International Journal for Housing Science and Its Applications
Publish August 5, 2025. Volume 46, Issue 3 Pages 3773-3780

https://doi.org/10.70517/ijhsa463319

Analysis of the spatial and temporal impacts of urban expansion on land resource change: a study based on regression methods

Xiaoxiao Wang[1,*], Zhenchen Lin[1], Xuanyi Li[1] and Benzheng Zhang[1]
[1] College of Architecture and Civil Engineering, Chongqing Metropolitan College of Science and Technology, Chongqing, 402167, China
Corresponding authors: (e-mail: wangxiaoxiao_1216@126.com).

Abstract This paper takes the Pearl River Delta (PRD) urban agglomeration as an example, based on the land use data from the Institute of Geographic Sciences and Resources of the Chinese Academy of Sciences (IGSR). With the help of remote sensing and GIS platform, Landsat image data are deciphered. The spatial and temporal land use change characteristics in the process of urban expansion are analyzed by kernel density analysis, superposition analysis, and regression analysis, and the contribution of each variable to the land resource change is quantitatively assessed. The results show that the expansion rate of the PRD urban agglomeration from 1988 to 2024 shows that Foshan expands from 53.03km² to 107.98km², Shenzhen expands by 6.03km² per year, and Guangzhou increases by a total of 217.64/km². The degrees of freedom of Foshan and Guangzhou continue to decrease, while those of Shenzhen increase. Slope (β=0.226) and built-up land (β=0.003) had the greatest influence on ecological land changes. Each indicator has a significant effect on the ecological land change, and the significance is less than 0.05.

Index Terms regression analysis, superposition analysis, kernel density analysis, land resource change, urban expansion

I. Introduction

With the acceleration of urban population growth, economic development and urbanization, land resources are becoming more and more limited, and the demand for land for urban development is also increasing, and the scarcity of land and the inefficiency of land use limit the quality of social and economic development [1]-[3]. As the most basic guarantee for human life and production activities, land has not only natural value, but also high economic and social value, which is an indispensable resource for today's social development. Since the industrial revolution, the rapid development of cities and industries, human demand for nature, has gradually exceeded the supply of the natural environment, which has exerted tremendous pressure on it.

Since the end of the 20th century, the sustainable development of population, resources and environment in harmony has attracted the attention of scientists, especially the rapid economic development and urbanization in recent decades has led to the intensification of the problem of land resource depletion and environmental pollution, and the study of land resource change has become a hotspot as the basic condition for human survival and development [4]-[7]. China's rapid economic development has led to resource consumption and ecological environment deterioration. At present, due to the agricultural structural adjustment, urbanization and industrialization process is accelerating, the structure of land resources changes in time and space level [8], [9]. In order to promote the coordinated development of population, resources, environment, and socio-economic benefits, China released the Outline of Territorial Planning (2016-2030) in 2017, which serves as a guideline for work related to territorial spatial development, protection, and remediation.

The increasing disconnection between lands has severely limited the carrying capacity of land resources. However, urbanization leads to the growth of urban population, decentralization of land management and the lack of scientific leadership in land management, and the number and severity of land and environmental problems increase, such as soil erosion, degradation of arable land, and deterioration of land functions, and present different status in different regions [10]-[13]. The spatio-temporal analysis of land resources under urban expansion is an important basis for optimizing land allocation and managing land development and remediation, as well as for the scientific preparation and implementation of urban territorial spatial planning [14], [15]. Therefore, how to maximize the economic intensive use of land resources has become an important realistic program for the construction of new urbanization.

In this paper, multi-period remote sensing images of the Pearl River Delta (PRD) urban agglomerations as well as urban road network vector data are acquired from the Institute of Geographic Sciences and Resources of the Chinese Academy of Sciences (IGSR). With the help of remote sensing and GIS platforms, the Landsat image data are decoded using the maximum likelihood algorithm of supervised classification, and the land use data are obtained by decoding. Further, through overlay analysis with and ArcGIS kernel density analysis tools, urban land expansion areas were obtained and land resource density maps were generated. Three study areas were extracted from the PRD urban agglomeration, i.e., Guangzhou, Foshan, and Shenzhen, and the expansion speed and expansion freedom of the three cities were analyzed. Then, based on the Wald x^2 statistics of logistic regression, a land resource density-town expansion regression model was developed and the relationship between each variable was statistically analyzed.

II. Overview of the study area and methodology

The Pearl River Delta (PRD) urban agglomeration, geographically located between 111°22′-115°25′E, 21°28′-24°26′N, is situated in the southeast of Guangdong Province, downstream of the Pearl River, adjacent to Hong Kong and Macao, with Guangzhou and Shenzhen as its core, including nine cities, namely Zhuhai, Foshan, Huizhou, Dongguan, Zhongshan, Jiangmen and Zhaoqing. Surrounded by hills, mountains and islands, with a plain in the center, the region has a subtropical climate with high temperatures and heavy rainfall, typical vegetation is subtropical evergreen broad-leaved forests, and the geomorphology and hydrology are characterized by a good water network with many rivers. In recent years, with the support of policies, the economy of the region has gained rapid development, and the social development is characterized by a high degree of rural industrialization and a rapid process of urban-rural integration. At present, the Pearl River Delta (PRD) urban agglomeration has become one of the most dynamic economic zones in the Asia-Pacific region, and is one of the three major regions in China with the largest concentration of population, the strongest innovation capacity and the strongest comprehensive strength. Therefore, it is typical to choose the Pearl River Delta to study the spatial and temporal evolution characteristics of urban expansion on land resource changes.

II. A. Data sources

This paper is based on the land use data from the Institute of Geographic Sciences and Resources of the Chinese Academy of Sciences, which is interpreted and interpreted using Landsat image data, and field verified that the classification accuracy of urban construction land reaches 98.26%, which is in line with the requirements of cartography. By extracting the land use in different periods, the feature types other than construction land were combined into one category, i.e., the classified images were binarized to obtain two major categories of construction land and non-construction land, and the image layers of the three periods were superimposed and analyzed to compute the area of urban expansion in the study period. Finally, ARCGIS 10.2 software was used to output the superimposed results into maps to obtain the urban expansion maps for 1988, 2000, 2012 and 2024, so as to explore the spatial and temporal distribution characteristics of urban expansion in the PRD urban agglomeration in the past 36 years.

II. B. Spatio-temporal characterization methods

II. B. 1) Rate of urban expansion

Urban expansion speed is to reflect the change of the area of a city built-up area in a certain time period [16]. The urban expansion rate can reflect the speed of urbanization of a city from the side, and it is one of the most basic indicators for studying urban expansion, and its calculation formula is as follows:

$$V = \frac{I_m - I_n}{\Delta t} \tag{1}$$

where, V denotes the expansion rate of the city in the study time period, Δt denotes the interval between the study time periods, I_m the area extracted at the end of the study phase in the same study time period, and I_n is the area extracted at the beginning of the study phase in the same study time period.

II. B. 2) Freedom of urban expansion

While the previous section used the expansion rate indicator to capture the change in area of urban expansion, this section proposes the attitude of expansion dynamics to reflect the dynamic rate of change in the built-up area over the study time period [17]. The formula for the degree of freedom of urban sprawl is as follows:

$$Q = \frac{I_m - I_n}{I_n} * \frac{1}{\Delta t} * 100\% \quad (2)$$

where Q denotes the degree of freedom of urban expansion over a period of time, Δt denotes the time intervals between each time period, I_m is the area extracted from the built-up area at the end of a study time period, and I_n is the area extracted from the built-up area at the beginning of a study time period. Based on the review of information as well as the reading of literature, the degree of freedom of urban expansion in the study area was categorized into five different classes: $Q \leq 5\%$ for slow expansion, $5\% \leq Q \leq 8\%$ for low expansion, $8\% \leq Q \leq 11\%$ for medium expansion, and $11\% \leq Q \leq 14\%$ for fast expansion, the $Q \geq 14\%$ is high speed expansion.

II. C. Data analysis methods

II. C. 1) Kernel density analysis

Urban land resource density is the ratio of the total length of the centerline of urban roads to the urban land area, and its mathematical expression is:

$$x = \sum_{i=1}^{n} L_i \Big/ \sum_{j=1}^{n} A_j \quad (3)$$

where: x is the land resource density, km/km^2. $\sum_{i=1}^{n} L_i$ is the total centerline length, km; and $\sum_{j=1}^{n} A_j$ is the area of urban land, km^2.

In spatial analysis, kernel density analysis is a commonly used analytical method, which belongs to the statistical method of nonparametric density estimation, calculating the quantity value per unit area based on point or line elements in order to fit individual points or folded lines to a smooth conical surface. Kernel density analysis can be used to identify roadways or utility lines that impact a town site. The Population field can be used in the ArcGIS 10.2 Density Analysis tool to give some elements more weight than others based on the importance of the element, and the field also allows the use of a single point to represent multiple observations.

II. C. 2) Superposition analysis

Overlay analysis is one of the most commonly used spatial analysis methods in GIS, which can be used to reveal the spatial and temporal changes of land use and identify the target area of the study [18]. In ArcGIS10.2 software, overlay analysis includes methods such as erasing, intersecting, viewing, joining and updating. On the one hand, this paper obtains the spatial distribution information of urban land expansion in the recent 30a by overlaying and cropping the extraction of the 2-phase urban land status map based on remote sensing image interpretation. On the other hand, the land resource density layer is added, the urban expansion map layer is used as a mask, the spatial statistics get the corresponding point information of land resource density and urban land expansion, and the land resource density information of the urban expansion area is extracted and converted to ASCII format, which provides relevant data for the regression analysis.

II. C. 3) Regression analysis

Regression analysis is a statistical analysis method to determine the interdependent quantitative relationship between 2 or more variables [19]. In this paper, using SPSS curve estimation module, regression analysis was conducted on the statistical results of urban spatial analysis to optimize the regression model of land resource network-urban land expansion. Curve estimation includes six models including linear, quadratic term, composite, logarithmic, cubic and exponential. It is convenient to compare and analyze the fitting results of each model graphically and tabularly to derive the optimal model. During the course of the study, this paper found through preliminary tests that the results of fitting logarithms to the dependent variable only were superior to the correlation model that took logarithms to both. This may be related to the fact that the dependent variable (land resources) itself increases linearly by itself after statistical treatment. In order to explore the quantitative relationship between urban land expansion areas and land resources, the land resources-urban expansion one-dimensional linear regression model, the curvilinear regression model and the logarithmic relationship model were established respectively.

In the land resource-town expansion model, there exists a town land expansion threshold, i.e., there is a critical value for land resource-driven town expansion. When the land resource is below this threshold, the town land will no longer expand. As a result, the model is ultimately formulated as a segmented function to distinguish the role of land resources in driving urban land use before and after the threshold. The regression analysis is mainly used to fit the part of the study that does not exceed the threshold of urban land expansion.

II. C. 4) Urban Land Expansion Turning Points

In order to further explore the shift in the degree of mutual promotion of land resources and urban expansion, this paper calculates the location of the node where the degree of promotion of urban expansion by land resources shifts based on the land resources-urban expansion model established by regression analysis and its turning point formula, which is calculated as follows:

$$X_0 = \begin{cases} \dfrac{-\beta_2 - \sqrt{\beta_2^2 - 3\beta_1 \cdot \beta_3}}{3\beta_3} & x \le x_{\max} \\ 0 & x \ge x_{\max} \end{cases} \tag{4}$$

where: X_0 denotes the turning point of town expansion, km/km^2; $\beta_i\left(i=1,2,3\right)$ is the regression coefficient; and $x_{\max}$ is the threshold value of town expansion, i.e., the area of town expansion beyond which is 0, km/km^2.

II. D.Data processing

The data processing process in this paper mainly includes three parts: remote sensing image interpretation, superposition analysis and spatial analysis, and regression analysis, and the technical route of the research is shown in Figure 1. (1) Remote sensing image interpretation. In this paper, with the help of ENVI 5.1 platform, based on the 2-phase remote sensing images, covering the urban land use changes in the study area in the recent 30 a, combined with the recent urban administrative boundaries of the study area cropping, radiometric calibration, atmospheric correction, according to the needs of the classification of land use types, using the maximum likelihood algorithm of the supervised classification of the interpretation of Landsat images. According to the research purpose of this paper, the land use classification system mainly includes three types of urban land, non-urban land and water, and the urban land type is extracted to generate the urban site map.

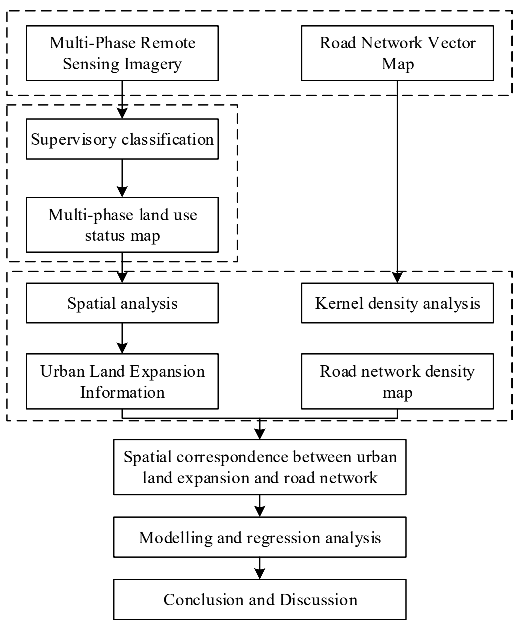

Figure 1: studies technical routes

(2) Through overlay analysis and spatial analysis, obtain the expansion areas of urban land, and count the corresponding point information of land resource density and urban land expansion. With the help of ArcGIS 10.2 software, the spatial distribution of urban land in each city in Phase 2 was overlaid with the above decoded spatial distribution map of urban land, and the spatial distribution of new urban land in the past 30 a was cropped and extracted. With the help of Kernel Density tool, the density of urban land resources was calculated and the land resource density map was generated. Using the urban expansion layer as a mask, the land resource density

corresponding to the urban land expansion area is obtained through overlay analysis, output in ASCII format, and converted to single-column text format.

(3) Regression analysis of the relationship between the two. With the help of SPSS statistical analysis software, statistically analyze the text files corresponding to land resource density and urban land expansion, and get the maximum value of land resource density, i.e. the urban expansion threshold. Finally, regression analysis is carried out on the relationship between the two, fitting analysis is carried out using the model proposed above to establish the optimal model of land resource density-urban land expansion, and the turning point node of urban land expansion is calculated based on the turning point formula.

III. Findings

III. A. Analysis of the spatial and temporal characteristics of urban change

III. A. 1) Analysis of the rate of expansion

Based on the Econometric classification data, the 12-period construction land data of the three main study areas of the PRD urban agglomeration (Foshan, Shenzhen, and Guangzhou) were extracted, and based on the urban expansion rate model, the urban expansion rate of the three cities in the study period is shown in Table 1. From the data in the table, it can be seen that compared with the main urban areas of Shenzhen and Guangzhou, the expansion of construction land in Foshan in the past 15 years is relatively small, from 53.03km² in 1988 to 107.98km² in 2024, an increase of only 54.95km², or about 2.0436 times. The cities in the three time periods under study show low, medium and fast expansion and increase year by year. The main reason for Foshan's increasing rate of urban expansion in the time period is that the coastal area needs to be used as a foreign trade outlet, sparsely populated, and the development started late, so the city of Foshan was slow to develop due to its own constraints during 1988-2000. In the latter two time periods, due to the government's policy-oriented role, the rate of urban expansion has been increasing, and reached the peak of the research period between 2006 and 2024.

Shenzhen's construction land area expands rapidly from 1988 to 2024, from 96.65 km² in 1988 to 313.67 km² in 2024, an increase of 217.02 km², or about 3.25 times, with a time span of 36 years and an average annual expansion of 6.03 km². From the table, it can be seen that the city of Shenzhen was in the stage of rapid expansion from 1988 to 2000, and was in the stage of high speed expansion from 2000 to 2006, and was still in the stage of high speed expansion from 2006 to 2024, and its expansion speed became faster than that of the second stage, and the built-up area reached its peak, indicating that the built-up area of the city has increased by 217.02km² in total. The built-up area reaches the peak, indicating that the built-up area shows a jumping expansion. The main reason for this is that the country emphasizes the promotion of the rise of the region, and the policy opportunities bring development opportunities to the central cities. Therefore, Shenzhen is still in the process of accelerated urbanization in this stage.

Guangzhou's built-up land area expands rapidly from 1988 to 2024, from 282.21 km² in 1988 to 500.3 km² in 2024, with a total increase of 217.64/km², a time span of 36 years, and an average annual expansion of 6.05 km².

From the table, it can be seen that the city of Guangzhou was in a high-speed expansion phase during 1988-2000, 2000-2012, and 2012-2024, but the expansion rate in the third phase declined compared to the second phase, but the decline was not significant. The main reason is that after 2008 China was affected by the economic crisis, the economy began to decline. On the other hand, Guangzhou, as a developed coastal city in the south of China, has experienced continuous rapid development in the previous phases, and the built-up area of the main city has reached a high scale of 500.3km² by 2024.

Table 1: research area expansion velocity

City	Period	Expansion area/km²	Expansion velocity at (km²/year)	Type of expansion
Foshan	1988-2000	11.40	0.95	Low speed expansion
	2000-2012	17.63	1.4692	Medium expansion
	2012-2024	25.92	2.16	Rapid expansion
Shenzhen	1988-2000	37.8	3.15	Rapid expansion
	2000-2012	98.36	8.1967	High speed expansion
	2012-2024	80.86	6.7383	High speed expansion
Guangzhou	1988-2000	70.56	5.88	High speed expansion
	2000-2012	86.29	7.1908	High speed expansion
	2012-2024	61.24	5.1033	High speed expansion

III. A. 2) Analysis of freedom of expansion

In order to reveal the extent to which the observations deviate from the predicted values, i.e., the degrees of freedom, the Pearson chi-square test model is usually used. In this paper, the Pearson's chi-square test formula is applied to calculate the degrees of freedom DFi^2 for each time period and the total degrees of freedom DF^2, and the results are shown in Table 2. From the data in the table, it can be seen that: the degree of freedom of Foshan shows a continuous decrease trend, and the degree of freedom of Shenzhen continues to increase throughout the study period, which proves that the expansion of construction land in Shenzhen is less and less influenced by the outside world during the study period, and the development is more free with fewer constraints. As for Guangzhou, the degree of freedom of the main urban area shows a decreasing trend during the whole study period, which is mainly due to the fact that the main urban area of Guangzhou expands earlier and faster, and its expansion is affected by the geographic location and the environment. The degree of freedom of Guangzhou is greater than that of Shenzhen and Foshan in the whole study period, which proves that the expansion of construction land in Guangzhou is less affected by the outside world, and it shows that the weights of the master plan are not balanced and lack of coherence, while Foshan is more affected by the outside world.

Table 2: Urban expansion degree of freedom

City	Year	1988-2000	2000-2012	2012-2024
Foshan	Time degree of freedom	2.42	1.62	1.50
	Global freedom	4.58		
Shenzhen	Time degree of freedom	0.89	2.22	2.26
	Global freedom	7.71		
Guangzhou	Time degree of freedom	42.23	15.89	10.82
	Global freedom	74.53		

III. B. Land resource changes

The spatio-temporal evolution of urban pattern is based on land use changes, which can be seen in the proportion of each type of land in the study area from 1988 to 2024 as shown in Table 3. The proportion of urban land during the 36-year period shows a significant growth, from 16.83% in 1988 to 35.29% in 2024. At the same time, the proportion of arable land decreases drastically, from 47.75% in 1988 to 26.48% in 2024, and the continuous decline of the arable land area also coincides with the continuous decrease of grain sown area and grain production in Xi'an City, as reported by the Statistical Bureau of the Pearl River Delta (PRD) Urban Agglomeration. Spatially, the main manifestation is that arable land decreases sharply with the expansion of urban construction land, and the contradiction between arable land and construction land is the main feature of the urban pattern change in this stage. The reduction was most serious between 2000 and 2012, and the continuous reduction of arable land in the PRD urban agglomerations only slowed down with the gradual saturation of urban construction in the PRD urban agglomerations. From the distribution point of view, in the process of urban expansion, suburban villages and towns also have a certain degree of low-density sprawl spatial expansion characteristics, due to the distance from the main urban areas and are spontaneous expansion, the intensity of expansion is not great.

With the construction of ecological civilization, there is a certain degree of slow growth of forest land in the Southeast region during 1988-2024, indicating that the work of returning farmland to forests has been steadily implemented in the PRD urban agglomeration. With the expansion of cities in the PRD urban agglomerations, part of the land on the outskirts of the cities has been left fallow and evolved into grassland, and the proportion of grassland has increased from 2.73% to 4.84% since 1988-2012, and the growth is reflected in the enhancement of protection measures in a number of cultural relics protection zones, which has resulted in changes in land use.

Table 3: Area and proportion of land use in Xi'an city from 1988 to 2024

Type	1988		2000		2012		2024	
town	Area	Specific gravity	Area	Specific gravity	Area	Specific gravity	Area	Specific gravity
Ploughing	408.26	16.83%	493.85	20.33%	762.8	31.24%	860.28	35.29%
Woodland	1158.46	47.75%	1022.06	42.07%	710.64	29.10%	645.39	26.48%
Grass	772.32	31.83%	789.95	32.52%	815.28	33.39%	811.46	33.29%
Waters	66.23	2.73%	94.39	3.89%	118.29	4.84%	86.36	3.54%
Other	20.46	0.84%	25.16	1.04%	32.84	1.34%	30.62	1.26%
Town	0.28	0.01%	3.78	0.16%	2.20	0.09%	3.40	0.14%

III. C. Results of regression analysis of land resource changes

Slope, distance from construction land, GDP growth rate, construction land growth rate and road density growth rate were entered into the regression model, and population growth rate was not entered into the model The results are shown in Table 4.Wald x^2 denotes the relative weight of each variable to assess the contribution of each variable to the predicted events. According to the Wald x^2 statistics of Logistic regression, the slope and the minimum distance of construction land have the greatest influence on the change of ecological land in Guangzhou from 1988 to 2024, and the rest is negatively correlated with the probability of transformation of ecological land, i.e., the greater the slope of the location of ecological land, and the farther away from the construction land, the lower the probability of change. Combining Exp(β) shows that for every 1° increase in slope, the probability of ecological land remaining unchanged increases by 1.263 times. The probability of ecological land remaining unchanged increases by 1.003 times for every 20 m increase in distance from construction land, and the GDP growth rate, construction land growth rate and road density growth rate are positively correlated with the probability of ecological land transformation, i.e., the higher the GDP growth rate, the faster the rate of construction land, and the higher the increase in road density in the region where the ecological land is located, the higher the probability of its transformation.

Table 4: Coefficients of binary logistic regression model

Variables	β	S.E	Wald	Sig.	Exp(β)
Grade	0.226	0.005	2642.789	0.001	1.263
Space distance	0.003	0.001	1263.012	0.001	1.003
GDP growth rate	-2.293	0.226	104.115	0.001	0.114
Growth rate	-0.168	0.048	13.140	0.001	0.850
Rate of road Density	-2.314	0.298	61.220	0.001	0.102
Constants	-1.363	0.042	50.602	0.001	0.263

The significance (sig.) of each factor in the model is less than 0.05, indicating that the indicators entering the model have a significant effect on the ecological land changes. The maximum value of the conditional indicator in the covariance diagnosis is 5.6, which is less than 10, and the values of the variances are also lower, so it can be considered that there is no obvious covariance relationship among the factors. The overall accuracy of the model prediction was 70.5%, and the squared maximum likelihood (-2loglikehood) was 33203.059. The regression model analysis results, the ROC analysis of the predicted value and the actual value of P is shown in Figure 2, and the AUC was obtained to be 0.772. Based on the above three results, this paper considers that the predicted value of the model has a certain degree of accuracy, which is acceptable. In addition, in order to exclude the possibility of sample distribution bias, this study randomly selected 10,000 ecological land samples in 2024 respectively, and tested how well they matched with the model, and the results showed that there were 8,307 samples whose simulation results were consistent with the observation results, which means that the regression model's goodness of fit reached 83.07%, indicating that the simulation accuracy was reliable.

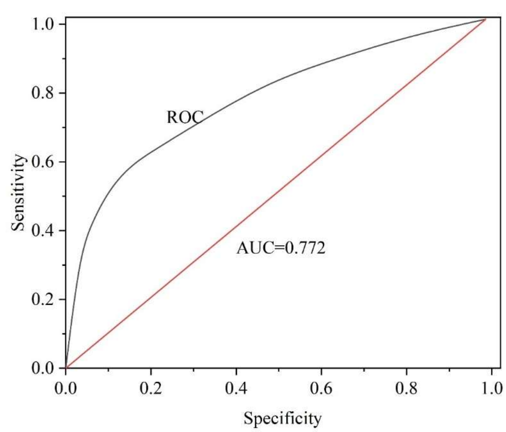

Figure 2: ROC curve

IV. Conclusion

Accurately grasping the spatio-temporal evolution characteristics of land resource changes and the contribution of urban expansion influence factors is of great significance to scientifically promote regional ecological protection. In this paper, we use kernel density analysis, superposition analysis, regression analysis and other methods to analyze the spatio-temporal impact analysis of urban expansion on land resource changes from the perspectives of urban expansion speed and urban expansion freedom. Taking the Pearl River Delta city cluster as an example, the following conclusions are drawn:

(1) Guangzhou freedom > Shenzhen > Foshan throughout the 1988-2024 study period, Guangzhou urban expansion is less affected by external influences, and Foshan is more affected by external influences because its economy is less developed and the western part belongs to the mountainous region.

(2) Foshan city, the main city of Guangzhou and Shenzhen in the 1988-2024 expansion rate time period increases mainly because: the country emphasizes the promotion of the rise of the region, the policy opportunities to the central city brings opportunities for development.

(3) Slope, distance from construction land, GDP growth rate, construction land growth rate and road density growth and other factors have a significant effect on the change of ecological land use (Sig.<0.05).

Funding

This work was supported by the 2024 Scientific and Technological Research Projects of Chongqing Municipal Education Commission, "Research on the Landscape Adaptability of Mountainous Industrial Heritage" (KJQN202402504).

References

[1] Wang, S., Liu, X., Chen, X., & Song, M. (2024). An evaluative study of economic security from the perspective of land resource assets. Land Use Policy, 139, 107062.

[2] Mahtta, R., Fragkias, M., Güneralp, B., Mahendra, A., Reba, M., Wentz, E. A., & Seto, K. C. (2022). Urban land expansion: the role of population and economic growth for 300+ cities. Npj Urban Sustainability, 2(1), 5.

[3] Tian, C., Luan, W., Wang, X., & Jin, X. (2024). Land price, government debt, and land-use efficiency in the coastal cities of China under the constraint of land scarcity. Journal of Environmental Management, 371, 123144.

[4] Sun, M., Wang, J., & He, K. (2020). Analysis on the urban land resources carrying capacity during urbanization——A case study of Chinese YRD. Applied Geography, 116, 102170.

[5] Kuang, B., Lu, X., Han, J., Fan, X., & Zuo, J. (2020). How urbanization influence urban land consumption intensity: Evidence from China. Habitat International, 100, 102103.

[6] Chang, B., & Chen, L. (2021). Land economic efficiency and improvement of environmental pollution in the process of sustainable urbanization: Case of eastern China. Land, 10(8), 845.

[7] Huang, J., & Xue, D. (2019). Study on temporal and spatial variation characteristics and influencing factors of land use efficiency in Xi'an, China. Sustainability, 11(23), 6649.

[8] Hou, Y., Chen, Y., Li, Z., & Wang, Y. (2023). Changes in land use pattern and structure under the rapid urbanization of the Tarim River Basin. Land, 12(3), 693.

[9] Tian, Y., Liu, B., Hu, Y., Xu, Q., Qu, M., & Xu, D. (2020). Spatio-temporal land-use changes and the response in landscape pattern to hemeroby in a resource-based city. ISPRS International Journal of Geo-Information, 9(1), 20.

[10] Zhou, W., Elshkaki, A., Zhong, S., & Shen, L. (2021). Study on relative carrying capacity of land resources and its zoning in 31 provinces of China. Sustainability, 13(3), 1459.

[11] Han, W., Zhang, X., & Zheng, X. (2020). Land use regulation and urban land value: Evidence from China. Land Use Policy, 92, 104432.

[12] Zhang, Y., Long, H., Tu, S., Ge, D., Ma, L., & Wang, L. (2019). Spatial identification of land use functions and their tradeoffs/synergies in China: Implications for sustainable land management. Ecological Indicators, 107, 105550.

[13] Liu, J., & Huang, X. (2024). Spatio-temporal evolution and drivers of high-quality utilization of urban land in Chinese cities. Land, 13(7), 1077.

[14] Hersperger, A. M., Oliveira, E., Pagliarin, S., Palka, G., Verburg, P., Bolliger, J., & Grădinaru, S. (2018). Urban land-use change: The role of strategic spatial planning. Global Environmental Change, 51, 32-42.

[15] Wang, C., Liu, S., Zhou, S., Zhou, J., Jiang, S., Zhang, Y., ... & Mao, X. (2023). Spatial-temporal patterns of urban expansion by land use/land cover transfer in China. Ecological Indicators, 155, 111009.

[16] Anlin Li,Lede Niu & Yan Zhou. (2022) .Prediction method of construction land expansion speed of ecological city based on BP neural network. International Journal of Environmental Technology and Management,25(1-2),108-121.

[17] Shikhar Shrestha,Olivia Lewis,Daniel Harris,Peter Rock,Anita Silwal,Sumeeta Srinivasan & Thomas J Stopka. (2025) .A multi-method spatial examination of factors associated with changes in geographic accessibility to buprenorphine providers in HEALing communities study states Kentucky, Massachusetts, and Ohio. Preventive medicine reports,53,103045.

[18] Javid Hussain,Nafees Ali,Xiaodong Fu,Jian Chen,Sayed Muhammad Iqbal,Altaf Hussain & Hikmat Salam. (2025) .Geospatial mapping of potential aggregate resources using integrated GIS-AHP, geotechnical, petrographic and machine learning approaches. Earth Science Informatics,18(4),336-336.

[19] Sebahattin Serhat Turgut,Huseyin Ayvaz,Muhammed Ali Dogan,Dolores Pérez Marín & Ahmed Menevseoglu. (2025) .Detecting carob powder adulteration in cocoa using near and mid-infrared spectroscopy: A comprehensive classification and regression analysis. Food Research International, 208,116132-116132.