

Research on the Development of “Ghost City” Based on Night Light Data: Taking Sichuan Province as an Example

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Abstract

Due to the improvement of urbanization level and unreasonable development in China, many cities have begun to appear as “Ghost City”; that is, the phenomenon of high vacancy rate and low occupancy rate in urban areas. The emergence of this phenomenon will seriously affect the healthy development of cities. Therefore, the monitoring and analysis of the urban “Ghost City” index is of great significance to urban population and urban construction. This paper uses Landsat8 remote sensing image data, night light remote sensing image data, and resident population data of various cities and counties in Sichuan Province to calculate the “Ghost City” index, and obtains the “Ghost City” Index of prefecture-level cities and county-level cities in Sichuan Province. Based on the judgment criteria of the Ghost City, the calculation results show that three cities have become “Ghost City” within the research scope; eight cities have a tendency to develop into “Ghost City”; the rest of the cities have developed well and there has not been a “Ghost City” phenomenon. According to this conclusion, this paper studies the similarities and differences between the cities that are the ghost towns or the cities with the development trend of ghost towns, analyzes the reasons for the formation of ghost towns and makes suggestions for the urbanization of Sichuan Province, and provides reference for the direction of urban development and rational planning.

Keywords

Urbanization, DMSP/OLS, “Ghost City” Index, Light Gray Value

1. Introduction

Since the reform and opening-up, China’s urbanization has increased, and the

urbanization process has gradually accelerated, and the demand for housing has also risen sharply. The National Urban Land Use Data Summary Results Analysis Report [1] mentioned that the national urban land area increased by 1.65 million hectares in 2009-2014, with an average annual growth rate of 4.2%, indicating that urban construction land is increasing in a large amount. The development and unreasonable development of the city led to the emergence of empty cities or ghost cities, that is, the phenomenon of high housing vacancy rate and low occupancy rate [2].

Due to the insufficient monitoring of the dynamic changes of urban population information, the phenomenon of “Ghost City” has appeared one after another. The emergence of this phenomenon has seriously affected the development of the city and restricted the advancement of urbanization, resulting in the waste of land resources and weakening urban operational efficiency. The criterion for “Ghost City” is that the ratio of urban population to built-up area is less than 0.5 or slightly higher than 0.5 (the standard is based on the land occupation standard from the Ministry of Housing and Urban-Rural Development, the built-up area per square kilometer holds 10,000 people), this criterion known as the “Ghost City” Index. This study takes Sichuan Province as an example, combined with the 2013 Landsat8 OLI_TIRS and DMSP/OLS night-time remote sensing image data, through the fitting of the urban population and the extraction of the built-up area, to achieve the city-level and county-level cities in Sichuan Province. The analysis and monitoring of the “Ghost City” index, and through the analysis of the reasons for the formation of the ghost city phenomenon, propose corresponding countermeasures, and provide the basis for urban development and planning.

2. Research Scope and Data

2.1. Research Scope

Sichuan Province has complex landforms and has four types of landforms: mountains, hills, plains and plateaus. Therefore, this paper selects Sichuan Province as the research scope and provides reference for the study of ghost cities in other cities in China. Sichuan governs 18 prefecture-level cities, 3 autonomous prefectures, 17 county-level cities, 108 counties, and 4 autonomous counties. In this study, only 18 prefecture-level cities and 17 county-level cities were selected as research areas analysis (Figure 1) and monitoring of the “Ghost City” index in Sichuan Province.

2.2. Data Sources

1) Luminous remote sensing image data. The night-time remote sensing image data used in this paper is from the National Geophysical Data Center (<https://www.ngdc.noaa.gov/eog/dmsp/downloadV4composites.html>) and is defined by the Defense Meteorological Satellite Program. The Operational Linescan System (hereinafter referred to as OLS) on the linear scanning service system

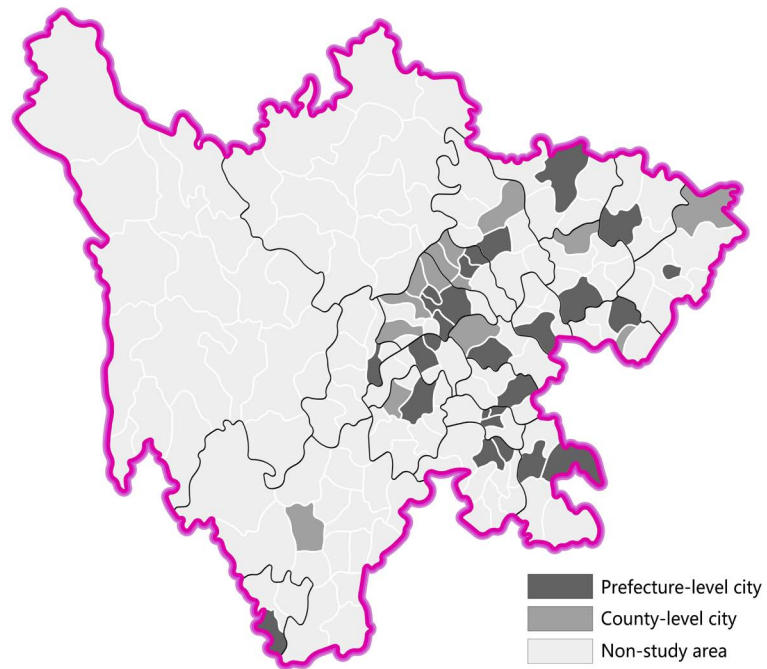


Figure 1. Research scope.

(DMSP) was taken in 2013. In this paper, the data of the night light in Sichuan Province extracted by the study is 0 - 63, the saturated light gray value is 63, and the spatial resolution is 1km (Note: Due to the DMSP/OLS luminous remote sensing image data on the National Geophysical Data Center website as of 2013, the research data selected in this paper is the 2013 data).

2) Landsat8 OLI_TIRS remote sensing image data. The satellite imagery covering the whole region of Sichuan Province was selected in 2013. The data comes from the Geospatial Data Cloud Platform of the Computer Network Information Center of the Chinese Academy of Sciences (<http://www.gscloud.cn>).

3) Population data of city-level and county-level cities at various levels. From the China Statistics Information Network (<http://www.tjcn.org/>).

4) Other auxiliary data. It mainly includes vector administrative boundaries at the national, provincial, municipal, and county levels in China.

3. Data Processing

3.1. DMSP/OLS Data Processing

In order to obtain the remote sensing image data of the study area, the obtained DMSP/OLS luminous remote sensing image data is tailored according to the administrative boundary vector data of Sichuan Province, and the DMSP data of various cities and county-level cities in Sichuan Province are obtained (**Figure 2**).

3.2. Extraction of Urban Built-up Areas of Landsat8 OLI_TIRS Data

The Landsat data of the studied cities were analyzed, and the land use data including the use of construction land, forest land and water bodies were obtained.



Figure 2. DMSP data of various cities and county-level cities in Sichuan Province.

The important basis for assessing the level of urban development is urban construction land. Researchers at home and abroad have made a lot of research on the extraction of urban construction land. Among them, Xu Hanqiu [3] proposed to use the IBI building land index to extract urban built-up areas from remote sensing images. Accuracy can reach more than 96%. The IBI building land index can be constructed by the three indexes of normalized building index NDBI, vegetation cover index NDVI and improved normalized water body index MNDWI.

Calculation formula as follows:

$$\text{NDBI} = (B6 - B5) / (B6 + B5) \quad (1)$$

$$\text{NDVI} = (B5 - B4) / (B5 + B4) \quad (2)$$

$$\text{MNDWI} = (B3 - B6) / (B3 + B6) \quad (3)$$

Among them, B3, B4, B5 and B6 are the green band, the red band, the near-infrared band, and the SWIR1 band of the Landsat8 OLI_TIRS image.

The IBI building land index formula is as follows:

$$\text{IBI} = \frac{[\text{NDBI} - (\text{NDVI} + \text{MNDWI}) / 2]}{[\text{NDBI} + (\text{NDVI} + \text{MNDWI}) / 2]} \quad (4)$$

Substituting the Equation (1), Equation (2), Equation (3) into the Equation (4), the finishing can be obtained:

$$\text{IBI} = \frac{2(B6 - B5) / (B6 + B5) - (B5 - B4) / (B5 + B4) - (B3 - B6) / (B3 + B6)}{2(B6 - B5) / (B6 + B5) + (B5 - B4) / (B5 + B4) + (B3 - B6) / (B3 + B6)} \quad (5)$$

Due to space limitations, the processing results of all prefecture-level cities and county-level cities cannot be displayed. Only the construction land and built-up areas extracted by the IBI index of Mianyang City are displayed here, as shown in **Figure 3** and **Figure 4**.

4. Research Ideas and Methods

The research process of this paper for the ghost city index (**Figure 5**) is as follows:



Figure 3. Mianyang City construction land extracted by IBI index.



Figure 4. Mianyang City built-up area.

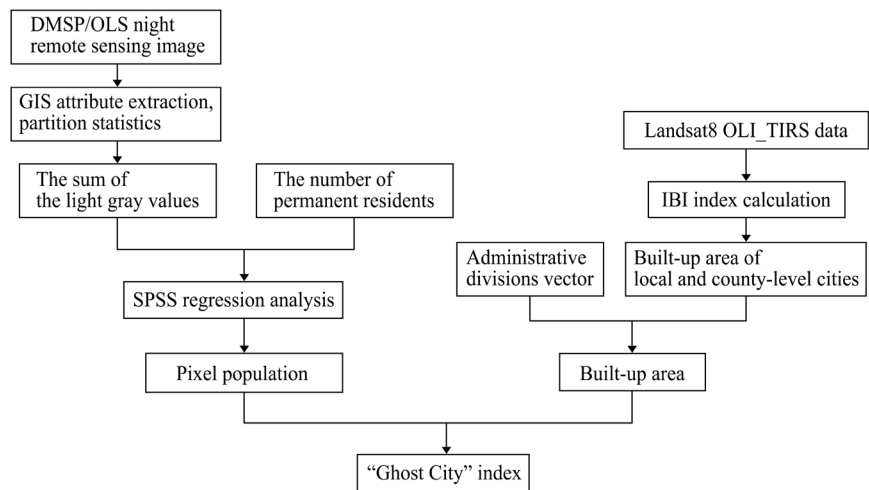


Figure 5. Research process.

Note: The study obtained the population of the population by analyzing the population and lighting data of various cities and counties in Sichuan Province, and extracted the built-up area of Landsat8 OLI_TIRS data with relevant software to obtain the ghost city index of Sichuan Province. The data involved in

this study may have certain errors due to the difficulty of obtaining. It is only for the study of the ghost city index method, and the data will be continuously improved in future research.

4.1. Population Spatialization

The administrative boundary vector data of Sichuan Province is overlapped with the night light remote sensing image, and the DMSP/OLS data of each city and county level city is obtained through the cropping in the GIS data management tool, and the data of night light intensity greater than 6 is obtained through attribute extraction, and after extraction, the data is extracted. The light intensity distribution is shown in **Figure 6**. After obtaining the data of night light intensity greater than 6 in various cities and counties, use the zoning statistics function to calculate the sum of the light gray values of the nighttime lighting data of each city and county level (**Table 1, Figure 7**).

Many scholars have confirmed that the spatial distribution of population has a certain correlation with nighttime lighting data. This paper will fit and analyze the sum of the light intensity and the resident population of 18 prefecture-level cities and 17 county-level cities in Sichuan (**Figure 8**). In the figure, the sum of the light intensity values of each city is X, and the number of permanent residents in each city is Y.

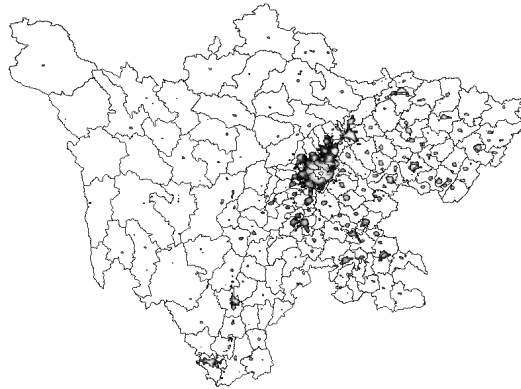


Figure 6. DMSP data with a light intensity greater than 6.



Figure 7. DMSP partition statistics.

Table 1. The sum of the light gray values of the Prefecture-level city and County-level cities.

Number	Prefecture-level city	The sum of the light gray values	County-level city	The sum of the light gray values
1	Zigong	9030	Guanghan	18,012
2	Luzhou	10,281	Wanyuan	1313
3	Ya'an	2835	Xichang	15,436
4	Dazhou	7789	Jiangyou	11,139
5	Yibin	12,647	Dujiangyan	13,323
6	Suining	12,078	Jiayang	5566
7	Nanchong	17,385	Longchang	4178
8	Ziyang	7026	Chongzhou	12,724
9	Neijiang	9780	Langzhong	7771
10	Guang'an	8266	Huaying	2206
11	Bazhong	6779	Qionglai	6271
12	Leshan	16,604	Emeishan	7266
13	Mianyang	28,371	Pengzhou	15,973
14	Deyang	21,901	Maerkang	1265
15	Meishan	14,333	Mianzhu	10,371
16	Panzhihua	22,618	Shifang	8421
17	Chengdu	178,623	Kangding	4061
18	Guangyuan	19,091		

Source: Author self-painting.

According to **Figure 8**, the matching of the city's light intensity value with the resident population has a good effect. Therefore, the population quantity information extracted by real-time remote sensing data is scientific and accurate. The urban population is obtained by fitting the regression equation. The calculation formula of the urban population Num1 of the prefecture-level city and the urban population of the county-level city is as follows:

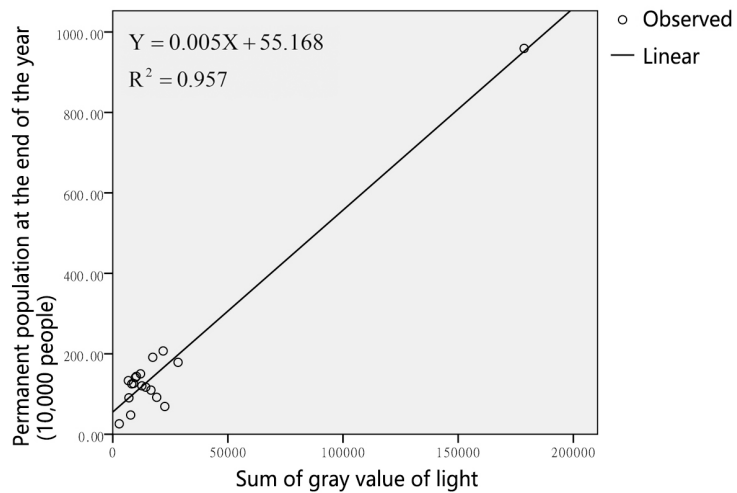
$$\text{Num1} = 0.005 \times \text{DN} \quad (6)$$

$$\text{Num2} = e^{3.461 - \frac{1954.13}{\text{DN}}} \quad (7)$$

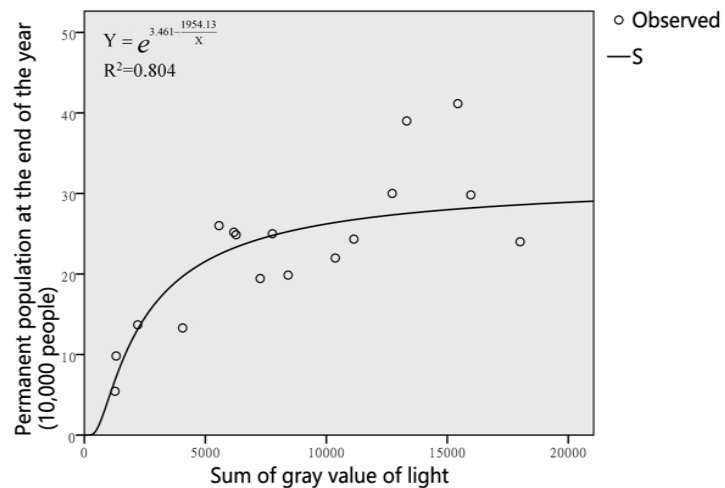
Note: DN is the sum of the light gray values of the city and county level cities.

4.2. "Ghost City" Index

Ghost City is an urban disease in the process of urban development due to unrestricted expansion, lack of rational planning and unbalanced development, and the urban housing vacancy rate is too high and the occupancy rate is too low. In recent years, residents from the top to the bottom of the country have gradually realized the importance of the rational development of the city and began to pay



(a)



(b)

Figure 8. Light and population fit curve. (a) Prefecture-level city; (b) County-level city.

attention to the development of “healthy cities”. The existence of the “Ghost City” phenomenon is inevitably inconsistent with the trend of urban healthy development. The “Ghost City” index is an important indicator to measure whether the city has become a “Ghost City” [4]. Therefore, the monitoring of the “Ghost City Index” is particularly important.

According to the built-up area of prefecture-level cities and county-level cities in Sichuan Province extracted from the previous article and the urban population obtained according to the fitted regression equation, the “Ghost City” index of prefecture-level cities and county-level cities in Sichuan Province is calculated (Table 2). The calculation formula is as follows:

$$\text{Index} = \frac{\text{Num}}{S} \quad (8)$$

Note: Index is the “Ghost City” index of the Prefecture-level city and County-level cities; Num is the urban population; S is the built-up area.

Table 2. The “Ghost City” index of the Prefecture-level city and County-level cities.

Number	Prefecture-level city	Urban population (10,000 people)	Built-up area (km ²)	Ghost City index	County-level city	Urban population (10,000 people)	Built-up area (km ²)	Ghost City index
1	Zigong	45.15	106.48	0.42	Guanghan	28.57	48.63	0.59
2	Luzhou	51.41	109.37	0.47	Wanyuan	7.19	11.20	0.64
3	Ya'an	14.18	29.20	0.49	Xichang	28.06	37.02	0.76
4	Dazhou	38.95	68.00	0.57	Jiangyou	26.72	35.00	0.76
5	Yibin	63.24	93.52	0.68	Dujiangyan	27.50	34.25	0.80
6	Suining	60.39	75.90	0.80	Jianyang	22.42	26.00	0.86
7	Nanchong	86.93	109.00	0.80	Longchang	19.95	23.00	0.87
8	Ziyang	35.13	43.03	0.82	Chongzhou	27.31	29.40	0.93
9	Neijiang	48.90	58.01	0.84	Langzhong	24.77	26.50	0.93
10	Guang'an	41.33	46.90	0.88	Huaying	13.13	12.50	1.05
11	Bazhong	33.90	28.00	1.21	Qionglai	23.32	21.13	1.10
12	Leshan	83.02	68.01	1.22	Emeishan	24.34	18.80	1.29
13	Mianyang	141.86	110.00	1.29	Pengzhou	28.18	21.26	1.33
14	Deyang	109.51	69.79	1.57	Maerkang	6.80	5.06	1.34
15	Meishan	71.67	45.20	1.59	Mianzhu	26.38	14.00	1.88
16	Panzhihua	113.09	69.38	1.63	Shifang	25.25	13.30	1.90
17	Chengdu	893.12	528.90	1.69	Kangding	19.68	3.80	5.18
18	Guangyuan	95.46	50.43	1.89				

Source: Author self-painting.

5. Analysis of Calculation Results

According to the Ghost Town Index obtained above, 35 cities in Sichuan Province (18 prefecture-level cities and 17 county-level cities) can be divided into three categories:

There are 3 cities with an index less than 0.5, including Zigong, Luzhou and Ya'an. Such cities have become ghost towns, and their urban development has serious problems, and there has been an imbalance between urban population and urbanization. Therefore, it is necessary to implement new urbanization and realize ghosting urbanization through rational use of land resources and planning.

There are 8 cities with indices ranging from 0.5 to 0.8, including Dazhou, Nanchong, Yibin, Suining, Guanghan, Wanyuan, Xichang and Jiangyou. Although this type of city has not become a ghost town, its urbanization still has problems. It also needs to provide a more rational urbanization development strategy for the city in terms of policies and planning.

There are 24 cities with indices greater than 0.8, including Ziyang, Neijiang, Guang'an, Bazhong, Leshan, Mianyang, Deyang, Meishan, Panzhihua, Chengdu, Guangyuan, Dujiangyan, Jianyang, Longchang, Chongzhou, Langzhong,

Huaying, Qionglai, Emeishan, Pengzhou, Maerkang, Mianzhu, Shifang and Kangding. The urbanization of this type of city is more reasonable, basically achieving the balanced development of urban population and urbanization. In the later stage of construction and development, it is necessary to monitor the urban population and urbanization information in real time to avoid the development trend of “ghost town”.

In summary, there are three cities in Sichuan Province where there are ghost towns, and another eight cities have a tendency to become “ghost towns”. The rest of the cities are developing better. In general, the overall situation of the province is good. According to the construction of the ghost city index in Sichuan Province, it can be concluded that in the process of urban development in Sichuan Province, it is still necessary to pay attention to the rational use of resources and the rationality of urban development, so that the city that is a ghost city can basically achieve ghost city transformation and cities that have not become ghost towns avoid forming a trend toward ghost towns or become ghost towns.

6. The Reason for the Formation of Ghost Towns

According to the previous analysis of the ghost city index, the ghost towns in Sichuan Province are mainly distributed in the southeast, and the cities with ghost town development trends are mainly distributed in the northeast. There is basically no ghost town phenomenon in central Sichuan. The central part of Sichuan Province is dominated by cities such as Chengdu and Mianyang, and Chengdu, as the capital of Sichuan Province, is therefore more attractive to people, so there is no ghost city phenomenon.

According to a large number of literature research, many scholars also pay more attention to the ghost city phenomenon. Among them, Nie Xiangyu [5] and Duan Lufeng [6] have elaborated on the types of ghost towns. The types are mainly disaster-type ghost cities, fading ghost cities, and planning advanced type ghost cities, planning lag ghost cities and real estate ghost cities. Among them, the disaster-type ghost town is mainly caused by the city’s lack of popularity, which leads to becoming an empty city. The decline-type ghost town is caused by the depletion of resources in the process of urban development, resulting in the loss of population, thus forming a ghost city. Planning advanced ghost towns is Due to unreasonable planning, far exceeding the demand of urban planning population, many construction land is idle. Planning a lag-type ghost town is because the planning cannot meet the needs of the urban population, the planning function is too single or the public service facilities and infrastructure are not perfect, resulting in urban population outflow. Real estate-type ghost town is due to the emergence of real estate speculation, resulting in the expansion of the real estate market, making the urban housing occupancy rate too low, vacancy rate is too high, thus forming a ghost town.

According to the study of the similarities and differences between cities (Table 3), the cities that formed the ghost city phenomenon and the development

Table 3. Comparison of similarities and differences between cities.

Num	Type	Place	Site	Topography	City culture	City positioning	Differences	Commonalities
1		Zigong	Southeastern Sichuan Province	Low hills	Millennium Salt, Dinosaur Township, Nanguo Lamp City, Gourmet House	Chinese historical and cultural city		
2	Ghost City	Luzhou	Southeastern Sichuan Province	Hilly, Flat dam	Red culture, Wine culture	Chinese historical and cultural city		
3		Ya'an	Western Sichuan Province	Mountains, Hills	The Ancient Tea Horse Road, the Huidi Culture of the Han Dynasty, and the Sanya Culture	Ethnic corridor, Tourism city		
4		Dazhou	Northeastern Sichuan Province	Mountains, Hills	Yuan Jiu Denggao, Shiqiao Fire Dragon	Chinese gas capital		
5		Nanchong	Northeastern Sichuan Province	Low hills	Red culture, silk culture, Three Kingdoms culture, Jialingjiang culture	Chinese outstanding tourist city	Each city has its own distinctive culture, but it lacks the promotion and creation of culture	Have a long history and culture, and all focus on development tourism
6		Yibin	Southern Sichuan Province	Mountains, Hills	Wine culture, bamboo culture, tea culture, Miaoxiang culture	Chinese historical and cultural city, Chinese outstanding tourist city		
7	Have a ghost town development trend	Suining	Central Sichuan Province	Hills	Calligraphy, poetry culture, Sichuan opera	Chinese outstanding tourist city		
8		Guanghan	Chengdu Plain	Plain, Shallow hill	Jinyan Lake, Fanghu Park, Guanghan Confucian Temple, Guanghan Dongchan Temple, Han Dynasty Ancient Tombs	Chinese outstanding tourist city		
9		Wanyuan	Northeastern Sichuan Province	Mountains	Red culture, lychee road	Bashan tourist attraction		
10		Xichang	Southern Sichuan Province	Mountains, Flat dam	National culture, satellite launching	Chinese outstanding tourist city		
11		Jiangyou	Northwestern Sichuan Province	Plains, Hills	Zhongba Soy Sauce, Jiangyou Fuzi	Chinese outstanding tourist city		

Source: Author self-painting.

trend of ghost towns in this study are not in line with the disaster-type and the decline-type ghost city. Most of the cities (such as Luzhou, Ya'an, etc.) are mainly tourism development. Due to the excessive development of tourism, most of the buildings or service facilities in urban construction are aimed at tourism. In order to pursue the interests of the tourism industry, the large-scale construction of the tourism industry has led to a reduction in the utilization rate of urban land, thus forming a ghost town. In addition to this, there are also ghost towns created by cities in order to promote development, large-scale construction of new districts, and new districts that are not attractive to the population and enterprises.

7. Conclusions and Suggestions

In this study, the 2013 DMSP/OLS night light remote sensing image and Land-

sat8 OLI_TIRS remote sensing image were used to construct the ghost city index of each city in Sichuan Province. The lower the utilization rate of urban land resources, the lower the ghost city index; the higher the utilization rate of urban land resources, the higher the ghost city index. "Ghost Town" is always closely linked with the urbanization of the Great Leap Forward and over-exploitation of real estate. It is a subjective "making city" movement that lacks rational cognition and scientific considerations [7]. Therefore, the study of the Ghost Town Index is conducive to the monitoring of the urbanization of the city, which is conducive to the healthy and rapid development of each city.

The existence of ghost towns will result in low land resource utilization and waste of land, and will hinder the healthy and rapid development of cities. Therefore, how to rationally urbanize is a key issue for urban development. Combined with the previous analysis of the Sichuan Ghost Town Index and the reasons for the formation of ghost towns, the paper puts forward suggestions on the future of ghosting and rational urbanization in Sichuan.

1) Government level: In the process of urban development, the stage of growth of urban development is overemphasized, while the ups and downs of urban development may be neglected [8]. Therefore, in the process of development, scientific decision-making should be made to rationally plan the situation of the city. The distribution law of urban population density is declining from the traditional central area to the suburbs, so the intensity of human activities in the newly developed areas of the city is significantly lower than that of the urban old city [9]. In the process of urbanization, the construction of the new district must be gradual and gradual, and it is necessary to strengthen the supervision and management of urban planning to prevent the emergence of unorderly spreading [10] and lead to the formation of "empty cities" and "ghost cities".

2) Planner level: Each city has its own unique culture and resources. In the planning, it should avoid the "Same Imagines of the City" and all construction methods cannot be copied. Planning and design should focus on the development of traditional culture with urban characteristics, strengthen residents' sense of identity with the city, and enhance the vitality of the city.

In summary, ghost towns will bring various environmental problems such as land waste and waste of resources. Cities such as Ya'an and Zhangzhou should be committed to revitalizing "ghost towns". Therefore, each city should implement scientific and rational urban planning. When planning and constructing, it should be realistic and conform to local conditions and integrate local culture to enhance the city's attractiveness and vitality.

Conflicts of Interest

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

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