive evaluation value increased from 0.179501 in 2008 to 0.878006 in 2019, indicating that the contribution of the overall development of the two subsystems to their coupling coordination degree has been increasing since 2008. (3) The coupling coordination degree of sustainable land use and economic development in Guangdong Province from 2008 to 2019 showed an overall upward trend, from 0.042365 in 2008 to 0.759012 in 2019. The coupling coordination degree among the two subsystems of sustainable land use and economic development in Guangdong Province from 2008 to 2019 had steadily improved. The coupling coordination degree has also changed from low coupling coordination stage to good

coupling coordination stage.

In the future, Guangdong province will propose optimization measures based on resource endowments, and regional conditions to build a coordinated development pattern of efficient sustainable land use and and economic development. In this process, strict protection system of cultivated land and forest land is implemented, and dynamic monitoring system of agricultural land is implemented. In addition, we will strengthen the overall planning of land and improve the quality of land use and productivity. At the same time, combined with the development background of Guangdong Province, the economic development speed of Guangdong Province will gradually accelerate in the future, and so as to coordinate sustainable land use and economic development, Guangdong Province should promote the optimization of industrial structure and develop tertiary industry and high-tech industry. At the same time, the construction of environmental facilities in Guangdong Province will be further improved to realize the ecological, economic, and social sustainable development of land resources. This study analyzes the coupling and coordination relationship between sustainable land use and economic development in Guangdong Province and puts forward some suggestions for optimization. But there are still some deficiencies in the research process. Due to the difficulty of obtaining index data and limited references, the evaluation indexes selected in this paper are not systematic and comprehensive, which influences the measurement results. In the future, we should extract index data as much as possible, improve the index system, and improve the credibility of research results.

References

[1] H. R. Sun, M. C. Fu, "Research on human dimensions of land use changes in Nanjing based on canonical correlation analysis", *China Population, Resources and Environment*, Vol.24, No.5, pp.422-425, 2014.

[2] K. Liu, Y. E. Li, Q. Wu, J. F. Shen, "Driving force analysis of land use change in the developed area based on probit regression model: A case study of Nanjing city, China", *Chinese Journal of Applied Ecology*, Vol.26, No.7, pp.2131-2138, 2015.

[3] X. H. Zhu, S. J. Zhong, "Effects of high-speed rail on urban land use from the perspective of "space of flow": An analysis based DPSIR-PLS model", *Resources Science*, Vol.41, No.12, pp.2262-2273, 2019.

[4] Q. T. Wei, R. C. Lu, Z. D. Ye, "Study on coupling relationship between land use change and socioeconomic development in Guiping city", *Acta Agriculturae Jiangxi*, Vol.31, No.8, pp.145-150, 2019.

[5] Y. Zhou, R. H. He, "Research on the coupling relationship between economic development and land ecological security in the Yangtze River Delta", *Journal of Shandong Agricultural University (Social Science Edition)*, Vol.23, No.03, pp.80-89+186, 2021.

[6] G. Fischer, L. X. Sun, "Model based analysis of future land use development in China", *Agriculture Ecosystems & Environment*, Vol.85, No.1-3, pp.163-176, 2001.
DOI: https://doi.org/10.1016/S0167-8809(01)00182-7

[7] A. S. Hadeel, T. J. Mushtak, X. L. Chen, "Application of remote sensing and GIS to the study of land use/couver change and urbanization expansion in Basrah Province, Southern Iraq", *Geo-Spatial Information Science*, Vol.12, No.2, pp.135-141, 2009.
DOI: https://doi.org/10.1007/s11806-009-0244-7

[8] U. Weiland, A. Kinder, E. Banzhaf, A. Muller, "Indicators for sustainable land use management in Santiage de Chile", *Ecological Indicators*, Vol.11, No.5, pp.1074-1083, 2011.
DOI: https://doi.org/10.1016/j.ecolind.2010.12.007

[9] X. S. Li "Study on sustainable use of urban land in urbanization process", *Jiangxi Building Materials*, Vol.35, No.8, pp.45, 2015.

[10] J. Chen, L. Wang, X. Y. Zhao, S. G. Cheng, "The relationship between urbanization and land use in Guiyang city", *Earth Science*, Vol.44, No.9, pp.2944-2954, 2019.

[11] S. Hasan, W. Z. Shi, X. L. Zhu, S. Abbas, H. U. A. Khan, "Future simulation of land use changes in rapidly urbanizing South China based on land change modeler and remote sensing data", *Sustainability*, Vol.12, No.11, pp.4350, 2020.
DOI: https://doi.org/10.3390/su12114350

[12] A. K. Braimoh, T. Onishi, "Spatial determinants of urban land use change in Lagos, Nigeria", *Land Use Policy*, Vol.24, No.2, pp.502-515, 2007.
DOI: https://doi.org/10.1016/j.landusepol.2006.09.001

[13] C. Li, Y. Q. Kuang, N. S. Huang, C. Zhang, "The

long-term relationship between population growth and vegetation cover: an empirical analysis based on the panel data of 21 cities in Guangdong Province, China", *Int. J. Environ. Res. Public Health*, Vol.10, No.2, pp.660-677, 2013.
DOI: https://doi.org/10.3390/ijerph10020660

[14] Y. Q. Ye, J. E. Zhang, B. A. Bryan, L. Gao, Z. Qin, L. L. Chen, "Impacts of rapid urbanization on ecosystem services along urban-rural gradients: a case study of the Guangzhou-Foshan Metropolitan Area, South China", *Ecoscience*, Vol.25, No.3, pp.235-247, 2018.
DOI: https://doi.org/10.1080/11956860.2018.1442086

[15] Q. Wu, H. Q. Li, R. S. Wang, "Monitoring and predicting land use change in Beijing using remote sensing and GIS", *Landscape and Urban Planning*, Vol.78, No.4, pp.322-333, 2006.
DOI: https://doi.org/10.1016/j.landurbplan.2005.10.002

[16] Z. Zhang, M. Zhou, G. L, Ou, S. K. Tan, Y. Song, L. Zhang, X. Nie, "Land suitability evaluation and an interval stochastic fuzzy programming-based optimization model for land-use planning and environmental policy analysis", *Int. J. Environ. Res. Public Health*, Vol.16, No.21, pp.4124, 2019.
DOI: https://doi.org/10.3390/ijerph16214124

[17] C. Wei, Q. W. Lin, L. Yu, H. W. Zhang, S. Ye, D. Zhang, "Research on sustainable land use based on production-living-ecological function: a case study of Hubei Province, China", *Sustainability*, Vol.13, No.2, pp.996, 2021.
DOI: https://doi.org/10.3390/su13020996

[18] X. M. Ji, K. Wang, T. Ji, Y. H. Zhang, "Coupling analysis of urban land use benefits: a case study of Xiamen city", *Land*, Vol.9, No.5, pp.155, 2020.
DOI: https://doi.org/10.3390/land9050155

[19] Z. Z. Lai, D. M. Ge, H. B. Xia, Y. L. Yue, Z. Wang, "Coupling coordination between environment, economy and tourism: a case study of China", *Plos One*, Vol.15, No.2, pp.e0228426, 2020.
DOI: https://doi.org/10.1371/journal.pone.0228426

[20] F. J. Qi, "Study on coupling relationship between rural land consolidation and economic development", *Co-Operative Economy & Science*, No.8, pp.20-21, 2014.

[21] L. Sun, *Study on coupling coordination between urbanization and sustainable land use in Heilongjiang Province*, Master's thesis, Harbin Nornal University, Harbin, China, pp.21-28, 2021.

[22] Y. Q. He, X. X. Pan, Y. Wang, S. Y. Lei, "Evaluation and analysis on coupling coordinated development of urban resource, environment and economy in Jiangxi province in China", *Applied Mechanics and Materials*, Vol.295-298, pp.2457-2463, 2013. DOI: https://doi.org/10.4028/www.scientific.net/AMM.295-298.2457

[23] X. G. Li, S. J. Wang, Y. Sun, "The dynamic effect and coupling coordination of land carrying capacity and economic development-An empirical study based on Beijing-Tianjin-Hebei urban agglomeration", *Economic Theory and Business Management*, No.12, pp.98-109, 2018.

[24] Y. W. Zhang, F. Wang, "Coupling and coordination of land ecological security and economic development in Guangdong Province from 2000 to 2018", *Research of Soil and Water Conservation*, Vol.28, No.1, pp.242-249, 2021.

[25] F. Y. Hu, Y. Zheng, Z. L. Zhou, "Evaluation study between land ecological security and economy based on entropy weight and coupling coordination degree", *Journal of Anhui Agri. Sci.*, Vol.43, No.18, pp.266-270, 2015.

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