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A Comprehensive Framework to Evaluate Urban Land Use Efficiency Based on Dynamic Evolution, Driving Mechanism and Influencing Factors

Bohang Zhang[1], **Lihua Chen**[2]

[1]School of Natural Sciences, The University of Manchester, Manchester, UK
[2]Department of Architecture, Hefei University of Technology, Hefei, China
Email: bohang.zhang@student.manchester.ac.uk

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Abstract

Urban land use efficiency is the key index to measure the quality of urban land use. This paper attempts to build a comprehensive framework to analyze the spatial-temporal dynamic evolution, driving mechanism and influencing factors of urban land use efficiency by using data envelope analysis model, Malmquist index, spatial autocorrelation analysis method and Tobit model. The case study in Yunnan Province of China shows that the overall average values of technical efficiency, pure technical efficiency and scale efficiency during the research period are 0.8686, 0.8959 and 0.9698 respectively. The overall spatial distribution for urban land use efficiency shows a random spatial pattern, but there is a significant spatial autocorrelation in local space. The internal driving mechanism for the change of urban land use efficiency is dominated by technological progress change, while the technical efficiency change has a negative effect. In terms of the impact on urban land use efficiency, some factors have positive effects, while others have negative effects. This research can provide decision-making basis for Yunnan Province to formulate urban land use policies and provide method and practice references for the research on urban land use efficiency.

Keywords

Urban Land Use Efficiency, Comprehensive Framework, Dynamic Evolution, Driving Mechanism, Influencing Factors

1. Introduction

The land is essential to human growth and sustainability development (Aal, Kamel, & Alyami, 2020). Urban land is the spatial carrier supporting the development of urban economy, society and ecological environment, and its utilization efficiency directly affects the urban sustainable development (Sarkodie & Owusu, 2022), which is of great value and significance to the formulation of urban land use policies and urban planning and construction (Zhu, Zhuang, & Zhang, 2018). The research on urban land use is one of the core issues of the current global sustainable development, which has been identified as the basic research with strategic value and significance by various countries in the world, and is the research hotspot and frontier field with global significance (Wang, 2013). Land use efficiency is a basic problem in the framework system of land use research. Land use efficiency is realized through the way of land exploitation and utilization (Yan, Liao, Li, & Shi, 2012), which changes the land use structure, landscape pattern and ecological environment. More importantly, it has an important and profound impact on the circulation of materials and energy flow of the urban ecosystem (Yuan, 2016), and is a direct manifestation of the realization of land value in the process of urban economic and social development (Zhang & Jin, 2015).

The study on urban land use efficiency has been a key research field in recent years. The academic circles worldwide have carried on thorough discussions and analysis on it, and have obtained fruitful results. On the whole, the researches on evaluation of urban land use efficiency mainly include four aspects. Firstly, the basic issues of urban land use efficiency evaluation, such as the theoretical basis and model of land use efficiency evaluation, have been expanded and improved (Guastella, Pareglio, & Sckokai, 2017; Herzig et al., 2018; Penazzi, Accorsi, & Manzini, 2019). Secondly, the methods of urban land use efficiency evaluation are explored deeply, and the system of quantitative evaluation methods has been basically formed, mainly including single index evaluation method (Liu, Gao, & Zhuang, 2005), multiple index comprehensive evaluation method (Huang & Wang, 2019; Wang, 2019), AHP method (Masini et al., 2019), data envelope analysis method (Hua & Ye, 2018), efficiency evaluation method based on stochastic frontier model (Baráth & Fertő, 2015), and efficiency evaluation method based on slack variable measurement (Yang, Duan, Ye, & Zhang, 2014). Thirdly, studies on the evaluation and application of urban land use efficiency from different perspectives have been widely carried out, mainly including improving urban land use efficiency from the perspective of the structure and direction of urban land use (Deilmann, Lehmann, Reißmann, & Hennersdorf, 2016), discussing the spatial-temporal change characteristics and laws of urban land use efficiency (Tang, Wang, Ji, Xu, & Xiao, 2021), building kinetic simulator of urban land use efficiency (Coelho et al., 2016), and analyzing the relationship between urban space expansion and urban land use efficiency (Zitti, Ferrara, Perini, Carlucci, & Salvati, 2015). Finally, at the spatial scale, there are not only studies on land use efficiency of single city, multiple cities, urban agglomerations (Huang & Peng, 2016; Li, Hu, Kuang, & Chen, 2017; Liu & Li, 2021), but also studies on urban land use efficiency of special areas such as river basins (Jin, Deng, Zhao, Guo, & Yang, 2018; Schiavina et al., 2022; Wang & Han, 2023).

Since the 21st century, with the rapid promotion of urbanization and industrialization in China, urban population and land demand have increased rapidly, and the scale of urban land use has also shown an accelerated growth trend. However, there are also some prominent problems in Chinese cities, such as blind expansion of land use scale, extensive utilization of land resources, and contradiction between supply and demand of construction land, which leads to low efficiency of land use in some cities and has become an important factor restricting urban sustainable development. At present, urban land use efficiency has become a key demand for China's urban spatial development and the improvement of urbanization efficiency, and the Chinese government has upgraded it to an important position in the national development strategy. Therefore, it is an important task to reasonably measure the efficiency of urban land use in China, discuss the characteristics of its historical changes, and then put forward policies and measures to improve the efficiency of urban land use in China.

Through the analysis and sorting of existing studies, it can be seen that the existing researches on urban land use efficiency in China have achieved fruitful results (Lin, Wang, Fu, Luo, & Yi, 2021), mainly focusing on the measurement and evaluation of urban land use efficiency from the perspective of time series or space (Zhang, Li, Fu, & Qi, 2020). However, these studies remain within the traditional scope of urban land use efficiency research. Faced with the increasingly complex issues of land use efficiency in Chinese cities, existing research is inadequate for comprehensively and systematically analyzing the problems and challenges confronting urban land use efficiency in China. Therefore, there is a need for more comprehensive integrated studies that encompass the dynamic evolution, driving mechanisms, and influencing factors of urban land use efficiency. Nonetheless, such integrated research remains limited, particularly studies that explore the relationship between urban land use efficiency and urban land use input-output indicators. Consequently, conducting integrated research on the dynamic evolution, driving mechanisms, and influencing factors of urban land use is not only of significant importance but also holds urgent practical application value. The importance of this research lies in its ability to measure urban land use efficiency through integrated approaches, analyze the spatiotemporal evolution characteristics and patterns of urban land use efficiency, and subsequently uncover the driving mechanisms behind the spatiotemporal evolution of efficiency. This enables the identification of the primary factors influencing efficiency levels, thereby providing a more comprehensive and systematic foundational understanding for comprehending and managing urban land use efficiency.

Based on this, this paper attempts to build a comprehensive framework and technique method system for the integration research on dynamic evolution, driving mechanism and influencing factors of urban land use efficiency, and takes 16 cities in Yunnan Province of China as cases to deepen the understanding of the characteristics, internal driving mechanism and influencing factors of urban land use efficiency evolution in Yunnan Province in recent years, so as to provide more accurate decision-making basis for the formulation and regulation of urban land use policies in Yunnan Province. At the same time, this research can also provide theoretical method and practice references for the research on urban land use efficiency, and provide reference for similar researches on urban land use efficiency.

2. Research Method

The spatial-temporal dynamic evolution of urban land use efficiency forms the foundation of this research. Through spatial-temporal dynamic evolution analysis, the characteristics and patterns of changes in urban land use efficiency can be identified, and high-efficiency and low-efficiency areas can be pinpointed. Furthermore, this enables the exploration of the spatial autocorrelation of efficiency, thereby achieving a comprehensive understanding of urban land use efficiency. More importantly, the analysis of the spatial-temporal dynamic evolution of urban land use efficiency provides key information for investigating the driving mechanisms and influencing factors of efficiency, thereby laying the groundwork for conducting integrated studies.

The overall idea of this comprehensive framework consists of 3 steps. Firstly, data envelope analysis (DEA) model is used to calculate the urban land use efficiency of each year during the research period, so as to obtain the dynamic evolution characteristics and laws of efficiency; at the same time, the urban space is divided according to the overall dynamic evolution of urban land use efficiency, and then spatial autocorrelation analysis technique is used to explore the difference of spatial distribution for urban land use efficiency. Secondly, Malmquist index is used to calculate the dynamic change of total factor productivity (TFP) for urban land use, thus revealing the driving mechanism for urban land use efficiency. Finally, Tobit regression method is used to explore the relationship between efficiency and input and output indexes, and find the main factors affecting efficiency, thus completing the system integration research of urban land use efficiency from three aspects, namely spatial-temporal dynamic evolution, driving mechanism and influencing factors. The technical route of the study is shown in **Figure 1**.

As illustrated in **Figure 1**, the study comprises four specific computational and analytical processes. Firstly, the DEA model is employed to calculate the technical efficiency, pure technical efficiency, and scale efficiency of urban land use. Secondly, the temporal characteristics of urban land use efficiency are analyzed, and spatial zoning of urban land use efficiency is delineated. This includes conducting spatial autocorrelation analyses of urban land use efficiency, encompassing both global and local spatial autocorrelations. Thirdly, the Malmquist index is utilized to calculate the total factor productivity of urban land use for each year, thereby uncovering the driving mechanisms behind the temporal changes in urban land use efficiency. Lastly, using technical efficiency as the dependent variable and input-output indicators as independent variables, a Tobit regression model is established to analyze the factors influencing urban land use efficiency. This approach enables the identification of the primary factors that govern urban land use efficiency.

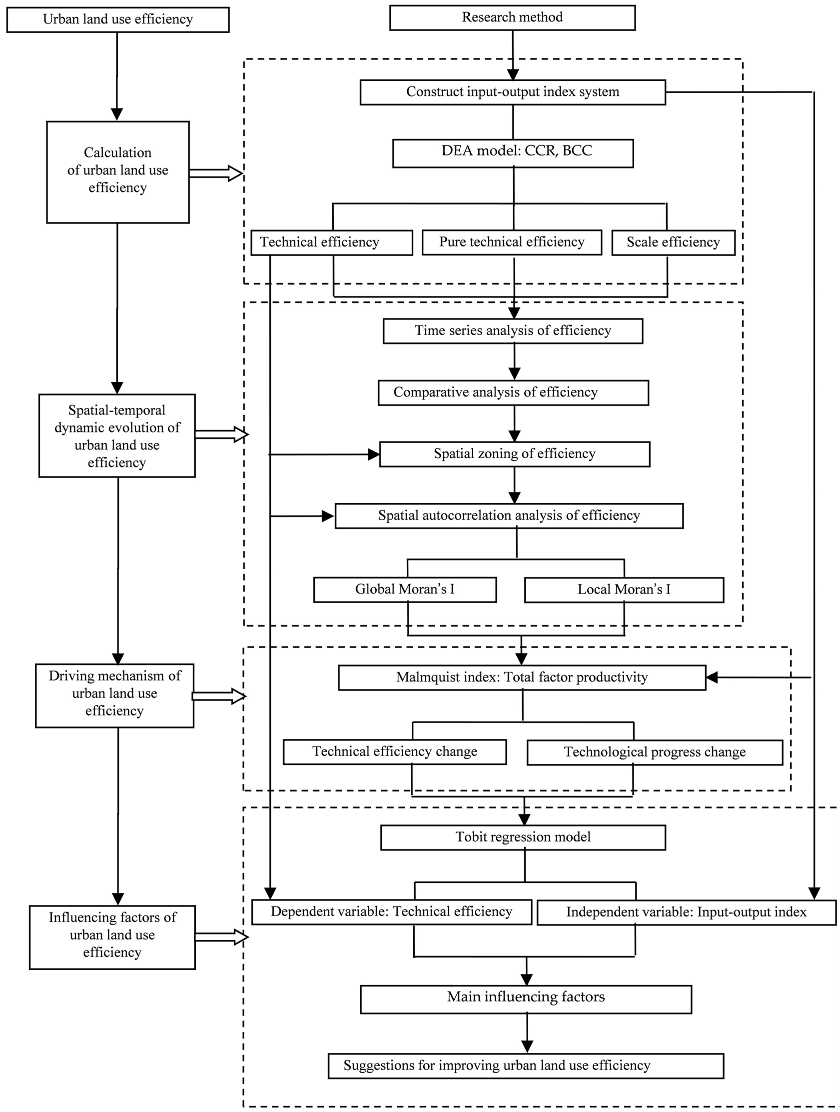


Figure 1. Technical roadmap for comprehensive framework to evaluate urban land use efficiency.

2.1. DEA Model

DEA model is a method to evaluate the efficiency of decision-making units (DMU) with multiple inputs and outputs (Banker, Charnes, & Cooper, 1984; Wang, Yang, & Li, 2021). There are many application models of DEA, among which CCR model and BCC model are the basic models of DEA and the most commonly used models. This paper uses these two models to evaluate the urban land use efficiency of Yunnan Province, and the calculation principle and process are as follows.

Let's assume that there are n DMUs, each of which has m inputs x_{ij} ($j = 1, \cdots, m$), and s outputs y_{ir} ($r = 1, \cdots, s$) ($x_{ij} \geq 0$, $y_{ir} \geq 0$), with slack variables s^- and s^+, then the relative efficiency of DMUs has the following CCR evaluation model:

$$\begin{cases} \min \theta \left(0 < \theta \le 1\right) \\ s.t. \sum_{i=1}^{n} x_{ij}\lambda_i + s^- = \theta x_{oj} \left(j = 1, \cdots, m \right) \\ \sum_{i=1}^{n} y_{ij}\lambda_i - s^+ = \theta y_{or} \left(r = 1, \cdots, s \right) \\ \lambda \ge 0, s^+ \ge 0, s^- \ge 0 \end{cases} \quad (1)$$

In the formula, λ_i is the weight variable of each DMU on a certain index. CCR model is obtained under the assumption that the DMU is constant returns to scale (CRS). θ calculated by CCR model is the comprehensive technical efficiency (TE) of the DMUs. If the constraint of "sum of λ_i is 1" is added to the above formula, it becomes the BCC model with the DMU as variable returns to scale (VRS), and the calculated θ is the pure technical efficiency (PTE) of the DMUs. As the comprehensive technical efficiency includes pure technical efficiency and scale efficiency (SE), then:

$$\text{SE} = \text{TE}/\text{PTE} \quad (2)$$

Furthermore, when the θ of CCR is 1 and both s^- and s^+ are 0, DMU is DEA efficiency, indicating that this DMU is in the optimal production frontier, and the output has reached the optimal level on the basis of the original input, and both technology and scale are efficient. When the θ of CCR is less than 1, the DMU is DEA inefficiency, and both technology and scale are inefficient. In this case, the input can be reduced to θ times of the original input by optimizing the combination without reducing the original output.

2.2. Malmquist Index

DEA model can be used to calculate the input and output efficiency of multiple DMUs at the same time section, which is essentially a static efficiency and cannot reflect the internal driving mechanism of efficiency. That is, the change of efficiency is driven by technological progress change (TC), technical efficiency change (TEC) or both. To this end, this research uses Malmquist index to analyze the internal driving mechanism for urban land use efficiency. At present, the most widely used total factor productivity (TFP) index is Malmquist index, which can calculate the TFP, TC and TEC of DMU, so as to understand the dynamic evolution results of DMU efficiency in time series more deeply and systematically (Ding & Wu, 2019). Malmquist index is widely used to measure TFP in different periods, and it can be used to study the dynamic evolution laws of efficiency of different DMUs in multiple periods (Martinho, 2017). Then, the characteristics of internal driving mechanism of efficiency are obtained The calculation principle of Malmquist index is as follows.

$$\text{TFP} = \text{TEC} \times \text{TC} \quad (3)$$

$$\text{TFP} = \text{PTEC} \times \text{SEC} \times \text{TC} \quad (4)$$

In Formula (3), TFP, TEC and TC are the total factor productivity, and the changes of TE and technological progress at the time t and t + 1 respectively.

Under the condition that VRS is assumed, TEC can be further decomposed into pure technical efficiency change (PTEC) and scale efficiency change (SEC), thus the final Malmquist index model is obtained, as shown in Formula (4), where PTEC and SEC are the changes of PTE and SE at the time t and $t+1$ respectively. In specific calculation, distance function is used to calculate the change between input and output in the period from t to $t+1$. The formula is as follows:

$$\begin{aligned}
&\text{TEC} = \frac{D^{t+1}\left(x_{t+1}, y_{t+1}\right)}{D^{t}\left(x_t, y_t\right)} \\
&\text{PTEC} = \frac{D_{vrs}{}^{t}\left(x_{t+1}, y_{t+1}\right)}{D_{vrs}{}^{t}\left(x_t, y_t\right)} \\
&\text{SEC} = \frac{TEC}{PTEC} = \frac{D^{t+1}\left(x_{t+1}, y_{t+1}\right)}{D^{t}\left(x_t, y_t\right)} \times \frac{D_{vrs}{}^{t}\left(x_t, y_t\right)}{D_{vrs}{}^{t}\left(x_{t+1}, y_{t+1}\right)} \\
&\text{TC} = \sqrt{\frac{D^{t}\left(x_{t+1}, y_{t+1}\right)}{D^{t+1}\left(x_{t+1}, y_{t+1}\right)} \times \frac{D^{t}\left(x_t, y_t\right)}{D^{t+1}\left(x_t, y_t\right)}}
\end{aligned} \tag{5}$$

In Formula (5), (x_t, y_t) and (x_{t+1}, y_{t+1}) are the input and output vectors of time t and $t+1$ respectively. D^t and D^{t+1}, $D_{\text{vrs}}{}^t$ and $D_{\text{vrs}}{}^{t+1}$ are the distance functions of the actual output and the optimal output under the ideal state of time t and $t+1$ respectively based on CRS and VRS. When TFP is greater than 1, it indicates that TFP increases positively from t to $t+1$; when TFP is less than 1, TFP decreases. TE increases when TEC is greater than 1, and decreases when TEC is less than 1. When PTEC is greater than 1, the level of factor allocation, utilization and management is improved, otherwise, it is decreased. When SEC is greater than 1, SE increases, otherwise, it decreases. When TC is greater than 1, the technology is progressing, otherwise it is regressive. In conclusion, TEC greater than 1 indicates that urban land use efficiency is driven by changes in technical efficiency, and TC greater than 1 indicates that urban land use efficiency is driven by changes in technological progress.

2.3. Spatial Autocorrelation Analysis

Spatial autocorrelation analysis is a spatial data analysis method to study whether the observed value of a certain position in space is correlated with the observed value of its adjacent position and the degree of correlation (Anselin, 1995; Nolè, Lasaponara, Lanorte, & Murgante, 2014), so as to test whether an attribute of a spatial object is distributed adjacent or dislocated. Moran's I (including global Moran's I and local Moran's I) is the most commonly used method to calculate spatial autocorrelation. The calculation formula of global Moran's I is as follows:

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\left(x_i - \bar{x}\right)\left(x_j - \bar{x}\right)}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \tag{6}$$

$$S^2 = \frac{1}{n}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2, \bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{7}$$

where I is the global Moran's I value, n is the number of space units, x_i and x_j are the observation values of the i-th space unit and j-th space unit, respectively. The w_{ij} is the spatial weight value, indicating the adjacent relation of the i and j. If it is adjacent, $w = 1$; otherwise, it is 0. The global Moran's I is generally (−1, 1). When I is greater than 0, it indicates positive spatial autocorrelation, and the distribution is spatially clustered. When I is less than 0, it indicates negative spatial autocorrelation, and the spatial distribution is scattered. The value of 0 indicates that there is no spatial autocorrelation, meaning the spatial distribution is random. Global Moran's I is a global evaluation of spatial autocorrelation, which cannot reflect the degree of autocorrelation between a local space and its surrounding local space. Therefore, local spatial autocorrelation analysis must be carried out. The local indications of spatial autocorrelation (LISA) reflects the spatial agglomeration degree of each observed value and its adjacent observed value. For the i-th space element, the calculation formula of local Moran's I is as follows:

$$I_i = \frac{\left(x_i - \bar{x}\right)}{S^2} \sum_{i,j=1}^{n} w_{ij}\left(x_j - \bar{x}\right) \tag{8}$$

In the formula, I_i is the local Moran's I value, and the meanings of other variables are the same as those in Formula (6). By calculating the local Moran's I, the cluster map of LISA can be obtained, which is used to show the spatial positive autocorrelation between the research index value and the average value of the adjacent index with high-high and low-low, the spatial negative autocorrelation with high-low and low-high, and no significant spatial autocorrelation (spatial randomness). In addition, the significance of global Moran's I and local Moran's I can be tested with the standardized statistic Z value, and the test formula is as follows:

$$Z(I) = \frac{I - E(I)}{\sqrt{VAR(I)}}, Z(I_i) = \frac{I_i - E(I_i)}{\sqrt{VAR(I_i)}} \tag{9}$$

where Z is the global Moran's I test value, $E(I)$ is the expectation of I and $VAR(I)$ is the variance of I. Z_i is the lacal Moran's I test value foe the i study area, $E(I_i)$ is the expectation of I_i and $VAR(I_i)$ is the variance of I_i.

2.4. Tobit Regression Model

In order to explore the relationship between urban land use efficiency and input and output indexes, it is generally necessary to establish a regression model to reveal the quantitative relationship between each input and output index and efficiency, so as to find out the main factors affecting efficiency. Since the efficiency value obtained by DEA model ranges from 0 to 1, which is a typical bounded variable. It is likely to cause deviation by using the traditional least square method for regression estimation. Therefore, this research applies Tobit regression model to explore the main influencing factors of urban land use efficiency. Tobit regression model is an econometric model that solves the limitation or truncation of dependent variables (Wang & Qin, 2017). It is applicable to dependent variables continuously distributed on non-negative values. Its basic formula is as follows:

$$Y = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + \varepsilon \tag{10}$$

In the formula, Y is the dependent variable, X_i is the independent variable, β_0 is the intercept, β_i is the coefficient of each independent variable, n is the number of independent variables, and ε is the random error vector, which conforms to normal distribution. Taking the comprehensive technical efficiency (TE) of urban land use as the dependent variable and each input and output index as the independent variable, the Tobit regression model is established, and then the influence degree and nature of each input and output index on the TE are judged according to the coefficient, so as to analyze the main factors affecting the efficiency.

3. Study Area and Data

3.1. Overview of the Study Area

Yunnan Province is located in the southwest border of China, with an area of 394,100 km^2. Yunnan Province has 16 cities under its jurisdiction, including 8 prefecture-level cities and 8 autonomous prefectures, as shown in Table 1 and Figure 2. In recent years, 16 cities in Yunnan Province are in the critical period

Table 1. The 16 cities in Yunnan Province, China.

Prefecture-level Cities	Shorthand	Autonomous Prefectures	Shorthand
Kunming	KM	Chuxiong	CX
Qujing	QJ	Honghe	HH
Yuxi	YX	Wenshan	WS
Baoshan	BS	Xishuangbanna	XSBN
Zhaotong	ZT	Dali	DL
Lijiang	LJ	Dehong	DH
Pu'er	PE	Nujiang	NJ
Lincang	LC	Diqing	DQ

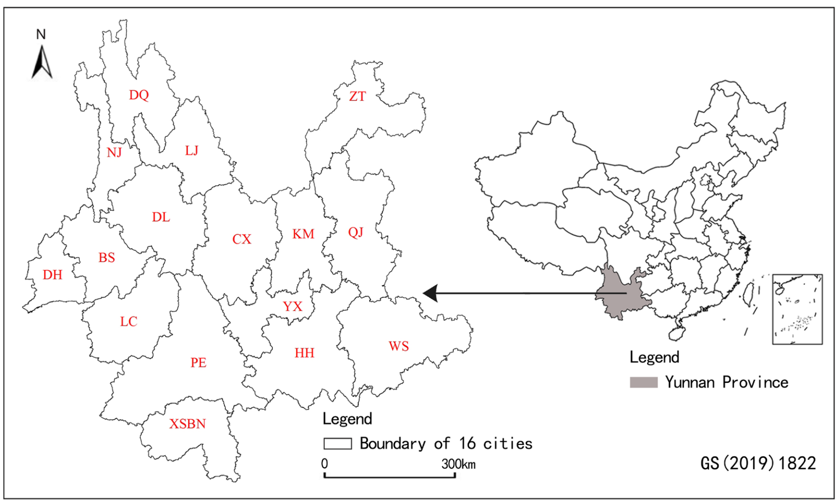


Figure 2. Location sketch of Yunnan Province, China.

of rapid development of new urbanization and industrialization, and the scale of urban land use is expanding day by day. However, there is no relevant research on the returns brought by this scale expansion. Therefore, this research analyzes the characteristics of land use efficiency in 16 cities and explores its historical evolution laws, so as to provide decision-making basis for Yunnan Province to formulate urban land use policies and coordinate the relationship between urban economic and social development and land resources, thus finally realizing the healthy and sustainable development of land use.

3.2. Index System and Data Source

The index system is fundamental to comprehensive evaluation, and DEA efficiency assessment is no exception. The DEA evaluation index system comprises two main components: input indices and output indices. Input indices reflect the quantity of various resources invested by the decision-making unit in the production process, while output indices represent the quantities of various outputs obtained by the decision-making unit through the allocation and utilization of the invested resources. Selecting appropriate input and output indices is crucial for constructing an effective DEA evaluation index system.

The necessary input of land resources, human resources and capital for urban land use can obtain various outputs of urban economy, society and environment through the allocation and utilization of input resources. Based on the basic idea of input and output, this research constructs an index system for evaluating the urban land use efficiency in Yunnan Province. In accordance with the principles of target, simplicity and data availability in establishing DEA evaluation index system, in terms of input indexes, urban built-up area is selected as the land resource input index, urban employment is selected as the human resource input index, and public budget expenditure is selected as the capital input index. In terms of output indexes, the total production value of the secondary and tertiary industries is selected as the economic benefit output index, the total retail sales of consumer goods is selected as the social benefit output index, and the green coverage rate of urban built-up areas is selected as the environmental benefit output index. The constructed comprehensive evaluation index system is shown in Table 2. According to Table 2, relevant data of 16 cities in Yunnan Province from 2008 to 2019 are collected. In order to maintain the consistency of data, all index data are from the Yunnan Statistical Yearbook (2009-2020) published by the Yunnan Provincial Bureau of Statistics. The data can also be viewed on the official website (https://stats.yn.gov.cn) of Yunnan Provincial Bureau of Statistics.

Table 2. Index system for measuring urban land use efficiency in Yunnan Province, China.

Index Type	Primary Index	Secondary Index
Input Index	Land resource	Urban built-up area
	Human resource	Urban employment
	Capital	Public budget expenditure

Continued

Output Index	Economic benefit	Total production value of the secondary and tertiary industries
	Social benefit	Total retail sales of consumer goods
	Environmental benefit	Green coverage rate of urban built-up area

4. Results Analysis

Based on the aforementioned methods and data, this study calculates the land use efficiency of 16 cities in Yunnan Province over the past 12 years. Building upon this foundation, the research initially analyzes the spatiotemporal dynamic evolution characteristics of urban land use efficiency in Yunnan Province, encompassing four components: dynamic changes in efficiency values, spatial zoning of efficiency, global spatial autocorrelation, and local spatial autocorrelation. Subsequently, the total factor productivity of urban land use in Yunnan Province is calculated to examine the driving mechanisms behind the changes in urban land use efficiency. Finally, through modeling, the study analyzes the factors influencing urban land use efficiency in Yunnan Province, thereby identifying the primary determinants affecting urban land use efficiency.

4.1. Spatial-Temporal Dynamic Evolution of Urban Land Use Efficiency

4.1.1. Overall Analysis

DEA model is used to calculate the TE and PTE of urban land use in different cities of Yunnan Province from 2008 to 2019, and then the SE is calculated, thus obtaining the dynamic change results of urban land use efficiency in Yunnan Province in nearly 12 years, as shown in Table 3. On the whole, the overall average values of TE, PTE and SE of urban land use in Yunnan Province during the research period are 0.8686, 0.8959 and 0.9698 respectively. TE and PTE are all less than 0.9, while SE is significantly higher, showing the characteristics of "two low and one high". In terms of the TE, it is greater than 0.9 only in 2010, and less than 0.9 in the rest years. Meanwhile, it is less than the average value for 5 consecutive years from 2015 to 2019. In terms of the PTE, it is greater than 0.9 in 2008~2011, 2013 and 2019, and is less than the average value for 5 consecutive years from 2014 to 2018. The SE is greater than 0.9 in 12 years, and is less than the average value only in 2012, 2013, 2015 and 2019. The overall characteristics of "two low and one high" indicate that the low TE of urban land use in Yunnan Province is due to the low PTE. That is, there are deficiencies in the allocation, utilization and management of input resources, and there is a large space for improvement in the future. High SE indicates that under the overall technical level, urban land use in Yunnan Province has reached a relatively high level in terms of scale agglomeration of input and output, but there is limited space for future improvement. Obviously, the key to improve the TE of urban land use in Yunnan Province is to vigorously improve the PTE. That is, it is necessary to improve the technical level of the development and utilization of the input resources, and fully improve the reasonable utilization of the input resources, so as to catch up with the level of scale agglomeration, thus improving the TE of urban land use.

Table 3. Dynamic change analysis of urban land use efficiency in Yunnan Province in 2008-2019.

Year	TE	PTE	SE
2008	0.8855	0.9043	0.9793
2009	0.8834	0.9112	0.9710
2010	0.9083	0.9217	0.9860
2011	0.8796	0.9048	0.9719
2012	0.8646	0.8959	0.9655
2013	0.8921	0.9367	0.9520
2014	0.8714	0.8888	0.9809
2015	0.8458	0.8729	0.9693
2016	0.8426	0.8679	0.9704
2017	0.8401	0.8637	0.9721
2018	0.8509	0.8646	0.9830
2019	0.8585	0.9178	0.9361
Average Value	0.8686	0.8959	0.9698

The change trend of urban land use efficiency in Yunnan Province in nearly 12 years is shown in **Figure 3**. According to **Figure 3**, the SE value is the maximum in each year, followed by the PTE value, while the TE value is the minimum. The change of TE shows a downward trend in fluctuation, which can be divided into three stages, namely the W-shaped change stage from 2008 to 2013, the continuous decrease stage from 2013 to 2017, and the slow increase stage after 2017. In the W-shaped change stage, the TE shows an obvious fluctuation and reaches 0.9083 in 2010, the maximum value in nearly 12 years. In the continuous decrease stage, the TE decreases from 0.8921 in 2013 to 0.8401 in 2017, a decrease of 5.83%, reaching the minimum value in nearly 12 years. After 2017, the TE value shows a slow upward trend, reaching 0.8585 in 2019, an increase of 2.19%. On the whole, the TE value decreases from 0.8855 in 2008 to 0.8585 in 2019, a decrease of 0.027 or 3.05%. Obviously, there is still a large space for improvement and optimization of urban land use efficiency in Yunnan Province. The change trend of PTE is basically the same as that of TE, which shows a fluctuation in three stages. The change of SE is relatively gentle. Except in 2013 and 2019, it basically shows a gentle change trend in small fluctuation. Furthermore, from the beginning and end of the research period, the TE and SE both show a downward trend, with a decrease of 3.05% and 4.41% respectively, while the PTE increases slightly, with an increase of 1.49%. Obviously, the sharp decrease of SE is the main reason for the decrease of TE at the end of the research period. To sum up, the SE of urban land use in Yunnan Province shows a high-value change, the PTE shows a mid-value change, and the TE shows a low-value change in nearly 12 years. This also shows once again that the key to improve the TE of urban land use in Yunnan Province is to improve the PTE and convert the input resources into output as much as possible, thus improving the efficiency.

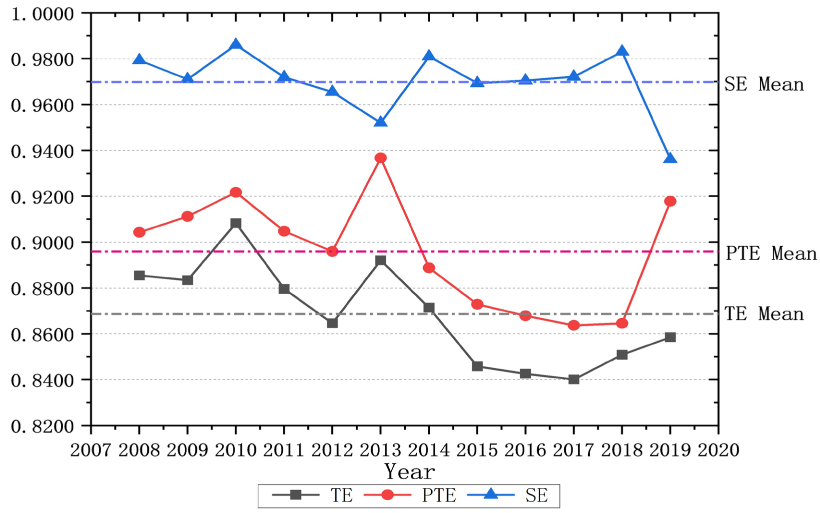


Figure 3. Change trends of urban land use efficiency in Yunnan Province in 2008-2019.

4.1.2. Spatial Zoning of Urban Land Use Efficiency

In order to further analyze the spatial pattern characteristics of urban land use efficiency in Yunnan Province, based on the interval distribution of TE values, 16 cities in Yunnan Province are divided into four echelons according to the classification criteria of equal to 1 (high efficiency), 0.9 - 1 (relatively high efficiency), 0.8 - 0.9 (medium efficiency) and less than 0.8 (low efficiency). The results are shown in **Figure 4**. In 2008, the first echelon consists of 5 cities with DEA efficiency, including Kunming, Yuxi, Wenshan, Xishuangbanna and Nujiang, with efficiency value of 1. The second echelon consists of 3 cities, including Chuxiong,

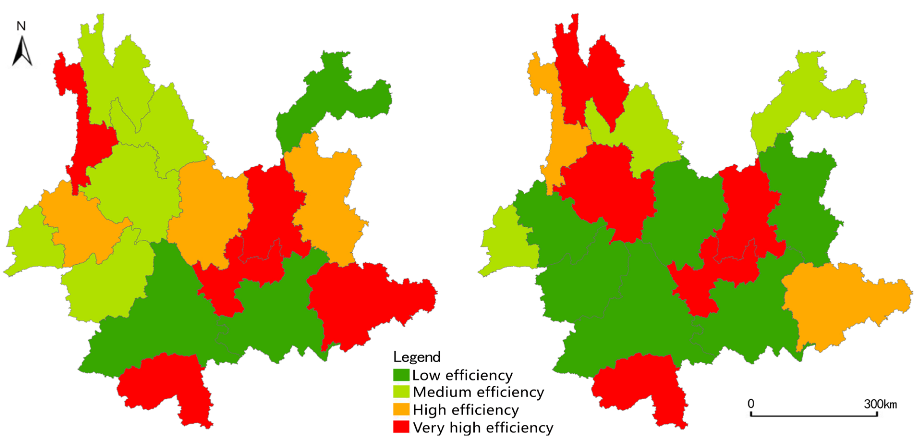


Figure 4. Spatial zoning of urban land use efficiency in Yunnan Province in 2008 (left) and 2019 (right).

Qujing and Baoshan. The third echelon consists of 5 cities, including Diqing, Dali, Lijiang, Dehong and Lincang. The fourth echelon consists of 3 cities, including Zhaotong, Honghe and Pu'er. In 2019, the first echelon consists of 5 cities including Kunming, Yuxi, Xishuangbanna, Dali and Diqing, the second echelon consists of 2 cities including Wenshan and Nujiang, the third echelon consists of 3 cities including Lijiang, Dehong and Zhaotong, and the fourth echelon consists of 6 cities including Honghe, Baoshan, Chuxiong, Lincang, Qujing and Pu'er.

In terms of spatial distribution, Yunnan Province forms an obvious spatial agglomeration area of efficient urban land use with Kunming and Yuxi as the center and Chuxiong, Qujing and Wenshan as the two wings in 2008, while the cities with medium and low efficiency are mainly distributed in the western and southern regions of Yunnan Province. Yunnan Province forms a spatial agglomeration area of efficient urban land use with Kunming and Yuxi as the center in 2019, while Xishuangbanna, Dali and Diqing shows a dotted distribution. The cities with relatively high and medium efficiency are distributed in the eastern and western border regions of Yunnan Province, while the cities with low efficiency form the largest and contiguous spatial agglomeration area. On the whole, the spatial distribution for urban land use efficiency in Yunnan Province has two obvious characteristics. First, Kunming, Yuxi and Xishuangbanna are always the agglomeration areas of urban land use with high efficiency in Yunnan Province; Second, the number of cities with low efficiency increases from 3 in 2008 to 6 in 2019. In terms of spatial distribution, the cities with low efficiency are mainly distributed in southern regions in 2008, while that in southern and central regions in 2019, forming an obvious trend of spatial diffusion.

4.1.3. Global Spatial Autocorrelation Analysis

Based on the TE data of 16 cities, the global Moran's I of urban land use efficiency in Yunnan Province from 2008 to 2019 is calculated. The results are shown in **Table 4** and **Figure 5**. On the whole, the global Moran's I values of all the years during the research period are negative, and the land use efficiency of the 16 cities may have a negative spatial autocorrelation, which may be a discrete spatial pattern. In terms of specific values, the minimum value of global Moran's I in 2010 is −0.3726, which is closest to −1, and the possible negative spatial autocorrelation is the most obvious. In 2012, the maximum value of the global Moran's I is −0.1100, close to 0, indicating that the spatial distribution of that year is more random. According to **Figure 5**, the global Moran's I fluctuates during the research period, which can be divided into three stages, including the gentle change stage from 2008 to 2010, the sharp change stage from 2010 to 2015, and the gentle change stage after 2015. In the first stage, the global Moran's I values are all less than −0.3000. In the second stage, the global Moran's I values fluctuate sharply. Firstly, it sharply increases from −0.3726 in 2010 to −0.1735 in 2011, an increase of 53.43%, showing an obvious V-shaped trend; Secondly, from 2012 to 2015, the global Moran's I shows an inverted N-shaped trend, experiencing repeated fluctuations of "high-low-high-low", from the maximum value of −0.1100 in 2012 to

−0.2809 in 2015. In the third stage, the global Moran's I shows a stable trend, which basically fluctuates slightly around −0.2700, indicating that the spatial distribution of urban land use efficiency in Yunnan Province tends to be stable.

Table 4. Statistical values of global Moran's I of urban land use efficiency in Yunnan Province.

Year	Global Moran's I	Z Value	*p* Value
2008	−0.3339	−1.4979	0.1342
2009	−0.3327	−1.5233	0.1277
2010	−0.3726	−1.7096	0.0873
2011	−0.1735	−0.5997	0.5487
2012	−0.1100	−0.2408	0.8097
2013	−0.3192	−1.4007	0.1613
2014	−0.1312	−0.3577	0.7205
2015	−0.2809	−1.1970	0.2313
2016	−0.2470	−0.9959	0.3193
2017	−0.2915	−1.2295	0.2189
2018	−0.2916	−1.2195	0.2226
2019	−0.2610	−1.0619	0.2883

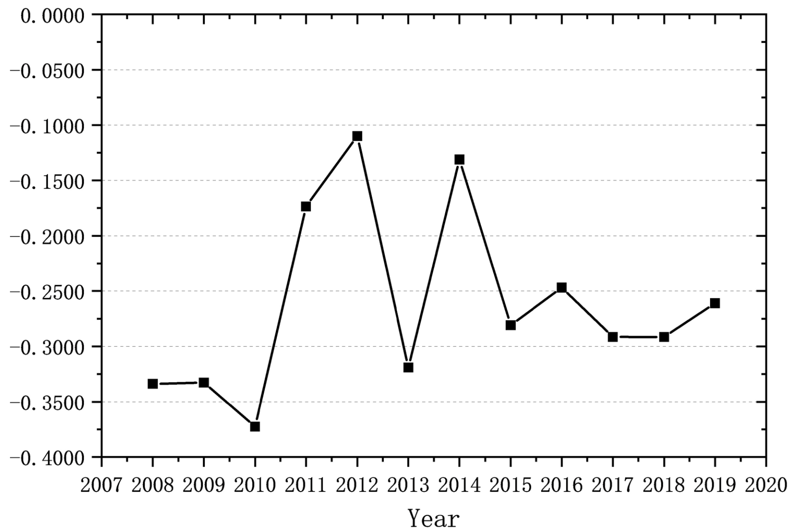
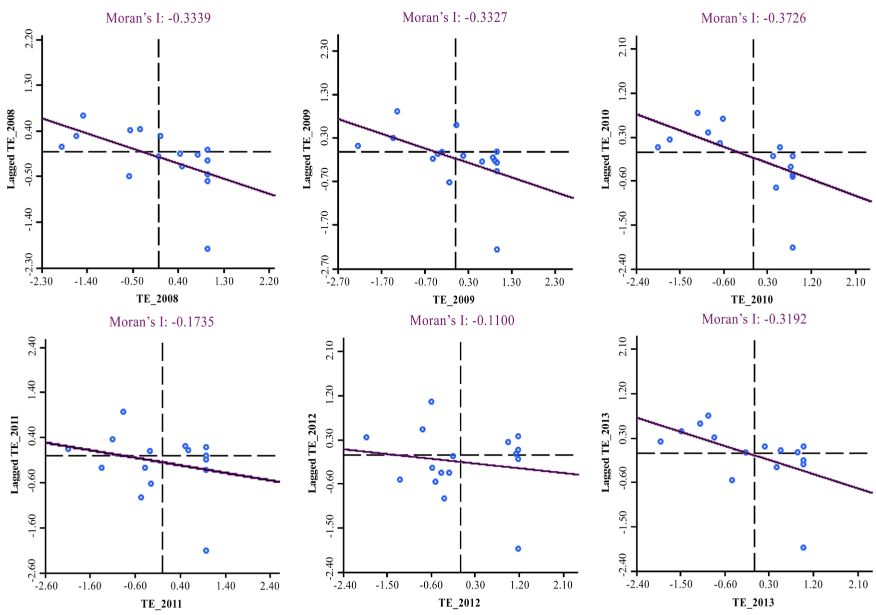


Figure 5. Trends in global Moran's I of urban land use efficiency in Yunnan Province

Negative values may indicate a negative spatial autocorrelation, but it still needs to pass a significance test. According to **Table 4**, only the Z value of 2010 is −1.7096 and p value is 0.0873, passing the significance test of Z value less than -1.65 and p value less than 0.1. The remaining years fail to pass the significance test with confidence level of 0.1. Therefore, except in 2010, there is no significant difference between global Moran's I and $E(I)$ in other years, which accept the null hypothesis (land use efficiency is randomly distributed in space), and there is no significant global spatial autocorrelation, showing that the overall spatial distribution of urban land use efficiency in Yunnan Province is neither aggregated nor discrete, but a random spatial pattern.

4.1.4. Local Spatial Autocorrelation Analysis

The global Moran's I only reveals the global comprehensive characteristics, but cannot show the local spatial relationship between each city and its adjacent cities. This research adopts local Moran's I to obtain the local spatial relationship of urban land use efficiency in Yunnan Province. The results are shown in **Figure 6** and **Table 5**. The local Moran's I scatter plot (**Figure 6**) portrays the spatial aggregation types of urban land use efficiency in each year. According to **Figure 6**, during the study period, most cities in Yunnna Province are in II and IV quadrants (spatial negative autocorrelation) belonging to low-high and high-low types, and only a few cities are in I and III quadrants (spatial positive autocorrelation) belonging to high-high and low-low types. In 2008, the number of cities in I to IV quadrants is 2, 5, 1 and 8 respectively, and in 2019, the number of cities in I to IV quadrants is 3, 5, 3 and 5 respectively. The number of cities with high-high and low-low types increased, indicating that the agglomeration effect of local space has been enhanced. According to **Table 5**, during the research period, Xishuangbanna, Zhaotong, Dali and Lijiang show a discrete spatial pattern, forming a heterogeneous area of spatial distribution of land use efficiency with Xishuangbanna, Zhaotong, Dali and Lijiang as the core. In particular, Xishuangbanna shows a stable and continuous local negative spatial autocorrelation, becoming the only city in Yunnan Province with significant local spatial autocorrelation in each year. Lincang shows a positive spatial autocorrelation in three years, which indicates that a certain degree of spatial pattern of agglomeration has been formed with Lincang as the core.



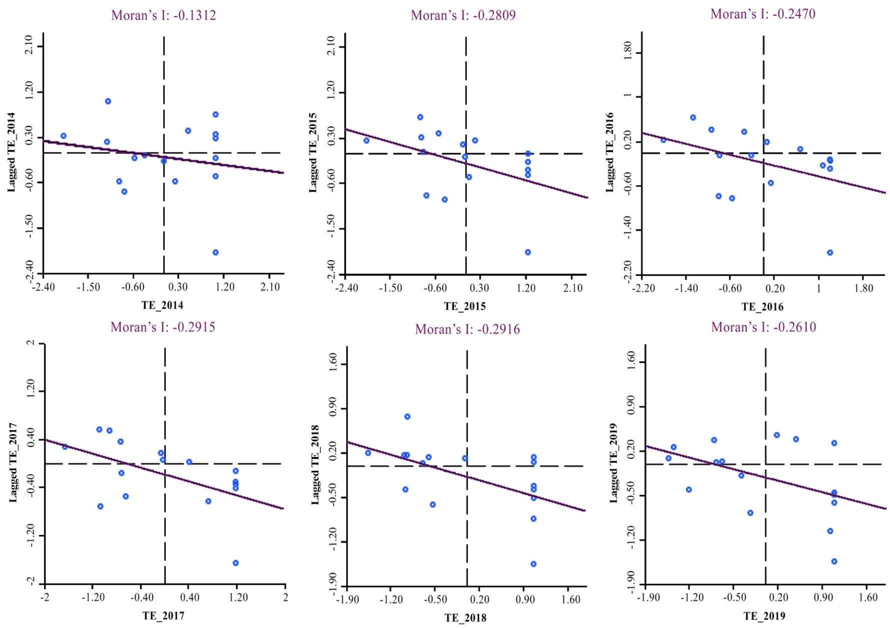


Figure 6. Local Moran's I scatter plot of urban land use efficiency in Yunnan Province.

Table 5. Analysis of local Moran's I of urban land use efficiency in Yunnan Province.

Year	Local Moran's I				
	Xishuangbanna	Zhaotong	Lincang	Dali	Lijiang
2008	−1.8597	—	—	—	—
2009	−2.1335	−1.2297	—	—	—
2010	−1.5905	—	—	—	—
2011	−2.0375	−0.8424	0.4510	—	—
2012	−2.2720	—	0.3148	—	—
2013	−1.8855	—	—	—	—
2014	−2.0417	−1.1449	—	—	—
2015	−2.4397	—	0.3863	—	—
2016	−2.1870	—	—	—	—
2017	−1.9417	—	—	−0.4556	—
2018	−1.6292	—	—	—	−0.7334
2019	−1.6600	—	—	—	—

Note: "—" represent local Moran's I can not pass the significance test at the level of 5%.

In order to more clearly reveal the spatial distribution pattern characteristics of urban land use efficiency in Yunnan Province, the cluster map of local spatial autocorrelation is drawn, as shown in Figure 7. According to Figure 7, Xishuangpana shows a high-low pattern of local spatial distribution in all years, while Dali shows a high-low pattern of local spatial distribution in 2017. Both of them show an obvious discrete spatial pattern with high and low values adjacent to each other. Zhaotong shows a low-high pattern in 2009, 2011 and 2014, while Lijiang shows low-high only in 2018. Both of them show a discrete spatial pattern with low and high values adjacent to each other. Lincang shows a low-low pattern in 2011, 2012 and 2015, showing an obvious spatial agglomeration pattern with low values adjacent to each other. On the whole, there is no "hot spot" area with high value agglomeration in urban land use efficiency in Yunnan Province, and only one "cold spot" area with low value agglomeration, namely Lincang. The rest of the local spatial autocorrelation shows a local discrete distribution pattern with heterogeneous high and low values, indicating that there is a certain degree of local spatial heterogeneity.

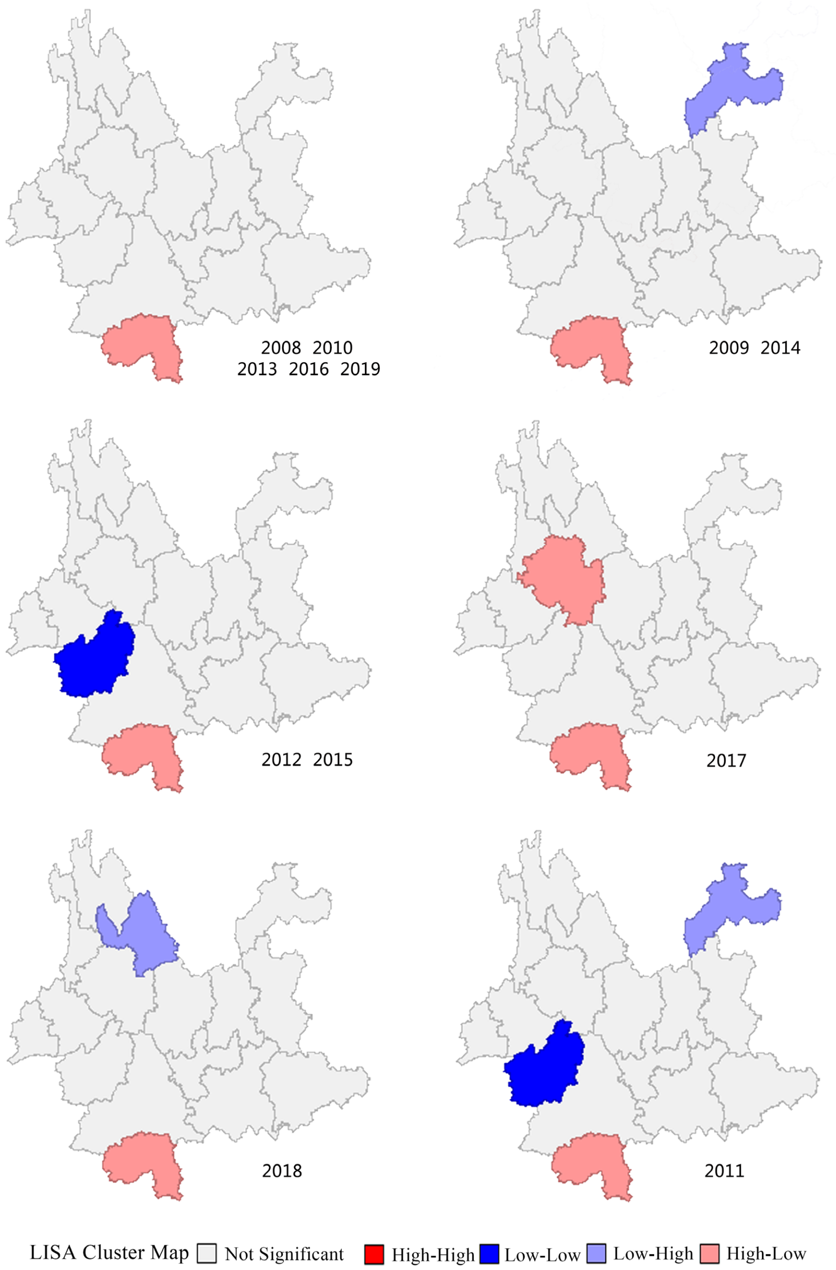


Figure 7. Cluster map of urban land use efficiency with local indications of spatial association in Yunnan Province.

4.2. Driving Mechanism of Efficiency Change

The TFP changes for urban land use in Yunnan Province based on Malmquist index are shown in Table 6 and Figure 8. On the whole, the average TFP of urban land use in Yunnan Province from 2008 to 2019 is 1.0661, which means an average annual increase of 6.61% in TFP, achieving positive growth and showing an upward trend. Among them, only the TFP values in 2014-2015 are less than 1, indicating that TFP in this period shows a downward trend, while TFP in other periods are all greater than 1, showing a positive growth trend. As can be seen from the time trajectory in Figure 8, on the whole, TFP shows an increase in fluctuation, reaching a minimum value in 2014-2015, a maximum value of 1.2477 in 2018-2019, and a second extreme value of 1.2221 in 2013-2014, thus forming two significant peaks.

Table 6. Analysis of local Moran's I of urban land use efficiency in Yunnan Province.

Time Period	TEC	TC	PTEC	SEC	TFP
2008-2009	0.9965	1.0450	0.9841	1.0127	1.0414
2009-2010	1.0304	1.0379	1.0188	1.0114	1.0695
2010-2011	0.9663	1.0845	0.9733	0.9927	1.0479
2011-2012	0.9845	1.0566	0.9932	0.9912	1.0402
2012-2013	1.0327	0.9739	1.0510	0.9826	1.0057
2013-2014	0.9742	1.2545	0.9489	1.0266	1.2221
2014-2015	0.9704	0.9981	0.9911	0.9792	0.9686
2015-2016	0.9951	1.0215	1.0009	0.9942	1.0165
2016-2017	0.9959	1.0680	1.0146	0.9816	1.0637
2017-2018	1.0121	1.0249	1.0370	0.9760	1.0373
2018-2019	1.0111	1.2340	1.0466	0.9661	1.2477
Average Value	0.9970	1.0694	1.0050	0.9921	1.0661

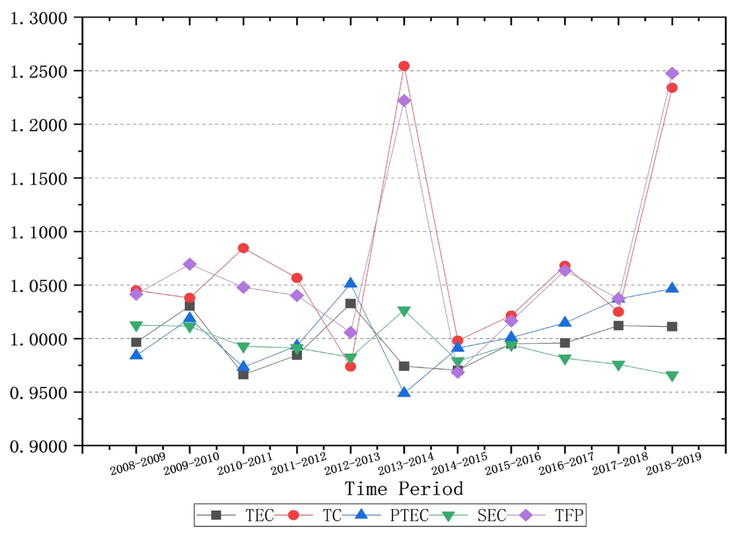


Figure 8. Trends of TFP and its decomposition index of urban land use in Yunnan Province.

From the change of decomposition efficiency of TFP for urban land use in Yunnan Province, TEC from 2008 to 2019 has a negative growth of less than 1 in 7 periods, and a positive growth of greater than 1 in 4 periods, while the overall average value is less than 1, that is, 0.9970, indicating that TE presents a trend of regression on the whole. This also shows that the efficiency of factors allocation, utilization and management operation for urban land use in Yunnan Province is insufficient, the structure of urban land use is unreasonable, and the way of urban land use is extensive. TC of urban land use in Yunnan Province only shows negative growth of less than 1 in 2012-2013 and 2014-2015, and positive growth of greater than 1 in the other 9 periods. The overall average value is 1.0694, greater than 1, and the annual TC increases by 6.94% on average. On the whole, TC shows an upward trend, indicating that Yunnan Province pays more attention to technological progress of urban land use. By comparing the change characteristics of TEC and TC, it can be seen that TEC shows a downward trend, and TC shows an upward trend, while TFP shows an upward trend. Obviously, TFP of urban land use in Yunnan Province is mainly driven by TC. However, due to the negative growth of TEC, the positive promoting effect of TC on TFP is delayed, indicating that there is still a large space to improve the resource allocation, utilization, management and scale agglomeration of urban land use in Yunnan Province in the future.

4.3. Influencing Factors of Efficiency Change

TE of urban land use is the integration of all input and output indexes, which reflects the overall efficiency of the DMUs in the allocation and utilization of factors and scale agglomeration. In order to further reveal the relationship between efficiency and input and output indexes, this research establishes a Tobit regression model to explore the main factors affecting efficiency, so as to provide more detailed decision-making information for the formulation and regulation of urban land use policies. This paper takes the TE of each year in each city of Yunnan Province from 2008 to 2019 as the dependent variable and the 6 input and output indexes of each year as the independent variable to establish the Tobit regression model. The formula is as follows:

$$\begin{aligned} &0 < TE_i \le 1 \\ &TE_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \varepsilon \end{aligned} \quad (11)$$

In the formula, TE_i is the TE of each year, X_1 to X_6 are input and output indexes, β_1 to β_6 are regression coefficients of each variable, β_0 is the intercept term, ε is the residual term, and i represent different years. Tobit regression results are shown in Table 7.

According to Table 7, all input and output indexes pass the significance test of 5% at least once and then enter the model. On the whole, at 5% confidence level, only the urban built-up area in 2009 and 2018 passes the significance test. In 2009, the coefficient affecting the TE is 0.0777, which has a positive effect on efficiency, while in 2018, the coefficient is −0.2118, which has a negative effect on efficiency.

The remaining 10 annual urban built-up areas fail to pass the test, indicating that although they have an impact on efficiency, it is not significant. This clearly suggests that blindly expanding urban scale cannot always improve efficiency, and the development model of "urban sprawl" is not desirable. Urban employment personnel only fails to pass the significance test in 2013 and 2015, public budget expenditure only fails to pass the significance test in 2019, and they all pass the significance test in other years. However, the coefficients of urban employment personnel and public budget expenditure are negative in all years, which have a negative effect. The total output value of the secondary and tertiary industries passes the significance test in all years, and the total retail sales of consumer goods fail to pass the significance test only in 2019. Both coefficients are positive, indicating that they have a positive effect on efficiency. The green coverage rate of urban built-up area fails to pass the significance test in 2008 and 2011-2015. It has a positive effect on efficiency in 2009 and 2010, while has a negative effect in 2016-2019.

From the number of years passing the significance test, the urban built-up area has the least influence on efficiency, followed by the green coverage rate and urban employment personnel. The total output value of secondary and tertiary industries has the biggest impact on efficiency, followed by public budget expenditure and total retail sales of consumer goods, both of which fail to pass

Table 7. Tobit regression analysis of influencing factors of urban land use efficiency in Yunnan Province.

Year	Urban Built-up Area X1		Urban Employment X2		Public Budget Expenditure X3		Total Production Value of the Secondary and Tertiary Industries X4		Total Retail Sales of Consumer Goods X5		Green Coverage Rate of Urban Built-up Area X6	
	coefficient	*p* Value	coefficient	*p* Value	coefficient	*p* Value	coefficient	*p* Value	coefficient	*p* Value	coefficient	*p* Value
2008	−0.0001	0.9999	−0.4311*	0.0021	−0.3743*	0.0100	0.1631*	0.0113	0.4591*	0.0000	0.0753	0.1658
2009	0.0777*	0.0313	−0.4096*	0.0000	−0.5340*	0.0000	0.1866*	0.0000	0.4560*	0.0000	0.0546*	0.0017
2010	0.0229	0.7827	−0.5060*	0.0000	−0.2951*	0.0001	0.1621*	0.0020	0.4356*	0.0000	0.0613*	0.0063
2011	−0.0833	0.4836	−0.3117*	0.0038	−0.3644*	0.0088	0.1931*	0.0010	0.3895*	0.0000	−0.0119	0.8226
2012	−0.1212	0.1197	−0.3699*	0.0000	−0.2170*	0.0026	0.2432*	0.0000	0.3554*	0.0000	0.0255	0.3964
2013	0.0110	0.8925	−0.1083	0.3479	−0.5067*	0.0000	0.1616*	0.0083	0.2183*	0.0000	−0.0074	0.8713
2014	−0.0276	0.7859	−0.3720*	0.0004	−0.2555*	0.0135	0.3469*	0.0000	0.1987*	0.0401	−0.0182	0.7343
2015	−0.1819	0.1357	−0.1947	0.0944	−0.2962*	0.0023	0.2542*	0.0179	0.2726*	0.0122	−0.1040	0.0957
2016	−0.0774	0.3579	−0.2441*	0.0064	−0.3927*	0.0000	0.3488*	0.0000	0.2151*	0.0099	−0.2039*	0.0003
2017	−0.1102	0.3265	−0.4301*	0.0000	−0.2303*	0.0108	0.4479*	0.0000	0.2379*	0.0191	−0.2460*	0.0011
2018	−0.2118*	0.0400	−0.3573*	0.0000	−0.2468*	0.0061	0.4244*	0.0001	0.2634*	0.0081	−0.4397*	0.0008
2019	−0.1029	0.3717	−0.3331*	0.0012	−0.1125	0.2351	0.3558*	0.0101	0.1895	0.0790	−0.8219*	0.0009

Note: * represent significance at 5% statistical level.

the test only in 2019. In terms of their relationship with efficiency, the total output value of the secondary and tertiary industries and the total retail sales of consumer goods are positively correlated with efficiency, while the urban employment personnel and the public budget expenditure are negatively correlated with efficiency. The other two indexes have positive and negative correlations with efficiency, but they are mainly negative. On the whole, there is a significant negative correlation between the input resource index and the efficiency of urban land use in Yunnan Province, which suggests that the input scale should be carefully controlled. Blindly expanding the input scale can not improve the efficiency, but cause the waste of resources and reduce the efficiency due to the excessively large input scale. At the same time, on the premise of a certain input scale, Yunnan Province should pay more attention to improving output indexes such as the total output value of secondary and tertiary industries and the total retail sales of consumer goods, so as to improve efficiency.

5. Discussion

According to the above analysis, output improvement can no longer rely on the expansion of input scale, but can only rely on technological changes to improve the technical efficiency of allocation, utilization and management of input resources, so as to convert input into output as much as possible, thus improving overall efficiency. It also means that the connotative growth path based on technological changes is the fundamental guarantee for achieving the comprehensive efficiency of urban land use in Yunnan Province. What needs special attention is that, as a core index of land use, urban built-up area directly reflects the scale of urban land use, but the Tobit regression results show that it has the least impact on efficiency. In nearly 12 years, it has a significant effect in only 2 years, and the coefficients are positive in only 3 years, while they are negative in the remaining 9 years. On the whole, its impact on efficiency is not significant, and most of the insignificant impact is negative. This shows that it's not that the larger the scale of urban land use, the better. If there is no adequate and reasonable development and utilization, resources will be wasted. Therefore, Yunnan Province should pay special attention to the economical and intensive use of urban land resources, and make change from the current growth path of simply expanding urban land scale to the smart growth path of optimizing resources reserve, so as to achieve the sustainable use of land resources.

The efficiency of urban land use in Yunnan Province still needs to be further improved. To this end, the following development proposals are put forward. First of all, different development strategies should be proposed according to different types of DEA efficiency. For cities with DEA efficiency, technological changes and innovative development should be emphasized. For cities with PTE efficiency but SE inefficiency, attention should be paid to improving the returns to scale under the current technological level, so as to achieve DEA comprehensive efficiency as soon as possible. For cities with DEA inefficiency, it is necessary to improve the allocation, utilization and management of input resources and strengthen the scale agglomeration effect, so as to achieve DEA comprehensive efficiency. Secondly, the TFP growth model should be constructed based on the synergistic drive of TEC and TC. Measures should be taken to steadily improve the productive technical efficiency of land use while continuing to promote technological changes and innovation. It is necessary to strengthen the application of advanced technology and modern information management means, continuously improve the allocation, utilization and management of input resources, and enhance scale agglomeration effect and returns to scale, so as to gradually achieve the positive growth of TEC. Finally, in terms of strengthening the control of the input scale of urban land use, it's not that the more the input, the better, but on the premise that the input scale is determined, the input resources should be most effectively allocated, developed and utilized by improving the technical level, and converted into output as much as possible, so that the valuable land resources can give full play to the optimum comprehensive benefits. In particular, the control of urban land use scale should be strengthened. It's not that the bigger the urban built-up area, the better. The blind expansion of urban area will only result in extensive use and waste of land resources. The scale of urban land use should keep a reasonable proportion with the input and output of factors. Only in this way can DEA efficiency be achieved and the economic, social and environmental benefits of valuable land resources be brought into full play.

6. Conclusion

This paper takes 16 cities in Yunnan Province as the research object, selects input indexes from land, human resources and capital, and output indexes from economic, social and environmental benefits to construct the evaluation index system for urban land use efficiency in Yunnan Province, and then analysis the spatial-temporal dynamic evolution, driving mechanism and influencing factors of urban land use efficiency in Yunnan Province by using DEA model, Malmquist index, spatial autocorrelation analysis and Tobit regression model based on the index data from 2008 to 2019. The conclusion is as follows. First of all, the average level of TE and PTE of urban land use in Yunnan Province is not high, and there is still a large space for improvement and optimization. The average value of SE is high, but its improvement space is limited. In the future, the key to improve the TE in Yunnan Province is to improve the PTE, and should focus on improving the allocation, utilization and management of land use input resources. In terms of spatial autocorrelation, the global Moran's I indicates that the urban land use efficiency in Yunnan Province shows a random distribution on the whole, while the local Moran's I indicates that there are 5 cities with significant local negative spatial autocorrelation and the spatial distribution characteristics of high-low, low-high and low-low. Secondly, the average TFP for urban land use in Yunnan Province from 2008 to 2019 is 1.0661, showing an upward trend, but the average TEC is less than 1, indicating that the TFP growth is driven by TC. In terms of factors affecting efficiency, too much input but insufficient output is the core problem of urban land use efficiency in Yunnan Province. In the future, special attention should be paid to controlling the input scale and increasing output by improving the technical level, so as to improve urban land use efficiency.

This research still needs to be further discussed in some aspects. Due to the limitation of data collection, this paper has only evaluated the urban land use efficiency of Yunnan Province at the level of 16 cities, and has not covered the land use efficiency at the level of counties and towns. If the research scale is expanded to counties or towns in the future, the research object will be more comprehensive, the research results will be more accurate, and the characteristics and laws of urban land use efficiency in Yunnan Province will be more systematically revealed. In addition, in terms of specific efficiency evaluation, this paper does not analyze and discuss the reasons and mechanisms for DEA inefficiency of some urban land use. It is still necessary to further explore whether the inefficiency is caused by input redundancy or output insufficiency, so as to obtain more comprehensive research results and provide more scientific decision-making basis for improving the efficiency of urban land use in Yunnan Province.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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