

Original Research

Temporal-Spatial Characteristics and Driving Factors of Urban Land Use Performance: Evidence from Guangdong

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Abstract

Based on the panel data of 21 cities in Guangdong Province from 2000 to 2019, this paper investigates the temporal-spatial characteristics and driving factors of urban land use performance (ULUP) in Guangdong Province by using entropy weight TOPSIS method, Dagum Gini coefficient, natural discontinuity method, standard deviation ellipse, gravity center model and geographic detector. The main conclusions are as follows: (1) There are great differences in the distribution of land use performance among cities in Guangdong Province, which decreases from the Pearl River Delta to the surrounding cities. From the time dimension, the land use performance of Guangdong Province generally shows an upward trend. (2) The cities in the Pearl River Delta are basically located in the first and second echelons, showing an agglomeration development trend and radiation driving role in space, which greatly improves the land use performance of the surrounding cities. Regional differences constitute the main source of internal differences in land use performance in Guangdong Province, followed by intraregional differences, and then over variable density. (3) During the study period, the directionality of the spatial distribution of ULUP in Guangdong Province has weakened, showing a spatial distribution pattern from northeast to southwest, and the evolution force of spatial distribution comes from the growth in northeast to southwest. The focus of land use performance is located in Dongguan and gradually moved to the border with Shenzhen. (4) From the perspective of division dimension, the driving factors from large to small are industrial economy, infrastructure, humanistic factors and government support. From the perspective of sub factors, five indicators such as economic growth, scientific and technological innovation talents, public transport, industrial upgrading and technological innovation have become the biggest driving factors.

Keywords: land use, performance evaluation, temporal and spatial evolution, driving factors

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Introduction

Urban land use plays an important role in human survival, urban planning and social development [1-2]. With the increasing degree of economic globalization and the acceleration of industrialization, urbanization and marketization, mankind has expanded the scope of land resource utilization. However, the unreasonable development and utilization of land resources lead to the prominent contradiction between man and land, resulting in frequent land degradation, biodiversity reduction and ecological environment pollution, which seriously restricts the sustainable development of economy and society. According to IPBES's "2018 Global Land Degradation Status and Recovery Assessment" report, more than 75% of the earth's land has been significantly degraded, threatening the well-being and peace of 3.2 billion people. As China's economy continues to "Bottom" and the global economy is in a general downturn, land is a "Fulcrum" and even a "Leverage". The State Council issued the implementation opinions on building a more perfect market-oriented allocation system and mechanism of factors in 2020, which reflects the reform direction of China's land management system and provides guidance for optimizing the allocation of land resources and sustainable land development. Under the constraints of scarce land resources, maximizing the overall benefits of land use is of great practical significance to promote the high-quality development of regional economy.

The research on land use performance involves many disciplines, such as statistics, land management, geography, economics and so on. The appraisal and evaluation of land use quality and productivity is conducive to clarify the current situation of regional land use economic and environmental benefits, fully tap the potential of land resources and realize the effective way of optimal allocation of land resources [3]. According to the existing literature, some scholars measure land use performance from a single index such as unit land output and building area ratio [4-5]. However, the input and output of land use is a complex process. There will be great one sidedness and limitations in measuring land use performance by a single index, which cannot comprehensively consider the whole picture of land use performance. Therefore, it is necessary to make a multi factor comprehensive index analysis of land use efficiency. The construction of multi factor comprehensive index generally takes land, capital and labor as the input indicators of land use, and measures the output indicators of land use from the aspects of economy, society and environment [6]. At present, the methods to evaluate land use performance mainly include stochastic frontier model [7], data envelopment analysis [8-9], principal component analysis [10], analytic hierarchy process and entropy weight method [11-12]. In order to improve the understanding of land use, we often link

land use performance with human activities, and pay attention to the underlying economic factors. In terms of the influencing factors of model selection, scholars generally select empirical influencing factors from the aspects of economy, society, humanities, government and so on [13]. In terms of model construction, obstacle factor diagnosis [14], coupling model [15], factor analysis model [16], fuzzy matter-element model and weighted summation model are generally used [17-18].

The existing research provides better enlightenment for clarifying the research of urban land use performance (ULUP), but the land use sustainability has not been well solved [19]. There are still breakthroughs in research perspectives, measurement methods, characteristics of temporal and spatial differences and analysis of driving factors [20]. For example, the traditional data envelopment method has limitations such as measurement error, lack of research topics from the perspective of dynamic evolution, and the traditional measurement model lacks spatial correlation factor analysis. Guangdong Province is a strong economic province in China. With the continuous advancement of urbanization and industrialization of urban economic construction, the contradiction between supply and demand of land resources has become increasingly prominent. The paper will take cities in Guangdong Province as a research sample to explore the current situation of urban land use and find effective ways to improve land use performance. The marginal contributions of this paper are as follows: Build a comprehensive evaluation system including environmental constraints, use the improved entropy weight TOPSIS method to make up for the shortcomings of measurement methods such as entropy weight method in previous studies, and the measurement results can more accurately reflect the current situation of ULUP in Guangdong Province. This paper use dagum Gini coefficient, natural discontinuity method, standard deviation ellipse, center of gravity model and other analysis methods to explore the spatial-temporal distribution and evolution characteristics of land use in Guangdong. In addition, the article use geographic detectors to investigate the core influencing factors affecting ULUP in Guangdong Province, so as to provide scientific reference for improving ULUP in Guangdong Province.

Materials and Methods

Study Area

Guangdong, the provincial capital Guangzhou, the largest economic province in China, is the seat of Swire's "Pangu country in the South China Sea" and the earliest birthplace of the maritime Silk Road. Guangdong province is located in the southernmost part of Chinese mainland. It is located at the North Latitude 20°13'-25°31' and the East Longitude

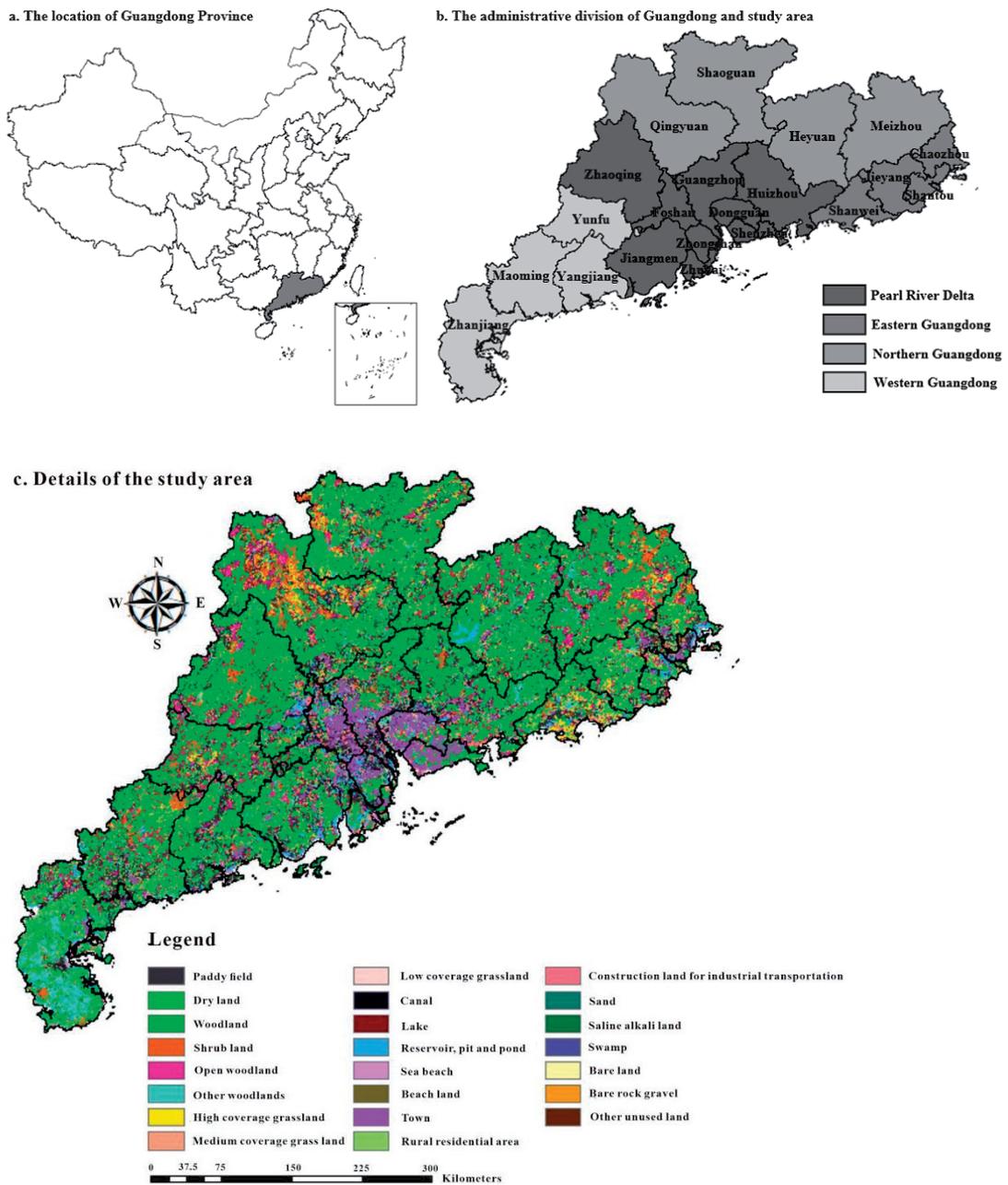


Fig. 1. Spatial distribution of land use types in the study area and Guangdong Province.

109°39'-117°19', East to Fujian, North to Jiangxi, Hunan, West to Guangxi, South to the South China Sea. The East and West sides of the Pearl River Delta are respectively bordered by Hong Kong and Macao special administrative regions, and the southwest Leizhou peninsula is separated from the Qiongzhou Strait and Hainan province. The land area of the province is 179800 square kilometers, accounting for about 1.87% of the national land area. Guangdong Province governs 21 prefecture level cities, which can be divided into four regions: the Pearl River Delta, northern Guangdong, eastern Guangdong and western Guangdong. Due to the imbalance of social and economic benefits and eco-environmental benefits among cities in Guangdong Province, improving the level of land

intensification and land use quality is the only way to achieve sustainable development.

Data Source

This paper selects 21 prefecture level and above cities in Guangdong Province from 2000 to 2019. The relevant data are from China Urban Statistical Yearbook, Guangdong statistical yearbook, EPS database, etc. If there is a lack of individual data, the interpolation method is used to complete it.

Referring to the existing literature on land use performance evaluation [21-23], this paper constructs the ULUP evaluation index system from three aspects: meeting the needs of human living, urban industrial and

Table 1. ULUP evaluation index system.

Target layer	Sub target	Criterion layer	Index layer	+/-		
ULUP	Investment	Land input level	Proportion of built-up area	+		
			Average investment in fixed assets	+		
			Average number of people in secondary and tertiary industries	+		
			Average power consumption of the whole society	+		
	Produce	Land use degree		Average construction land area	+	
				Population density of built-up area	+	
				Average road area	+	
		Land use benefit			Average output value of secondary and tertiary industries	+
					Average wage of on-the-job employees	+
					Average retail sales of social consumer goods	+
					Average fiscal revenue	+
		Ecological sustainability of land use			Greening coverage rate of built-up area	+
					Average industrial wastewater	-
					Ground average industrial smoke and dust	-
					Average industrial sulfur dioxide	-

commercial production and urban ecological sustainable development. Based on the input-output method, this paper takes the land input level, land use degree, land use efficiency and land use ecological sustainability as the criterion level indicators, including two first-class indicators, four second-class indicators and fifteen third-class indicators. Among them, the land input level includes four production factors: land, capital, labor and energy, which are the area of built-up area, investment in fixed assets, the number of people in secondary and tertiary industries and the power consumption of the whole society. The output is considered from three aspects: economic, social and environmental benefits, mainly considering the degree of land use, land use benefits and land use sustainability. Among them, the degree of land use is mainly measured from three aspects: construction land, population density and road area. Land use benefits include the output value of secondary and tertiary industries, employee wages, retail sales of social consumer goods and fiscal revenue. The ecological sustainability of land use includes the greening rate of built-up areas and industrial three wastes.

Methods

Entropy Weight TOPSIS Method

The core idea of this method is to unify the dimensions of each measurement index, give weight by entropy weight method, and then quantify and rank the performance by TOPSIS method. Entropy weight

method reduces the interference of subjective human factors, and TOPSIS method quantifies the ranking by comparing the relative distance between each measurement object and the best and worst scheme. The paper use entropy weight TOPSIS method to measure and evaluate the comprehensive level and subsystem level of land use performance in Guangdong Province, which makes the measured land use performance results more objective and reasonable [24].

Standard Deviation Ellipse Method

By measuring the direction and distribution of data, the output result is ellipse, and the spatial evolution characteristics such as central trend, discrete trend and direction trend of geographical elements are summarized. The long half axis of the ellipse represents the data distribution direction, and the short half axis represents the data distribution range. The difference is ellipticity, which indicates the directional characteristics of data spatial distribution. This paper uses the standard deviation ellipse to explore the spatial distribution and evolution characteristics of ULUP in Guangdong Province [25].

Dagum Gini Coefficient Method

This method was first used to measure income imbalance, and then widely used in the analysis of regional development differences. Dagum Gini coefficient can be decomposed into intra regional difference contribution, inter regional contribution

and hypervariable density [26]. In this paper, Guangdong Province is divided into four regions: Pearl River Delta, eastern Guangdong, northern Guangdong and western Guangdong. According to this method, the composition and source of spatial differences in ULUP in Guangdong Province can be revealed.

Geographic Detector Method

Geographic detectors can measure the spatial differentiation of geographic elements and the related driving factors behind them. The core idea is that if the independent variable has an important impact on the dependent variable, there should be similarity in the spatial distribution of the two. The value range of the detection power value q of the influencing factor is $[0,1]$. The greater the value of q , the greater the influence of this factor on the spatial distribution of ULUP. This paper use geographic detectors to detect the influencing factors of the spatial distribution of ULUP in cities in Guangdong Province [27].

Results and Discussion

Spatial Distribution Characteristics of Land Use Performance

Based on the constructed ULUP measurement system, the results are shown in Table 2. The results show that there are great differences in the distribution of land use performance among cities, showing a gradient differentiation pattern of Pearl River Delta (0.1211)>Eastern Guangdong (0.0354)>Western Guangdong (0.0066)>Northern Guangdong (0.0161). Shenzhen with the highest comprehensive score of 0.4326 and Heyuan with the lowest score of 0.0059 have a great difference. The former is 73.32 times higher than the latter, indicating that there are great differences in ULUP among cities in Guangdong Province, and the collaborative optimization ability of land use performance among different cities is weak. As a leading demonstration area of socialism with Chinese characteristics, Shenzhen has an obvious "Dominance" status. With the policy dividend of the special economic zone of reform and opening up, Shenzhen has become an international

Table 2. ULUP and level of each subsystem.

City	Composite index	Rank	Degree of investment	Rank	Utilization degree	Rank	Land benefit	Rank	Environmental benefit	Rank
Shenzhen	0.4326	1	0.6075	1	0.5052	1	0.3575	1	0.1896	3
Dongguan	0.2050	2	0.2572	2	0.4439	2	0.0886	3	0.2900	1
Guangzhou	0.1206	3	0.1799	3	0.1562	5	0.0923	2	0.1604	12
Zhuhai	0.1055	4	0.1476	5	0.2335	3	0.0576	6	0.2018	2
Foshan	0.0971	5	0.1608	4	0.0877	6	0.0710	4	0.1603	13
Zhongshan	0.0854	6	0.1450	6	0.0833	7	0.0602	5	0.1539	16
Shantou	0.0833	7	0.1126	7	0.1962	4	0.0464	7	0.1616	11
Yunfu	0.0272	8	0.0075	17	0.0585	9	0.0066	20	0.1579	15
Jieyang	0.0252	9	0.0250	9	0.0674	8	0.0140	8	0.1518	17
Chaozhou	0.0194	10	0.0218	11	0.0436	10	0.0130	9	0.1744	5
Huizhou	0.0185	11	0.0313	8	0.0242	15	0.0119	10	0.1650	10
Jiangmen	0.0159	12	0.0224	10	0.0263	14	0.0114	11	0.1772	4
Zhanjiang	0.0152	13	0.0130	13	0.0357	11	0.0092	14	0.1738	7
Shanwei	0.0136	14	0.0114	14	0.0308	12	0.0098	13	0.1440	20
Maoming	0.0129	15	0.0112	16	0.0281	13	0.0099	12	0.1592	14
Zhaoqing	0.0096	16	0.0144	12	0.0101	17	0.0071	16	0.1737	8
Yangjiang	0.0093	17	0.0112	15	0.0140	16	0.0076	15	0.1464	19
Qingyuan	0.0070	18	0.0056	19	0.0064	19	0.0070	17	0.1241	21
Meizhou	0.0070	19	0.0037	20	0.0100	18	0.0067	18	0.1512	18
Shaoguan	0.0068	20	0.0061	18	0.0053	20	0.0067	19	0.1740	6
Heyuan	0.0059	21	0.0033	21	0.0035	21	0.0060	21	0.1656	9

metropolis. Dongguan, Guangzhou and Shenzhen are geographically close, complementary industries and economies, and high land use performance. The land use performance of most cities in Guangdong Province is quite different and needs to be improved. Except that Shenzhen, Dongguan, Guangzhou and Zhuhai scored higher than 0.1, the distribution of land use scores in other cities was less than 0.1, accounting for 80.95% of the total number of cities investigated. The urban spatial differentiation characteristics of land input level, land use degree and land use benefit are also significant. The score differences between the first ranked Shenzhen and the last ranked Heyuan are 184.09 times, 144.34 times and 59.58 times respectively.

From the perspective of sustainable land use, Dongguan, Zhuhai, Shenzhen, Jiangmen and other cities in the Pearl River Delta have accelerated urban renewal and improved the living environment and urban quality as a whole. By making full use of coastal resources, environment and spatial advantages, cities in the Pearl River Delta create a good business environment, a new city in the international waterfront and bay area and an ecological livable demonstration new city. Shaoguan, Zhanjiang, Zhaoqing, Heyuan and other non Pearl River Delta cities are rich in land, forestry, mineral and tourism resources, with unique ecological environment. The government has made remarkable achievements in ecological environment treatment, and the quality of air and water environment is in the forefront of the province all year round. Although Qingyuan, Shanwei, Yangjiang, Meizhou and other non Pearl River Delta cities have a good natural ecological environment, the environmental pollution caused by production and life is particularly serious in development and construction,

environmental risks and potential safety hazards are prominent.

Time Characteristics of Land Use Performance

From the time dimension (Fig. 2), the land use performance of Guangdong Province generally shows an upward trend, from 0.0289 in 2000 to 0.0890 in 2019, and the land use performance has increased by 3.08 times. Among them, there was a “Cliff” decline in land use efficiency in 2008; Since 2009, the land use performance of Guangdong Province has been rising steadily. This is because the Guangdong Provincial Government upgraded the “Three Old Transformation” into the provincial development strategy (Transformation of old towns, old factories and old villages) in 2009. The overall planning of transformation policies promoted the comprehensive improvement of land, revitalized the stock of construction land, promoted industrial transformation, urban transformation and environmental reconstruction, and improved land use performance. The time changes of other subsystems are as follows: the input level of land use has slowed down since 2013, and land use has gradually developed towards intensification. The degree of land use has maintained a growth level of about 2.00% since 2009, and the intensity of land use has increased steadily. The degree of land performance has maintained a growth level of 15% since 2000, and the sustainable development of land use has maintained a positive growth level since 2009. The overall land use performance of Guangdong Province is getting better. Through the “Three Old Transformation” policy,

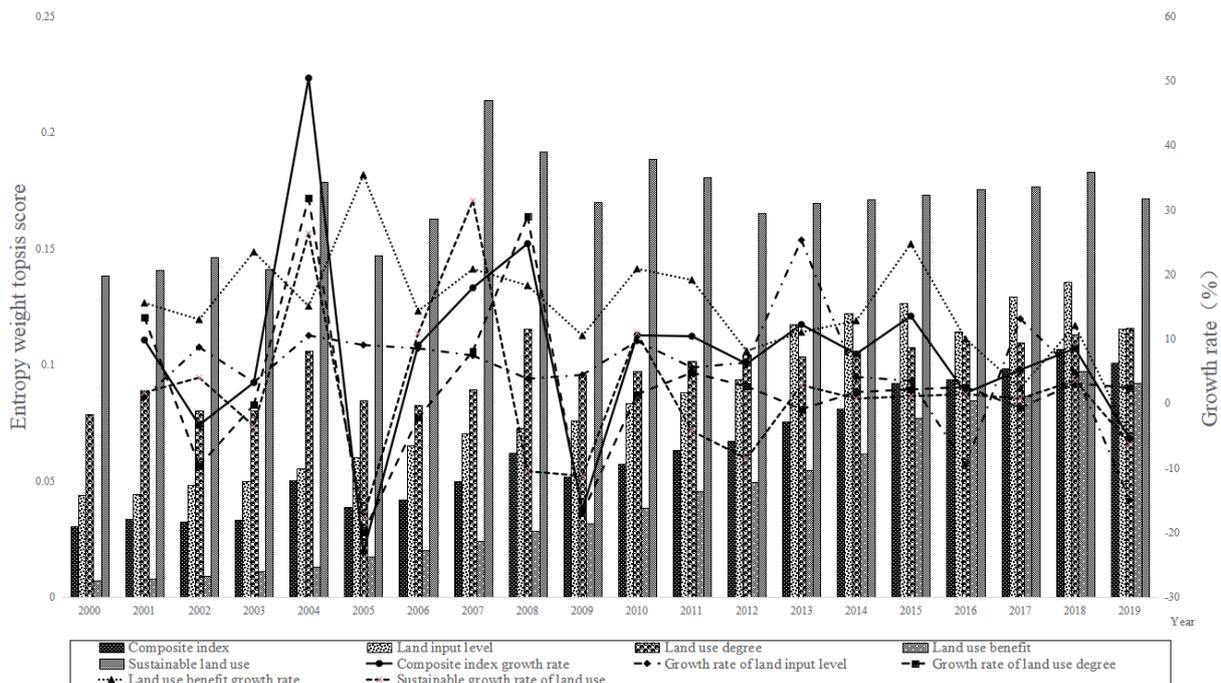


Fig. 2. Time characteristics of land use performance in Guangdong.

the allocation of land resources is gradually optimized to improve land use efficiency and benefits.

Cluster Analysis of Land Use Performance

Due to the large difference of urban area, in order to more intuitively reflect the difference of overall land use performance, ArcGIS 10.5 software is used to draw the land use performance of urban units in 2000 and 2019 (Limited to space, only two years are selected). According to the natural fracture method, we divide the sample cities into five echelon levels according to their performance from high to bottom.

The results show that (Fig. 3, Fig. 4), the land use performance generally decreases from the Pearl River Delta to the surrounding cities. The cities in the Pearl River Delta are basically located in the first and second echelons, showing an agglomeration development trend and radiation driving role in space, which greatly improves the land use performance of the surrounding cities. The first echelon is only Shenzhen, with the proportion of urban quantity and urban area being 4.7619% and 1.1105% respectively. The second echelon was promoted from the original third

echelon and expanded to six cities such as Dongguan, Guangzhou, Foshan, Zhongshan, Zhuhai and Shantou. The proportion of urban quantity and urban area increased from 4.7619% and 1.3679% in 2000 to 28.5714% and 10.7940% in 2019. Except Shantou, the cities in the Pearl River Delta are basically located in the first and second echelons. The third echelon was promoted from the fourth echelon. So far, it includes Jieyang, Chaozhou and Huizhou. The number of cities has decreased (from 23.8095% to 14.2857%), but the urban area has expanded (from 9.4260% to 10.9875%). Chaoshan area is composed of three prefecture level cities including Chaozhou, Shantou and Jieyang. It is the most potential area in Guangdong except the Pearl River Delta. So far, the fourth echelon cities include Zhanjiang, Maoming, Shanwei and Jiangmen, with a decrease in the number (from 33.3333% to 19.0476%) and a decrease in the urban area (from 32.7094% to 21.7219%). The fifth echelon cities remain basically unchanged, including Yunfu, Qingyuan, Shaoguan, Heyuan, Meizhou, Zhaoqing and Yangjiang. In 2019, the proportion of urban quantity and urban area were 33.3333% and 55.3861% respectively. Among them, except Zhaoqing and Yangjiang, all cities in northern Guangdong fall into the fifth echelon. Due to the low

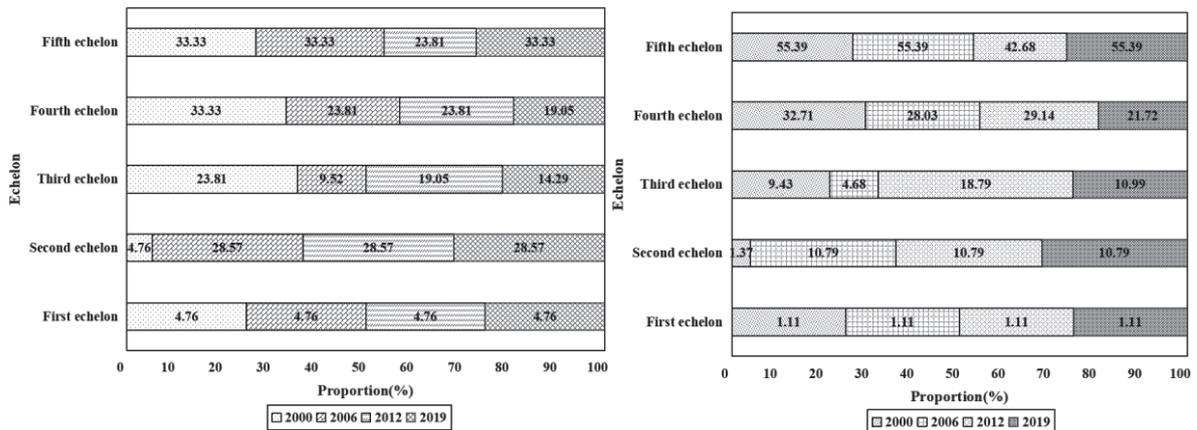


Fig. 3. Number proportion (left) and area proportion (right) of ULUP grading unit cities in Guangdong Province from 2000 to 2019.

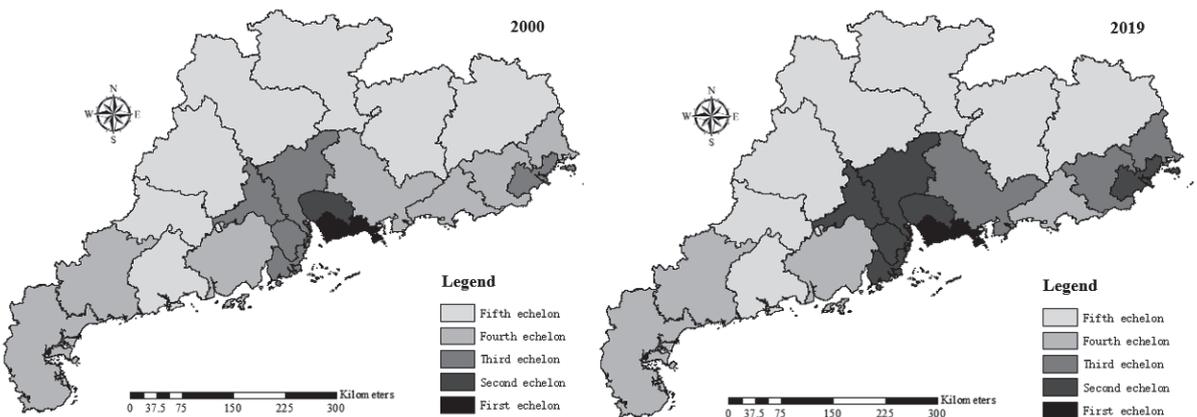


Fig. 4. Spatial distribution of land use performance in Guangdong Province.

social and economic benefits in the northern mountainous areas, the land use performance is poor.

Decomposition of Temporal and Spatial Differences in Land Use Performance

According to Dagum Gini coefficient method, the overall difference and subgroup decomposition results of ULUP in Guangdong Province from 2000 to 2019 are measured (Table 3). During the investigation period, the difference of ULUP in Guangdong Province was obvious, but there was a downward trend of fluctuation. At the end of the investigation period, the Gini coefficient of ULUP in 2019 decreased by 8.18% compared with 2000 at the beginning of the period. During the investigation period, interregional differences constitute the main source of internal differences in land use performance in Guangdong Province, with an average contribution rate of 67.19%, followed by intraregional differences, with an average contribution rate of 29.10%, followed by over variable density, with an average contribution rate of 3.71%. There are intraregional and inter regional differences in land use performance, which constitutes an important spatial feature of ULUP in Guangdong Province.

From the regional perspective, the internal differences of land use performance in the Pearl River Delta, eastern Guangdong, northern Guangdong and western Guangdong showed a narrowing trend, and

the internal differences of land use performance in northern and western Guangdong decreased the most. The internal differences of land use performance in the Pearl River Delta and eastern Guangdong showed a trend of fluctuation and narrowing. The Gini coefficient at the end of the investigation period decreased by 14.08% and 17.97% respectively. The internal difference of land use performance in northern Guangdong first decreased, then increased, and then decreased, showing an inverted N-shaped trend. The Gini coefficient at the end of the investigation period decreased by 70.51% compared with the beginning of the period. The internal difference of land use performance in western Guangdong is shrinking year by year, and the Gini coefficient at the end of the investigation period is 67.06% lower than that at the beginning of the investigation period. The Gini coefficient between regions shows that the difference of ULUP between the Pearl River Delta and eastern Guangdong at the end of the investigation period is larger than that at the beginning of the investigation period, with an increase of 5.37%, showing an inverted U-shaped change trend of first rising and then falling. The difference of ULUP between the Pearl River Delta and western Guangdong decreased by 2.82%, showing an inverted U-shaped change trend. The differences between the Pearl River Delta and northern Guangdong, between eastern and northern Guangdong, between eastern and western Guangdong, and between northern and western

Table 3. Dagum Gini coefficient and its decomposition.

Parameter type		2000	2003	2006	2009	2012	2015	2019
Total Gini coefficient	G	0.6699	0.6625	0.6653	0.6577	0.6503	0.6545	0.6151
Gini coefficient in the region	A	0.5425	0.5234	0.5087	0.5017	0.4933	0.5177	0.4661
	B	0.4135	0.4152	0.4109	0.3897	0.3981	0.3393	0.3392
	C	0.1153	0.0735	0.0473	0.1017	0.0489	0.0342	0.0340
	D	0.2013	0.1921	0.1780	0.1445	0.1048	0.0830	0.0663
Interregional Gini coefficient	A-B	0.5955	0.6002	0.6290	0.6407	0.6465	0.6575	0.6275
	A-C	0.9335	0.9244	0.9241	0.9044	0.8956	0.8853	0.8537
	A-D	0.8334	0.8398	0.8555	0.8532	0.8432	0.8350	0.8099
	B-C	0.8463	0.8140	0.7818	0.7071	0.6723	0.6301	0.5760
	B-D	0.6343	0.6236	0.6037	0.5667	0.5299	0.4903	0.4648
	C-D	0.4578	0.3868	0.3376	0.2445	0.2219	0.2023	0.1519
Intraregional differences	Gw	0.2007	0.1951	0.1928	0.1902	0.1868	0.1941	0.1723
Regional differences	Gcb	0.4295	0.4337	0.4475	0.4474	0.4455	0.4435	0.4257
Hypervariable density	Gt	0.0397	0.0337	0.0250	0.0201	0.0180	0.0169	0.0051
Contribution rate /%	Gw	29.9597	29.4491	28.9794	28.9190	28.7252	29.6562	28.0117
	Gcb	64.1140	65.4642	67.2629	68.0249	68.5068	67.7617	69.2083
	Gt	5.9263	5.0867	3.7577	3.0561	2.7680	2.5821	2.7800

Note: A-Pearl River Delta, B-Eastern Guangdong, C-Northern Guangdong, D- Western Guangdong.

Guangdong continued to shrink. The Gini coefficient at the end of the investigation period decreased by 8.55%, 31.94%, 26.72% and 66.82% respectively compared with the beginning of the period.

Spatial Evolution Pattern of Land Use Performance

ArcGIS 10.5 software is used to calculate and draw the ellipse parameters of the standard deviation of land use performance and the center migration trajectory of Guangdong Province (Table 4 and Fig. 5), so as to further explore its temporal and spatial distribution and evolution law. Table 5 shows that the ellipticity of the standard deviation of ULUP in Guangdong Province showed a significant downward trend during the study period, indicating that the directionality of its spatial distribution was weakened. The average azimuth angle is 75.873°, indicating that it presents a northeast-southwest distribution pattern in space. The extension amplitude of the long axis is higher than that of the short axis, indicating that the evolution force of its spatial distribution comes from the growth in the northeast-southwest direction. The fluctuation and expansion

of elliptical coverage area shows that the ULUP in Guangdong Province is expanding, which is consistent with the continuous diffusion process of urban renewal in Guangdong Province in recent years. Fig. 5 shows that the center of ULUP in Guangdong Province is located in Dongguan (The average center of gravity is 113.982°E, 22.836°N) and gradually shifted to the southwest, indicating that the ULUP in the southwest is higher than that in the northeast. The center of gravity has gradually moved from Dongguan to the border with Shenzhen. The average annual migration speed has experienced a change process from acceleration to slowing down, and the migration distance in 20 years is about 25.95 km.

Analysis on Driving Factors of Land Use Performance

Indicator Selection of Driving Factors

Land use performance is an important standard to measure the effect of land use. Affected by many factors such as economy, society and policy, identifying various factors is of great significance to improve urban

Table 4. Ellipse parameters of standard deviation of ULUP in Guangdong Province from 2000 to 2019.

Year	Central coordinates	Long half axis/ KM	Short half axis/ KM	Azimuth/(°)	Area/(10 ⁴ KM ²)	Oblateness
2000	(114.083°E, 22.833°N)	174.561	50.280	75.627	2.756	124.281
2003	(114.046°E, 22.846°N)	171.121	51.721	76.084	2.779	119.400
2006	(113.985°E, 22.817°N)	163.109	53.025	75.679	2.717	110.084
2009	(113.957°E, 22.837°N)	158.591	54.699	76.127	2.725	103.892
2012	(113.943°E, 22.838°N)	158.043	55.529	76.185	2.757	102.514
2016	(113.947°E, 22.831°N)	155.844	55.179	75.968	2.701	100.665
2019	(113.916°E, 22.851°N)	163.742	59.447	75.440	3.058	104.295

Note: the data source is calculated by arcgis10.5 software.

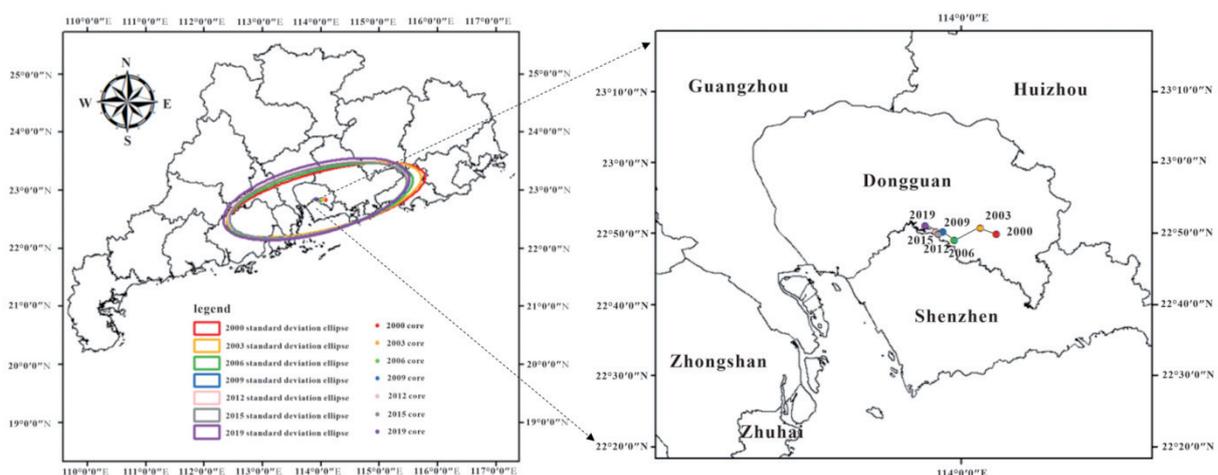


Fig. 5. Transfer track of land use performance focus in Guangdong Province.

Table 5. Selection of influencing factors and indicators.

Dimension	Index	Calculation method
Humanistic society	X1: College Students	Every 10000 College Students
	X2: Scientific and technical personnel	Proportion of employees engaged in scientific and technological innovation and geological exploration in employment
	X3: Innovative achievements	Patent applications per capita
	X4: Environmental administrator	Proportion of water conservancy, environment and public management employees in employment
Industrial economy	X5: Foreign investment	Proportion of actually utilized foreign investment in GDP
	X6: Industrial upgrading	Cosine angle of the proportion of three industries in GDP [30]
	X7: Financial development	Proportion of various loan balances of financial institutions in GDP
	X8: Economic growth	Per capita GDP
Infrastructure	X9: Highway facilities services	Highway mileage
	X10: Medical facility services	Number of hospital beds
	X11: Public transport services	Number of buses per 10000 people
	X12: Library stock	Library collection per 100 people
Government support	X13: Science and technology financial expenditure	Proportion of fiscal expenditure on science and technology in fiscal expenditure
	X14: Financial expenditure on Education	Proportion of fiscal expenditure on education in fiscal expenditure
	X15: Environmental regulation	Number of words related to environment in government work report [31]
	X16: Government intervention	Proportion of fiscal expenditure in fiscal revenue

land use efficiency. Based on existing studies [28-29], this paper measures the indicators affecting urban land use efficiency from four aspects: human and social environment, industrial and economic infrastructure, infrastructure construction and government support. The selection of influencing factors and indicators is shown in Table 5.

Analysis of Driving Factors

Through the geographic detector, we can identify the differences of the impact of different factors on the spatial layout of land use performance in Guangdong Province. According to the calculation principle of geographic detector, the independent variable should be type quantity. If the independent variable is numerical quantity, discretize each driving factor. In this paper, the driving factors are divided into four levels according to the equal division method. The detection results show that (Table 6), the 16 influencing factors selected in this study have passed the significance test of 1% level, and different driving factors have significant differences in the spatial distribution of land use performance in Guangdong Province. From the perspective of division dimension, the order of influence is: industrial economy (1.4266)>infrastructure (1.1440)>human factors (1.0981)>government support (0.8683). From the perspective of sub factors, five indicators such as economic growth, scientific and technical personnel, public transportation,

industrial upgrading and technological innovation have become the most influential driving factors in the land use performance of Guangdong Province.

Specifically, economic growth ($q = 0.4448$) and industrial upgrading ($q = 0.4318$) have become the main driving factors in the measurement dimension of industrial economy. The urban economic level determines the possibility of investment in various elements such as capital, labor and technology per unit land area, thus affecting the urban land use efficiency [32]. Since the reform and opening up, Guangdong's economy has maintained sustained and rapid growth. Efforts have been made to improve land use efficiency through urban renewal. At the same time, the economic structure has been evolving towards advanced and modernization, and the quality and efficiency of economic growth have been continuously improved. The proportion of tertiary industry in Guangzhou, Shenzhen and Dongguan has exceeded that of secondary industry. The proportion of tertiary industry in Zhuhai, Zhongshan and Jiangmen is increasing. Urban industrial upgrading has become an important driving force for green efficiency of land use.

Public transport services ($q = 0.4445$) and library stock ($q = 0.3496$) have become the main driving factors in the measurement dimension of infrastructure. As land resources are scarce and limited, public transport can alleviate urban population and traffic congestion and improve urban quality and service

efficiency [33-34]. The construction of urban culture cannot be ignored in the construction of urban modernization. Library is an important part of urban cultural development. It plays an important role in social education, transmitting scientific information and developing intellectual resources. It is conducive to improving the quality of workers, promoting scientific and technological innovation and promoting the development of urban land use and construction [35].

Scientific and technological personnel ($q = 0.4447$) and innovative achievements ($q = 0.4079$) have become the main driving factors in the measurement dimension of humanistic society. The development of urban economy needs scientific and technological investment, so as to promote the adjustment of urban industrial structure, promote the accurate investment of capital and labor, and finally bring about the adjustment of land use mode and the improvement of land use intensity and efficiency. Technological progress has effectively improved the investment intensity and labor productivity of land, which is the fundamental to promote intensive land use [36].

Science and technology financial expenditure ($q = 0.3018$) and environmental regulation ($q = 0.2366$) have become the main driving factors in the measurement dimension of government support. Fiscal Science and technology expenditure promotes the agglomeration of local innovation factor resources, promotes the significant improvement of industrial economic benefits, and is conducive to optimizing the development and utilization of land resources [37].

Environmental regulation can stimulate enterprises to carry out technological innovation, promote industrial structure upgrading, improve enterprise resource allocation efficiency and land output efficiency by reducing environmental pollution [38].

Government Policy Suggestion

Accelerate Urban Renewal

The government can implement urban renewal, strengthen the transformation of old urban communities and the construction of complete communities, establish a high-quality urban ecosystem, strengthen historical and cultural protection, shape the urban style, enhance the urban flood control and drainage capacity, and build a sponge city and resilient city. Accelerate the elimination of backward production capacity and revitalize the stock of land with the policy of “Positive Incentive & Reverse Force”.

Rational Planning

According to the municipal management requirements, comprehensively consider the regional industrial characteristics, scientific and technological innovation, social contribution, energy conservation and emission reduction, environmental protection and other conditions, and enrich and improve the evaluation indicators and standard values. Establish a normalized evaluation system for the utilization efficiency

Table 6. Detection results of influencing factors (q value of geographic detector).

Partition dimension	Code	Driving factors	q statistic	p value
Humanistic society	X1	College Students	0.1776***	0.00
	X2	Scientific and technical personnel	0.4447***	0.00
	X3	Innovative achievements	0.4079***	0.00
	X4	Environmental administrator	0.0679***	0.00
Industrial economy	X5	Foreign investment	0.3339***	0.00
	X6	Industrial upgrading	0.4318***	0.00
	X7	Financial development	0.2161***	0.00
	X8	Economic growth	0.4448***	0.00
Infrastructure	X9	Highway facilities service	0.3106***	0.00
	X10	Medical facility services	0.0394***	0.00
	X11	Public transport services	0.4445***	0.00
	X12	Library stock	0.3496v	0.00
Government support	X13	Science and technology financial expenditure	0.3018***	0.00
	X14	Financial expenditure on Education	0.1493***	0.00
	X15	Environmental regulation	0.2366***	0.00
	X16	Government intervention	0.1806v	0.00

Note: ***/**/* indicates the significance at the 1%/5%/10% levels, respectively.

of industrial space resources, dynamically adjust the identification standards of inefficient industrial space, carry out overall planning in combination with the revision of regulatory detailed planning in key areas, and integrate it into the recent land reserve plan, land supply plan and other special work.

Improve the Management Mechanism

The government should deepen land life cycle management and improve incentive policies. Government sector need to strengthen the implementation of industrial land use standards, establish a dynamic and real-time supervision and management mechanism, and implement the in-process and post-mortem supervision of land use. Strengthen the construction of special information platform for high-quality utilization of industrial space, deepen resource information mining and sharing, and improve the level of fine management. Promote the integrated construction of hub comprehensive transportation through land acquisition and demolition, improve the supporting transportation network and play the role of hub. With the help of urban renewal and transformation, move the development space, improve the urban environment and drive the comprehensive development of the area.

Conclusions

This paper uses entropy weight TOPSIS to calculate the land use performance of 21 cities in Guangdong Province from 2000 to 2019. Using Dagum Gini coefficient, natural discontinuity method, standard deviation ellipse, gravity center model and geographic detector, this paper analyzes the temporal and spatial distribution, evolution and driving factors of ULUP in Guangdong Province. The main conclusions are as follows: (1) There are great differences in the distribution of land use performance among cities, which decreases from the Pearl River Delta to the surrounding cities. From the time dimension, the land use performance of Guangdong Province generally shows an upward trend. In particular, in 2009, Guangdong province implemented the „Three Old Transformation“ policy, promoted the comprehensive improvement of land, revitalized the stock of construction land, promoted industrial transformation, urban transformation and environmental reconstruction, and improved land use performance. (2) The cities in the Pearl River Delta are basically located in the first and second echelons, showing an agglomeration development trend and radiation driving role in space, which greatly improves the land use performance of the surrounding cities. Interregional differences constitute the main source of internal differences in land use performance in Guangdong Province, with an average contribution rate of 67.19%, followed by intraregional differences, with an average contribution

rate of 29.10%, followed by over variable density, with an average contribution rate of 3.71%. There are intraregional and inter regional differences in land use performance, which constitutes an important spatial feature of ULUP in Guangdong Province. (3) During the study period, the spatial distribution direction of ULUP in Guangdong Province has weakened, and the spatial distribution pattern is northeast-southwest. The evolution force of spatial distribution comes from the growth in the northeast-southwest direction and shows an expansion trend. Moving from Dongguan to the border with Shenzhen, the average annual migration speed has experienced a change process from acceleration to slowing down. (4) From the perspective of division dimension, the influence of driving factors from large to small is: industrial economy (1.4266)>infrastructure (1.1440)>humanistic factors (1.0981)>government support (0.8683). From the perspective of sub factors, five indicators such as economic growth, scientific and technological innovation talents, public transportation, industrial upgrading and technological innovation have become the most influential driving factors in ULUP in Guangdong Province.

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Conflict of Interest

The authors declare no conflict of interest.

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