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Spatial Heterogeneity of Sustainable Land Use in the Guangdong–Hong Kong–Macao Greater Bay Area in the Context of the Carbon Cycle: GIS-Based Big Data Analysis

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Abstract: The primary object of this study is to survey the spatial heterogeneity of sustainable land use in the Guangdong–Hong Kong–Macao Greater Bay Area, The introduction of GIS technology into the evaluation index system under the traditional concept of circular economy, combined with the "double carbon target" and the methods of entropy weight analysis and superposition analysis led to the establishment of the evaluation index system for sustainable land use in the GIS model. The evaluation's findings indicate that: (1) Spatially, the horizontal gravity center of sustainable land use in the Guangdong–Hong Kong–Macao Greater Bay Area changed dimensionally from 2010 to 2021, and the spatial gravity center shifted from north to south. (2) In terms of time characteristics, sustainable land use showed a steady upward trend in the 11 years from 2010 to 2021. (3) There were regional differences and uneven development levels in the comprehensive evaluation of sustainable land use in the Guangdong–Hong Kong–Macao Greater Bay Area. It shows that there are great differences in the degree of social and economic development among federation-level cities in the Guangdong–Hong Kong–Macao Greater Bay Area. From the current research on the sustainable use of land resources, the evaluation of sustainable use of land based on the concept of a circular economy is less favorable. Thus far, there has been no case study on land sustainability in the Guangdong–Hong Kong–Macao Greater Bay Area based on carbon cycles. In this study, the results are systematically sorted out, and the influencing factors are analyzed in depth to provide theoretical guidance on the sustainable and circular development of society, culture, and economy in the Guangdong–Hong Kong–Macao Greater Bay Area.

Keywords: GIS; the idea of a circular economy; sustainable land use; carbon peaking and carbon neutrality; Greater Bay Area

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1. Introduction

An ecological economy, like a circular economy, is one that uses ecological laws to regulate human society's economic activity [1]. Under the traditional development model, people intensively develop resources and discharge a large amount of waste into the environment, which will inevitably lead to a serious shortage of resources and environmental pollution. Circular economy takes the reduction, reuse, and recycling of materials as its basic principle takes the efficient utilization and recycling of resources as its core and achieves a healthy economy and society by maximizing resource utilization and minimizing waste discharge. The purpose of rapid development is suggested in [2,3]. According to the law of ecology, human beings originally come from nature, and they coexist in a system (the Earth's biosphere) with biodiversity, and as a subsystem of the system of the Earth's biosphere, human beings and nature will interact with each other [4]. If the two are developed in a coordinated manner, there will be symbiosis, co-prosperity, and coordinated development; otherwise, an ecological crisis will be triggered due to the deterioration of the relationship between man and nature. By advocating the low input and high utilization of natural resources, the circular economy is committed to solving the contradiction between the unlimited demand for resources in humans' social and economic development and the limited resources on Earth [5,6].

Human beings depend on land as their primary habitat and form of travel, and wise land management will benefit both the productivity of the land and the level of sustainable development of human society. In 2015, the 17 Sustainable Development Goals (Sustainable Development Goals, referred to as SDGs) adopted by the United Nations Sustainable Development Summit included the Land Sustainable Development Goal [7], which aims to solve social problems in a comprehensive way, from 2015 to 2030, of economic and environmental development issues in three dimensions to achieve sustainable development [8]. As the basis of sustainable land use, sustainable land evaluation is of great significance for monitoring land development, improving land-use efficiency, and promoting regional comprehensive, coordinated, and sustainable development [9]. With the rapid advancement of the country's industrialization and urbanization, the land provides a strong guarantee for humans social and economic growth. At the same time, the development of the social economy and the continuous growth of the population has stimulated more demand for land. The scarcity of land resource supply and the infinity of demand has made the contradiction between man and land increasingly prominent [10]. Water and soil erosion and land pollution have occurred in the process of land use [11]. Extensive use, land quality decline, and other issues seriously restrict the sustainable use of land resources. Sustainable land use is an important part of sustainable development, which is related to long-term and stable economic and social development [12]. Therefore, it is of great significance to study the sustainable use of land for the sustainable development of the country's economy and society.

Internationally, in 1993, the "Sustainable Land Utilization Evaluation Outline" promulgated by the Food and Agriculture Organization of the United Nations (FAO) determined five evaluation criteria for sustainable land use, including land productivity and land security and stability [13,14] The land sustainability evaluation work has laid the foundation. A correct understanding of the connotation of sustainable land use is the basis of land sustainability evaluation [15,16]. Scholars in different disciplines have different understandings of the connotation of sustainable land use, mainly including socioeconomics and ecology [17].

With the development of a social economy and the growth of the population, land resources are faced with various crises such as land degradation, soil erosion, and quality decline, and the contradiction between man and land is increasingly prominent. Sustainable land use has gradually become a research hotspot for scholars. In relevant domestic research, regarding the selection of evaluation methods, Liu Xiaoling and other scholars compared the degree of sustainable land use before and after the adjustment of the administrative division of Acheng based on quantitative analysis and evaluation [18]. The spatio-temporal differences in land sustainability in major agricultural product-producing areas are revealed in three aspects: economy, economy, and society [19]; scholars such as Liu Donghong use methods like comprehensive evaluation and multi-objective linear weighting, The federation-level cities in Anhui Province conduct land sustainable use evaluations [20]. In the comprehensive evaluation of the sustainable use level of urban land in Hunan Province, Zhao Xu constructed an evaluation index system from the three aspects of resource environment, economic development, and social harmony [21]. Liu Qing [22] built an index system around four aspects of land use, including economic benefits, intensification, environmental ecology, and social harmony, in the comprehensive evaluation of sustainable land use in the Changsha–Zhuzhou–Xiangtan area; Sun Yan constructed an evaluation index system for the sustainable use of land resources from the perspective of fragmentation in the comprehensive evaluation of the sustainable use of land in various townships in Fenyi County, Jiangxi [23]. Chen Shiyin et al. show a time series evaluation of land-use sustainability in Zhanjiang City, based on land-use intensity, land-use degree, land-use efficiency, and a four-dimensional land-use performance evaluation model that was constructed with variable land-use benefits [24]. Fu Bojie believes that the sustainable use of land is to maintain and protect the stability and growth of land productivity, tap into the production potential of land resources, and give full play to the economic benefits of the land. On this basis, Fu Bojie established an evaluation system and method for the sustainable use of land on the three levels of ecology, society, and economy [25].

It can be seen from domestic and foreign literature research that scholars study the level of sustainable land use from different perspectives, and the research mainly focuses on the construction of the evaluation index system and evaluation methods. In terms of the construction of the evaluation index system, the index system based on the aspects of "economy-society-ecology" and "productivity, safety, protection, economic feasibility, and social acceptability" is the most extensive. Evaluation methods or models include an analytic hierarchy process, entropy value method, ecological footprint method, gray relational method, PSR model, triangular model, etc. Most of the spatial scales of evaluation are at national and provincial levels. Many studies have been carried out on the evaluation of the sustainable use of land resources, and several important results have been obtained. However, there are only a handful of land sustainable use evaluations based on the concept of a circular economy.

The Guangdong–Hong Kong–Macao Greater Bay Area is one of the regions with the highest degree of openness and the strongest economic vitality in China. In recent years, with the accelerated development of urbanization, a large number of people have gathered in the Greater Bay Area's Economic Zone, exacerbating the contradiction between urban construction land and agricultural land. It is of great importance and urgency to study the sustainable use of land. In this study, the spatial heterogeneity of the sustainable land use level in the Guangdong–Hong Kong–Macao Greater Bay Area was studied not only to further explore the construction and evaluation methods of the sustainable land-use evaluation system but also to explore the current situation and trend of the sustainable land use in the economic integration region of China. The purpose is to provide a research basis for formulating relevant land-use planning policies, promoting the sustainable development of a regional economy in the future, achieving the coordinated development and integration of land ecological service supply and socio-economic activities in the Guangdong–Hong Kong–Macao Greater Bay Area, and provide a reference for sustainable land use in the Greater Bay Area.

2. Materials and Methods

2.1. Study Area

The Guangdong–Hong Kong–Macao Greater Bay Area is located between 21~25° N latitude and 111~116° E longitude, including the two special administrative regions of Hong Kong and Macau, as well as Guangzhou, Shenzhen, Zhuhai, Foshan, Huizhou, Dongguan, Zhongshan, Jiangmen, and Zhaoqing of Guangdong Province. There are 9 core urban agglomerations, with a total area of 56,000 km^2. It has a climate that is classified as south subtropical marine monsoon, with an annual average precipitation of 1929.8 mm and an average temperature of 21.9 °C. The landforms are mainly low mountains, hills, and delta plains. Ecological spaces such as river banks, seashores, forests, and farmlands are diverse, population and economic elements are dense, and the trend of urban spatial integration is obvious [26,27]. Exploring ecological networks at a regional scale has become the focus of implementing sustainable development strategies in the Greater Bay Area.

2.2. Data Sources

The following sources are the primary ones used: (1) Data from the corresponding year: Statistical Yearbook of Guangdong Province, Guangdong Statistical Yearbook of Natural Resources and Environment, China City Statistical Yearbook, China Urban Construction Statistical Yearbook, Guangdong Land and Resources Yearbook, CEADs China carbon accounting database and statistical yearbook of federations-level cities. (2) Baidu POI (Data supermarket) and China POI Database. (3) shp vector maps such as the Guangdong–Hong Kong–Macao Greater Bay Area Administrative zoning map are derived from the National Basic Geographic Information System and DATAV.GeoAtlas (Aliyun map network). The missing data are supplemented by the means substitution method.

2.3. Construction of Evaluation Index System

According to the systematization, comprehensiveness, practicability, and transparency principles of index design and configuration, starting from the "3R principle" of the concept of circular economy [28], combined with the "dual carbon target" [29], seven aspects of land-resource security, land-resource input reduction, land output, land-use structure, land ecological and environmental protection, land recycling, and land low-carbon use were selected as the criterion layer, and a total of 48 indicators were selected as the index layer to construct the evaluation system, such as Table 1 shows.

Table 1. This Evaluation index system and weight of sustainable land use in the Guangdong–Hong Kong–Macao Greater Bay Area.

Layer of Criterion	The Weight	Indicator Layer	The Weight	The Positive and Negative
Output of land	0.1663	Agricultural output value per unit of cultivated land	0.0318	+
		Land area per unit of agricultural, forestry and fishery output value	0.0086	−
		Land area per unit of industrial output	0.0075	−
		Unit of tertiary industry output covers an area	0.0078	+
		Engel coefficient	0.0250	+
		Rate of urbanization	0.0148	+
		Per capita residential land area	0.0355	+
		Urban per capita disposable income	0.0141	+
		GDP output of construction land per unit	0.0212	+
Land-use structure	0.1174	Proportion of residential land	0.0179	+
		The proportion of land for public facilities	0.0414	−
		Proportion of industrial land	0.0201	−
		Rate of green land	0.0132	−
		Per capita land area	0.0248	+
Reduction in land resource input	0.1136	Fertilizer input per unit of cultivated land	0.0268	−
		Mechanical power input per unit of cultivated land	0.0070	+
		Local fixed asset investment	0.0277	+
		Local governments have invested in science, education and health	0.0176	+
		Local average labor force	0.0147	+
		Land average real estate investment	0.0198	+
Security of land resources	0.1573	Per capita cultivated area	0.0276	−
		Density of population	0.0167	−
		Grain per unit yield	0.0151	+
		Proportion of arable land under effective irrigation	0.0129	+
		The proportion of industrial and mining land in construction land	0.0155	+
		The proportion of the area of the nature reserve in the area of jurisdiction	0.0391	+
		Investment in industrial pollution control as a percentage of GDP	0.0306	+

Table 1. *Cont.*

Layer of Criterion	The Weight	Indicator Layer	The Weight	The Positive and Negative
Low-carbon land use	0.1514	The proportion of wetland area	0.0360	+
		Carbon emission intensity	0.0186	−
		Number of buses per 10,000 people	0.0314	+
		Elasticity coefficient of energy consumption	0.0158	−
		Local average carbon emissions	0.0097	−
		Forest cover rate	0.0092	+
		Energy consumption per unit of GDP	0.0130	−
		Green coverage of built-up areas	0.0177	+
Level of land recycling	0.1738	Rate of land consolidation	0.0096	+
		Multiple seed index	0.0146	+
		Arable land replenishment index	0.0568	+
		We will bring soil erosion under control	0.0211	+
		Cumulative waterlogging control area	0.0313	+
		Mine environmental restoration and treatment rate	0.0404	+
Land ecological environment protection	0.1203	Per capita park green area	0.0190	+
		Local expenditure on energy conservation and environmental protection	0.0232	+
		The proportion of days when the air quality is better than Grade II	0.0176	−
		The amount of pesticides used in average cultivated land	0.0197	−
		Local average waste-water discharge	0.0115	−
		Average emissions of sulfur dioxide	0.0094	+
		Garbage removal volume of urban land per unit	0.0199	+

In the index system, land-resource security is the premise of sustainable land use; land-resource input reduction, land output, and land-use structure reflect the principle of "reduction". Land ecological environment protection reflects the principle of "recycling"; while land recycling reflects the principle of "reuse". Land-use change directly or indirectly affects the carbon emission and absorption process between the terrestrial ecosystem and the atmosphere, which is a dual body of carbon emission and absorption [30]. Human economic activities on construction land will generate a large amount of carbon emissions, and land-use types such as woodland, wetland, and garden land are important carbon sinks. With the development of economic society, the difference between carbon emissions and carbon sinks gradually expands [31]. From the perspective of carbon as a major production waste and carbon balance, low-carbon land use reflects the principle of "recycling" [32]. Among them, the proportion of wetland area, forest coverage rate and green coverage rate of built-up areas represent carbon absorption and belong to a carbon sink [33–35]. Carbon emission intensity, average local carbon emission, and energy consumption per unit of GDP reflect carbon emission and belong to carbon sources. The number of buses per 10,000 people means green and low-carbon living [36–38].

3. Evaluation of Sustainable Land Use in Guangdong–Hong Kong–Macao Greater Bay Area from the Perspective of Circular Economy

The term "entropy" was first proposed by the German physicist Clausius in 1865 as a measure of uncertainty that can be used to indicate the degree of order in a system [39,40]. When the index values of selected indicators differ greatly, it means that the index contains more effective information and a smaller entropy value, and the corresponding weight is larger [41,42]. If the difference between the index values of the selected index is small, it means that the index contains less effective information, a large entropy value, and a small corresponding weight. In overcoming the human bias introduced by subjective balancing methods, the index weight can be measured in a way that is more scientific and objective.

3.1. Data Standardization

Since the dimensions and units of each index data are different, each index cannot be directly calculated and compared, so it is necessary to standardize the data. There are two types of indicators: positive indicators and negative indicators [43]. The standardized formulas for different types of indicators are as follows:

(1) Positive indicators:

$$r_{ij} = X_{ij} - min\{X_{ij}\}/max\{X_{ij}\} - min\{X_{ij}\} \tag{1}$$

(2) Negative indicators:

$$r_{ij} = max\{X_{ij}\} - X_{ij}/max\{X_{ij}\} - min\{X_{ij}\} \tag{2}$$

When there are "n" evaluation units and "m" evaluation indicators, in the formula: X_{ij} represents the j-th individual index of the i-th evaluation unit (i = 1, 2, . . . , n; j = 1, 2, . . . , m). r_{ij} is the data standardized by X_{ij}.

(1) Calculate the Contribution P_{ij} of the i-th Evaluation Unit Data under the j-th Single Indicator to this Indicator

$$P_{ij} = r_{ij}/\sum_{i=1}^{n} r_{ij} \tag{3}$$

(2) Calculate the Entropy Value e_j of the j-th Index

$$e_{ij} = -k\sum_{i=1}^{n} P_{ij} \ln P_{ij} \tag{4}$$

(3) Calculate the Information Entropy Redundancy d_j

$$d_j = 1 - e_j \tag{5}$$

(4) Calculate the Weight w_j of the j-th Single Indicator

$$W_j = d_j/\sum_{j=1}^{m} d_j \tag{6}$$

The weight of each individual index can be computed using the techniques above, and the weight of the criterion layer index can be generated through accumulation.

3.2. ArcGIS Superposition Analysis

Spatial analysis is a general name for the technology of comprehensive analysis of spatial data, which is one of the core parts of a geographic information system [44–47]. Based on the evaluation-oriented index system, this paper applied the raster calculator tool of *ArcGIS10.2*, took 11 regions as units, used the weighted superposition method to carry out the superposition analysis of each evaluation index, obtained the results of comprehensive and sustainable land use in each region and presented them spatially to reflect the spatial characteristics of sustainable land use in the Guangdong–Hong Kong–Macao Greater Bay Area.

$$R = \sum_{i=1}^{n} w_i Y_i \tag{7}$$

There, R is the comprehensive score of sustainable land use in the criterion layer, w_i is the weight of the ith index, and Y_i is the standardized value of the ith index.

3.3. Standard Deviation Ellipse and Center of Gravity

The standard deviation ellipse (*SDE*) [48–50] and spatial center of gravity [51–53] can directly reflect the discrete degree and directionality of sustainable land use space in the Guangdong–Hong Kong–Macao Greater Bay Area in different periods. *SDE* is mainly composed of angles, major axis, and minor axes. The geological representation of the short and short axis of the ellipse is the standard deviation of the dispersion degree of the spatial distribution, and the main trend direction of the confirmed case element of the angle (θ) response. The formula is:

$$\tan\theta = \left(\left(\sum_{i=1}^{n} xi^2 - \sum_{i=1}^{n} yi^2\right) + \sqrt{\left(\sum_{i=1}^{n} xi^2 - \sum_{i=1}^{n} yi^2\right)^2 + 4\left(\sum_{i=1}^{n} x\,yi\right)}\right)/2\sum_{i=1}^{n} x\,yi \tag{8}$$

$$\sigma_x = \sqrt{\frac{2\sum_{i=1}^{n}\left(\omega_i \widetilde{x}_i \cos\theta - \omega_i \widetilde{y}_i \sin\theta\right)^2}{\sum_{i=1}^{n} \omega_i^2}} \tag{9}$$

$$\sigma_y = \sqrt{\frac{2\sum_{i=1}^{n}\left(\omega_i \widetilde{x}_i \sin\theta + \omega_i \widetilde{y}_i \cos\theta\right)^2}{\sum_{i=1}^{n} \omega_i^2}} \tag{10}$$

This paper analyzes the evolution of the spatial pattern distribution center of sustainable land use in the Guangdong–Hong Kong–Macao Greater Bay Area. The formula is:

$$X = \sum_{i=1}^{n} M_i X_i / \sum_{i=1}^{n} M_i \tag{11}$$

$$Y = \sum_{i=1}^{n} M_i Y_i / \sum_{i=1}^{n} M_i \tag{12}$$

3.4. Calculate the Overall Evaluation Value

According to the weight obtained above, the sustainable land-use level of the evaluation unit under the concept of a circular economy [54–56] is calculated using the multi-objective linear weighting function as follows:

$$Y = \sum_{i=1}^{7}\left(\sum_{j=1}^{n} r_j w_j\right) \times a_i \tag{13}$$

Among them: Y represents the sustainable land use level of each evaluation unit under the concept of the circular economy; r_j represents the standardized value of the j-th individual index; w_j represents the weight of the j-th individual index; a_i represents the weight of the i-th criterion layer index (i = 1, 2, 3 . . . , 7; j = 1, 2, 3, . . . , 48). The calculation results are shown in Table 2.

Table 2. Evaluation results and ranking of sustainable land use in the Guangdong–Hong Kong–Macao Greater Bay Area in 2021.

City	Output of Land	Land Use Structure	Reduction in Land Resource Input	Security of Land Resources	Low-Carbon Land Use	Level of Land Recycling	Land Ecological Environment Protection	Comprehensive Evaluation	Ranking
Shenzhen	0.1289	0.0741	0.0201	0.0289	0.1154	0.0963	0.0454	0.0679	1
Guangzhou	0.1013	0.0713	0.0214	0.0336	0.0931	0.0897	0.0509	0.0668	2
Hong Kong	0.0991	0.0592	0.0318	0.0400	0.0770	0.0751	0.0524	0.0658	3
Foshan	0.0964	0.0583	0.0320	0.0547	0.0756	0.0585	0.0526	0.0650	4
Dongguan	0.0805	0.0486	0.0410	0.0568	0.0754	0.0545	0.0537	0.0642	5
Zhuhai	0.0799	0.0369	0.0459	0.0618	0.0715	0.0540	0.0591	0.0629	6
Macau	0.0794	0.0346	0.0545	0.0725	0.0705	0.0533	0.0598	0.0622	7
Huizhou	0.0660	0.0334	0.0571	0.0805	0.0630	0.0532	0.0657	0.0606	8
Zhongshan	0.0528	0.0297	0.0667	0.0812	0.0606	0.0527	0.0728	0.0603	9
Jiangmen	0.0340	0.0205	0.0726	0.1057	0.0384	0.0505	0.0773	0.0593	10
Zhaoqing	0.0313	0.0203	0.0897	0.1085	0.0334	0.0096	0.0780	0.0486	11

4. Result Analysis

4.1. Results and Analysis of Spatio-Temporal Evolution of Land Sustainable Development

4.1.1. In Terms of Time Characteristics, the Level of Sustainable Land Development in the Greater Bay Area Continues to Improve

In general, the score of land sustainable development in the Guangdong–Hong Kong–Macao Greater Bay Area showed an obvious upward trend from 2010 to 2021, and the level of land sustainable development continued to improve. Specifically, the score of land sustainable development in 2010 was 0.371, which was still at a relatively low level. The score for land sustainable development in 2015 was 0.407, which was slightly higher than that in 2010. The land sustainable development score in 2018 was 0.448; in 2021, the level of sustainable land development in the Guangdong–Hong Kong–Macao Greater Bay Area significantly increased to 0.735. The significant improvement in land sustainable development from 2010 to 2021 is mainly due to the steady development of the economy and the significant improvement of the ecological environment [57–59], which is closely related to the proposal and implementation of the 13th Five-Year Plan. During this period, the regional economy maintained a medium-high growth rate [60–63]. The results are shown in Table 3.

Table 3. Sustainable land development in the Guangdong–Hong Kong–Macao Greater Bay Area from 2010 to 2021.

Time	Comprehensive Sustainable Development and Utilization of Land
2010	0.371
2015	0.407
2018	0.448
2021	0.753

4.1.2. In Terms of Spatial Characteristics, the Center of Gravity of the Horizontal Space of Sustainable Land Use Shifted from North to South

The center of gravity model was used to calculate the offset trajectory of the center of gravity in the horizontal space of land for sustainable use in the Guangdong–Hong Kong–Macao Greater Bay Area. From Figure 1, it can be seen that the horizontal gravity center of sustainable land use in the Guangdong–Hong Kong–Macao Greater Bay Area from 2010 to 2021 changes dimensionally, and the spatial gravity center shifts from north to south.

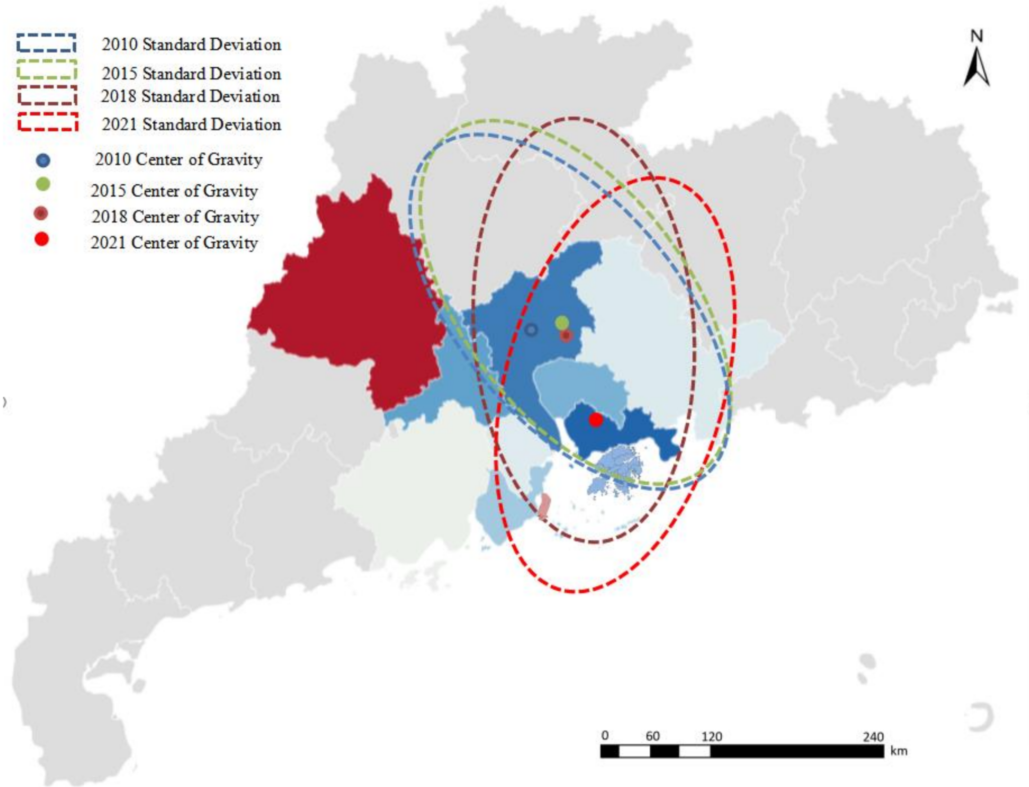

Figure 1. Elliptic diagram of standard deviation of sustainable land use spatial distribution in the Greater Bay Area.

The sustainable land-use level was centered on the provincial capital Guangzhou, and the standard deviation ellipse was distributed northwest to southeast. In 2010, the center of gravity of the standard deviation ellipse was located at Baiyun Mountain, Guangzhou (23.191213° N, 113.306527° E). By 2021, the center of gravity of the standard deviation ellipse will shift from the north to the southeast. The center of gravity of the standard deviation ellipse is located in the area of Shenzhen City (22.657618° N, 113.97127° E).

4.2. Regional Difference Analysis of Comprehensive Evaluation of Sustainable Land Utilization

Based on the calculation of the data in Table 2 above, it can be seen that the average level of sustainable land use in the cities at various levels in the Greater Bay Area under the concept of a circular economy is 0.0621. Shenzhen, Guangzhou, Hong Kong, Foshan, Dongguan, Zhuhai, and Macau are above the average level. These cities have a high level of sustainable land use and strong comprehensive land-use capabilities. The main reason is that Guangzhou is the provincial capital of Guangdong Province [64–66], which has advantages in terms of funds and policies for economic development and ecological environmental protection, while Shenzhen, Foshan, Dongguan, and Zhuhai are relatively close to the provincial capital and are driven by the radiation of the provincial capital city [67,68]. Located at the core of the Guangdong–Hong Kong–Macao Greater Bay Area, on the one hand, is conducive to strengthening the driving role of the "Hong Kong-Shenzhen" pole and promoting the economic development of Shenzhen and Hong Kong [69–71]. Therefore, these cities have strong economic and social development advantages, so the sustainable use of land shows a high level, but at the same time, in order to achieve true sustainable development, they must also pay attention to the protection of the entire ecological environment. The results are shown in Figure 2.

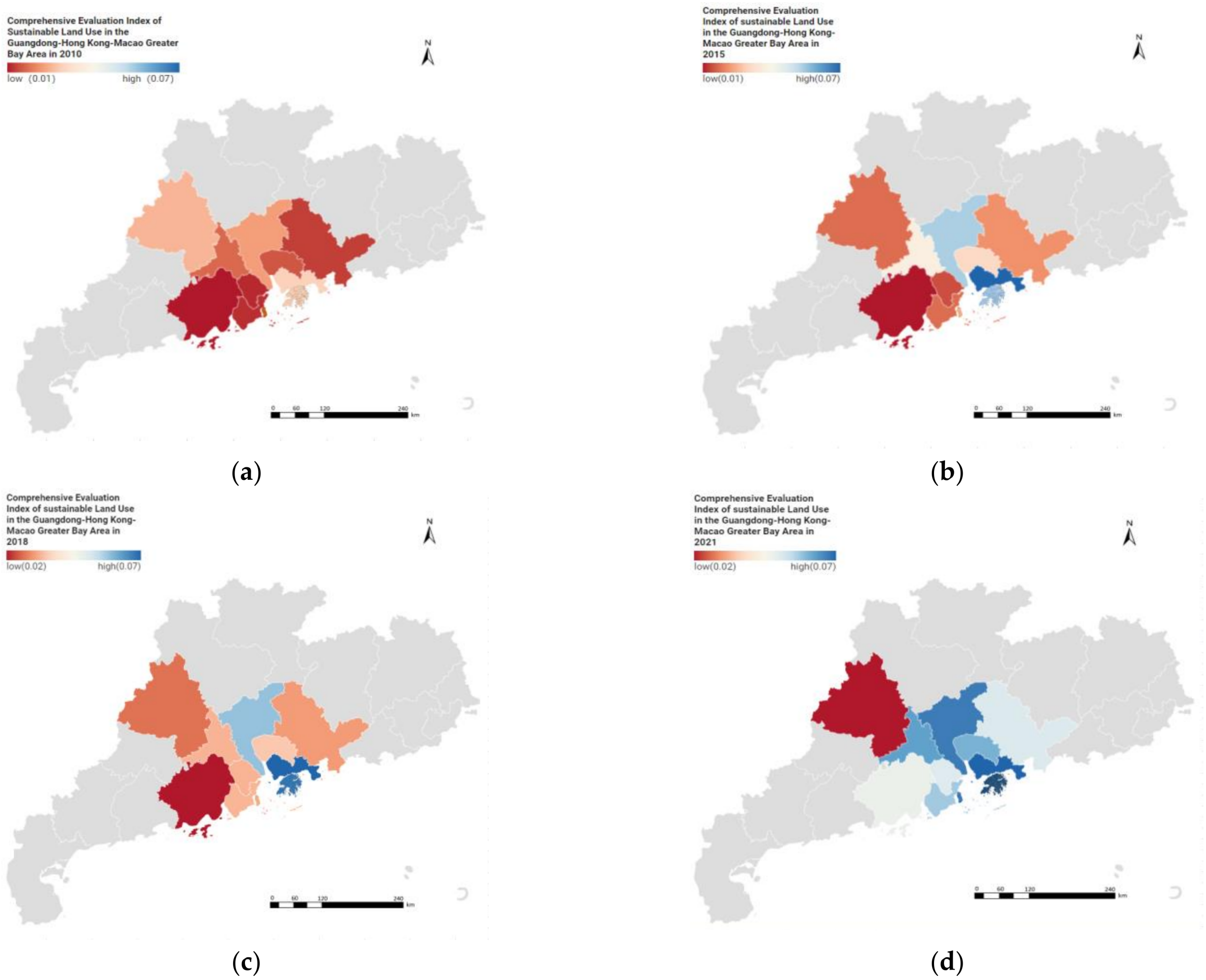

Figure 2. Comprehensive Evaluation of Sustainable Land Use in the Guangdong–Hong Kong–Macao Greater Bay Area (2010–2021): (**a**) In 2010; (**b**) In 2015; (**c**) In 2018; (**d**) In 2021.

Huizhou, Jiangmen, Zhongshan, and Zhaoqing are below the average level, the level of sustainable land use is low, and the comprehensive land-use ability is weak. When it comes to the economic development level of Huizhou, it can be found that the economy of its central district is very weak, and the economy of the following district is also not strong. Huizhou's construction level and economic level are disjointed. For example, Huicheng District in the central area has a relatively high level of urban development (there are large rural areas), but its economic level is backward and there is no other industry except real estate. The economic development level of Jiangmen is relatively backward among the nine cities in the Pearl River Delta [72–74]. In 2021, Jiangmen's economic aggregate was 360.1 billion yuan, ranking third from the bottom in the Pearl River Delta and only 3.5 billion yuan higher than second from the bottom in Zhongshan. Jiangmen's industrial level is not high, slow power conversion and other problems emerged, the economic development slowed down, and the ranking gradually declined. Zhaoqing is relatively far from the core areas of Guangdong and Shenzhen, and its industrial support and diffusion are limited. It lacks the support of large enterprises and its own high-tech industries, so its economic development is relatively slow [75–77].

The first reason for Zhongshan's economic stall is its geographic location. The Zhongshan economic recession is caused not only by the Guangzhou-Buddhist Shenzhen-Guan supercenter siphon effect but also by their own industrial upgrading lag factors.

Therefore, the results showed that there were obvious regional differences in the level of sustainable land use in the Greater Bay Area. The comprehensive score of the first place Shenzhen City was 0.0679, while that of the last place Zhaoqing City was 0.0486, with a difference of 0.0193, indicating that the level of sustainable land use in the Guangdong–Hong Kong–Macao Greater Bay Area was not balanced. In the future development process, we should prioritize coordinated development across all regions and increase economic and policy support for underserved areas.

4.3. Analysis of Regional Differences in Criterion Layer

The evaluation was conducted with seven layers of eligibility requirements: land-resource security, land-resource input reduction, land output, land-use structure, land ecological environment, land recycling level, and land low-carbon use. The specific evaluation results are shown in Table 4. The numerical range of land resource security is 0.0262. The numerical range of land resource input reduction is 0.0207. The numerical range of land output was 0.0277. The range of values for land use structure was 0.0282. the range of land ecological environment protection value was 0.0138. The range of land recycling level was 0.0472. The range of low-carbon utilization values for land was 0.0268. It can be seen that there is a relatively small gap between cities in land ecological environment protection, and a large gap in the other six aspects, among which the gap in land output is the largest, indicating that there are great differences in the degree of social and economic development among federation-level cities in the Guangdong–Hong Kong–Macao Greater Bay Area. In addition, the overall score of land-use structure is low, indicating that an unreasonable land-use structure is common in all regions of the Guangdong–Hong Kong–Macao Greater Bay Area. For example, the scores of land-use structures in Huizhou, Zhongshan, Jiangmen, Zhaoqing, and other cities are in the reverse position.

Table 4. Numerical range table of criteria layer for sustainable land use evaluation in the Guangdong–Hong Kong–Macao Greater Bay Area in 2021.

City	Output of Land	Land-Use Structure	Reduction in Land Resource Input	Security of Land Resources	Low-Carbon Land Use	Level of Land Recycling	Land Ecological Environment Protection
Max	0.0355	0.0414	0.0277	0.0391	0.0360	0.0568	0.0232
Min	0.0078	0.0132	0.0070	0.0129	0.0092	0.0096	0.0094
Value of range	0.0277	0.0282	0.0207	0.0262	0.0268	0.0472	0.0138

Meanwhile, by comparing the scores of different aspects of the same city, it is not difficult to find that different cities have different advantages and disadvantages in terms of sustainable land use. Shenzhen has the best performance in terms of land output, which is 0.1289, ranking first in the province, which is in line with the actual situation, but has the worst performance in terms of land resource security (0.0289), which may be related to urban expansion. Guangzhou, Foshan, and Dongguan are good in terms of land output, but poor in terms of land-use structure, so it is necessary to strengthen the rational allocation of land and optimize the land-use structure. The scores of Zhuhai and Macao are close to each other and their development is more balanced, but they are not outstanding in all aspects and have the potential for further development. Zhongshan, Jiangmen and Zhaoqing had a good performance in land recycling, but a poor performance in land-use structure.

5. Conclusions

This paper takes the land system of the Guangdong–Hong Kong–Macao Greater Bay Area as the research object, and firstly, introduces the evaluation index system under the traditional circular economy concept with GIS technology as the basis, combines it with the "double carbon target", and establishes the evaluation index system of sustainable land use with GIS model. The following results were obtained:

(1) Regional differences and uneven development levels are considered in the comprehensive evaluation of sustainable land use in the Guangdong–Hong Kong–Macao Greater Bay Area. Shenzhen, Guangzhou, Hong Kong, Foshan, Dongguan, Zhuhai, and Macao are above the average level of sustainable land use. These cities have a high level of sustainable land use (an average level of 0.0621), while the rest of the regions have a low level of sustainable land use.
(2) Through the analysis of the seven criteria layers, it is found that the difference in cities in the Greater Bay Area in land ecological environment protection is relatively small, while the difference between cities in the other six aspects is large, among which the difference between land output is the largest, indicating that there are great differences in the degree of social and economic development among federation-level cities in the Guangdong–Hong Kong–Macao Greater Bay Area.
(3) In terms of time characteristics, sustainable land use showed a steady upward trend in the 11 years from 2010 to 2021.
(4) In terms of spatial characteristics, entropy weight analysis and superposition analysis were used to establish the evaluation index system of sustainable land use in the GIS model. It is verified that the center of gravity model is used to calculate the deviation track of the center of gravity of the horizontal space of land for sustainable use in the Guangdong–Hong Kong–Macao Greater Bay Area. From 2010 to 2021, the horizontal gravity center of sustainable land use in the Guangdong–Hong Kong–Macao Greater Bay Area changed dimensionally, and the spatial gravity center shifted from north to south.

However, due to the limitations of research cognition and data acquisition, the index system of sustainable land use constructed in this paper is still to be discussed. For example, lack of soil slope, soil acidity and alkalinity, and other soil quality indexes closely related to the level of sustainable land use and the in-depth discussion on the rationality of established indexes, and some results may be inconsistent with reality. Therefore, the reliability of the research results and conclusions in this paper is greatly reduced. It is the goal of our future efforts to investigate the development of a land sustainable use evaluation index system by combining ecological environment and information system technology with multidisciplinary theories and methods.

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