Research on the change of Spatio-temporal characteristics of Urban built-up area based on remote Sensing-- A case study of Yulin City, Shaanxi Province

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Abstract: Since the reform and opening up, the process of urbanization in China has been at a high level. In order to accurately obtain the boundary of urban built-up area and the spatio-temporal change characteristics of urban built-up area in recent years, this paper takes Yulin City as an example. With the help of ArcGIS, ERDAS and other platforms, we combine spatial comparison method and index method to extract urban built-up area from DMSP-OLS night light data and Landsat image data. At the same time, the confusion matrix is used to verify the extraction boundary. The research shows that: (1) Using DMSP-OLS night light data and Landsat data to extract the built-up area, the overall accuracy can reach 99%; (2) The urban built-up area of Yulin City expanded at a high speed from 2005 to 2018; (3) The urbanization process in the northeast of Yulin City is obviously higher than that in the south in recent years. This study has a certain reference value for the extraction of urban built-up areas and the development of urbanization in Yulin City by using DMSP-OLS night light data and Landsat data.

1 Introduction
The process of urbanization has gradually become the research focus of geography in recent years. Urbanization is not only a process of population migration related to economic, policy, space and other factors, but also the only way of modernization and economic and social development [1][2]. Over the past 40 years of reform and opening up, it has been a period of time when China's urbanization development has created a world miracle and made great achievements in the construction of urban agglomerations. During this period, China's urbanization level has increased by 1.5 times, exceeding the world average urbanization level by 3.7 percentage points [3][4]. However, Yulin City, Shaanxi Province, as an important energy base in China, the development of urbanization is extremely uneven [5]. In order to promote the balanced development of urbanization in various areas of Yulin City and the rational use of land resources, it is necessary for us to understand the spatial pattern distribution of Yulin City in recent years, and an important manifestation that can directly reflect the process of urbanization is the rapid expansion of urban built-up areas [6]. The early urban expansion remote sensing research is basically carried out through the interpretation of aerial remote sensing data, which is more accurate and comparable than the traditional methods, but it costs a lot of money. With the development of science and technology, satellite remote sensing images and night light data have gradually become the main sources of urban expansion research [7][8]. Domestic and foreign scholars have also made use of DMSP-OLS night light data and satellite remote sensing images to carry out a series of related studies. For example, M.Che and others use the combination of SAR and DMSP-OLS night light data to reflect a
variety of spatio-temporal patterns of the city [9]. Sahoo et al analyze power consumption in India by comparing VIRS-DNB and DMSP-OLS data. Hu Lanli and others evaluate and analyze the GDP of Chinese provinces based on DMSP-OLS night light data [10]. Yan Shuqin and others explored the expansion of the built-up area of Wuhan metropolitan area and its driving factors based on DMSP-OLS night light data [11]. Wang Ruoxi and others combined DMSP-OLS night light data with Landsat data to extract urban built-up areas in Jiangxi Province, and also verified the reliability of the combination of DMSP-OLS night light data and Landsat data [12].

With the help of ArcGIS, ENVI and other platforms, taking Yulin City as an example, this paper combines DMSP-OLS night light data and Landsat data of Yulin City in 2005, 2013 and 2018 to extract urban built-up areas. this method can not only avoid "light spillover" effect, but also avoid the influence of bare land and cultivated land on urban built-up areas. In order to verify the accuracy of urban built-up area extraction, this paper uses confusion matrix to verify and analyze. This paper makes a comprehensive analysis of the changes of the temporal and spatial characteristics of the urban built-up area in Yulin City, so as to provide theoretical and technical support for the urbanization construction of Yulin City.

2 Data sources and basic situation

2.1 Overview of the study area
Yulin City is located in the northernmost part of China's Shaanxi Province, at the junction of the Loess Plateau and Maowusu Sandy Land, which is the transitional area between the Loess Plateau and the Inner Mongolia Plateau. It belongs to temperate semi-arid and sub-humid arid climate, with four distinct seasons, dry climate and long sunshine hours. It has obvious continental climate characteristics. Yulin City is very rich in energy and mineral resources, which is rich in coal, oil, gas and salt. It is the only national energy and chemical base in the country, which undertakes the important task of national energy strategic security. The urbanization level of the whole city has reached 55%, which is 13% higher than that at the end of the Eleventh five-year Plan. The urbanization process of Yulin City and the spatio-temporal changes of the built-up area are worthy of further exploration.

2.2 Data sources
(a) Night light data
The DMSP-OLS night light data used in this paper are from two different sensors, the data in 2005 and 2013 are from the Resource and Environmental Science and data Center of the Chinese Academy of Sciences, and the data in 2018 are from the NOAA National Geographic data Center of the United States. DMSP-OLS night light data have been widely used in urbanization and fire monitoring in recent years [13].

(b) Optical remote sensing image data
This paper selects the Landsat series remote sensing images of 2005, 2013 and 2018, and the cloud cover is less than 10%, which comes from the geospatial data cloud.

(c) Auxiliary data
This paper draws lessons from "Chinese Urban Statistical data" to obtain the built-up area of Yulin City from 2005 to 18, makes reference for obtaining the threshold of the built-up area, and makes use of the Yulin Statistical Yearbook to provide some urban construction and economic information, and the vector data of Yulin administrative region from the National basic Geographic Information Center are used.

| Data name     | Data source                                                                 | Time       | Spatial resolution |
|---------------|------------------------------------------------------------------------------|------------|--------------------|
| Night light data | Resource and Environmental Science and data Center of the Chinese Academy of Sciences. | 2005,2013  | 1km                |
2.3 Data preprocessing

(a) Night light data preprocessing

First of all, in order to avoid the influence of projection deformation on pixel area, two kinds of data are converted into Lambert azimuth equal area projection (Asia_Lambert_Conformal_Conic) in ArcMap. Because the night light data used are not images collected by the same sensor, we need to make different data have the same evaluation criteria. We use Zhang Mengqi [14] and others to carry out univariate quadratic regression modeling and parameters a, b, c determined by regression fitting to convert the DN value of DMSP-OLS night light data, and the DN value conversion equation:

$$DN' = a \times DN_0^2 + b \times DN_0 + c$$

(1)

In the formula, and are the DN values before and after sensor correction, respectively. Using this equation, the light data sets of different sensors are processed, and the mutually corrected data sets are obtained, and the sensor data sets of different years are corrected according to Table 2.

| Data       | a     | b     | c     |
|------------|-------|-------|-------|
| F16→F15    | -0.001447 | 1.091 | 0.913 |
| F15→F14    | -0.003202 | 1.093 | 1.766 |
| F14→F12    | 0.003413  | 0.628 | 2.717 |
| F12→F10    | 0.001906  | 0.832 | 0.886 |
| F16→F18    | 0.004262  | 0.673 | 0.766 |

After the above process, the same standard DMSP-OLS night light data can be obtained, and then extracted by using the administrative boundary mask of Yulin City, the DMSP-OLS night light data of Yulin City in 2005, 2013 and 2018 can be obtained.

(b) Remote sensing image data preprocessing

In this paper, in order to improve the quality of the remote sensing image, improve the visual effect of the image, highlight the required information and the amount of compressed image data, the radiometric calibration, atmospheric correction, mosaic and mask extraction of the Landsat5 TM image in 2005 and the Landsat8 TM image in 2013 and 2018 were processed by ENVI5.3, and the remote sensing images of Yulin in 2005, 2013 and 2018 were obtained.

3 Research methods

3.1 Spatial comparison method based on auxiliary data

The spatial comparison method based on auxiliary data was put forward by he Chunyang [15]. This method has two basic assumptions: (1) The relevant statistical data can accurately reflect the real area of the urban built-up area; (2) The urban built-up area patches that exist in the DMSP-OLS night light
data of the previous period also exist in the next period. On the basis of these two assumptions, firstly, a dynamic threshold is set, the urban built-up area is greater than the threshold, and the non-built area is less than the threshold. According to the threshold, the urban built-up area is extracted and its area is calculated. Then it is compared with the built-up area in the statistical data until the two data are close to each other.

Based on the above principles, this paper processes the DMSP-OLS night light data of Yulin City in 2005, 2013 and 2018 in ArcGIS platform. Although the extraction of urban built-up area based on DMSP-OLS night light data can reflect the change of urban built-up area. However, there is a "light spillover" effect in the night light data, which will make the non-built areas around the built-up areas be mistaken for built-up areas, so it is necessary to extract the relevant indexes from Landsat images in order to extract the urban built-up areas more accurately.

3.2 Index method

The NDVI and NDBI indices are extracted first, then the two indices are binarized and superimposed, and the urban built-up area can be obtained. The algorithm of normalized building index (NDBI) is:

$$\text{NDBI} = \frac{\text{MIR} - \text{NIR}}{\text{MIR} + \text{NIR}}$$

In the formula, MIR is the mid-infrared band and NIR is the near-infrared band.

The algorithm of Normalized vegetation Index (NDVI) is:

$$\text{NDVI} = \frac{\text{IR} - \text{R}}{\text{IR} + \text{R}}$$

In the formula, IR is near infrared band and R is infrared band.

The results of urban built-up area obtained by this method are visually interpreted and modified, and the area of the modified built-up area is obtained. Although this method can avoid the "light spillover" effect, the remote sensing data will be affected by the same spectral foreign bodies and different spectra, and the extracted urban built-up areas will also be affected by some bare land and sparse vegetation. In order to get a more accurate boundary of the urban built-up area in Yulin City, we fuse the extraction and correction results of the two kinds of data to get a new built-up area boundary.

3.3 Confusion matrix

In order to analyze and verify the accuracy of urban built-up area extracted by DMSP-OLS night light data and Landsat data, the confusion matrix is used as the accuracy evaluation index of urban built-up area boundary, and the specific evaluation indexes include overall accuracy, mapping accuracy, user accuracy and so on. In this paper, the overall accuracy (OA) and Kappa coefficient are selected to verify the accuracy of the results of urban built-up area extraction. Overall accuracy (OA) refers to the ratio of the number of class pixels correctly classified to the total number of categories, which can well represent the classification accuracy. The Kappa coefficient is a ratio that represents the proportion of error reduction between classification and completely random classification.

3.4 Urban built-up area expansion and morphological analysis method

In this paper, the intensity of urban expansion, the rate of urban expansion and the location of urban center of gravity are used to measure the change of the built area of Yulin City.

The intensity of urban expansion refers to the percentage of the expansion area in the total urban land area during the study period to measure the strength of urban expansion in different periods. Its calculation formula is:

$$\text{UII} = \frac{S_T - S_0}{TAL} / T$$

(4)
In the formula, UII represents the intensity of urban expansion, represents the area of urban built-up area in the later stage, represents the area of urban built-up area in the previous stage, TAL is the total area of the city (obtained by statistical yearbook), and T is the time interval.

The rate of urban expansion refers to the rate of change of urban area per unit time, which is of great significance for measuring the development of urban built-up areas.

\[ V = \frac{S_f - S_0}{T} \]  

(5)

In the formula, V represents the rate of expansion, represents the area of the urban built-up area in the later stage, represents the area of the urban built-up area in the previous stage, and T represents the time interval in years.

4 Results and discussion

4.1 Expansion of urban built-up areas

For the scope and area of urban built-up areas of Yulin City extracted by the above methods in 2005, 2013 and 2018, this paper calculates the intensity and rate of urban expansion in recent years, as shown in Table 3. The data obtained can directly see the rapid expansion of urban built-up areas in Yulin City in recent years, and the intensity of urban expansion is relatively large during the period from 2005 to 2013, reflecting the urbanization process of Yulin City at that time. During the five-year period from 2013 to 2018, although the intensity of expansion was a little lower than before, it was still in a state of continuous expansion. Yulin as an important energy base in China, the development of urbanization has a great relationship with the relevant policies of the government and the geographical location and energy advantages of Yulin.

| Year       | Urban expansion intensity/% | Urban expansion rate |
|------------|----------------------------|---------------------|
| 2005-2013  | 6.25                       | 19.75               |
| 2013-2018  | 4.91                       | 20.6                |

4.2 Morphological changes of urban built-up areas

Through the analysis of the center of gravity position change (figure1) and migration trajectory of urban expansion from 20005 to 2018, it is concluded that the center of gravity of the urban built-up area changed more actively during the period from 2005 to 2018. In 2005, the center of gravity of the built-up area of Yulin City is mainly in Jingbian County, and in 2013, the center of gravity of the urban built-up area of Yulin City gradually moved to the northeast, that is, the Shenmu area is close to the Shenmu area. The center of gravity of the urban built-up area in 2018 is close to the southwest on the basis of the center of gravity of the urban built-up area in 2013, that is, Yuyang District.

From the changes of these two stages, we can see the changing characteristics of the development direction of urbanization in Yulin City. Around 2005, Jingbian County of Yulin City built a number of expressways leading to various places, which has become an important transportation hub in western China, which may directly affect the key factors of the center of gravity of the built-up area of Yulin City. After 2010, the state has made great efforts to develop resources and energy, and Shenmu County is rich in mineral resources, which also has a great advantage in this period of development. Then, the center of gravity of the urban built-up area gradually shifted to Yuyang District.
4.3 Test results of confusion matrix

In this paper, the calculated relevant accuracy index, such as Table 4, the extracted correlation accuracy index quality is higher. This also confirms that the urban built-up area extracted by DMSP-OLS night light data and Landsat data has a certain credibility, and the accuracy of the extraction results does meet the research and related analysis of the urbanization process of Yulin City.

|        | 2005  | 2013  | 2018  |
|--------|-------|-------|-------|
| Overall accuracy | 99.08% | 97.81% | 97.42% |
| Kappa index     | 0.6169 | 0.5809 | 0.7533 |

5 Conclusion

In this study, the urban built-up areas of Yulin City in 2005, 2013 and 2018 were extracted by the combination of DMSP-OLS night light data and Landsat data, and their spatio-temporal variation characteristics were analyzed and discussed.

The main results are as follows:

1) This paper adopts the method of extracting urban built-up area by combining night light data with Landsat data. On the one hand, this method avoids the "light spillover" effect of using night light data alone. At the same time, on the other hand, it avoids the interference of bare land, water body and so on to the remote sensing image, and the collection of the two kinds of data has better accuracy and better effect, which makes the extraction results more consistent with the actual situation and has a certain degree of credibility.

2) Through the study of this paper, we can know that the speed of urban expansion in Yulin City is relatively fast in the past 15 years. During the research period, the speed of urban expansion continues to increase, and although the intensity of urban expansion decreases, it has also been in the stage of expansion. It reflects the development law of the urbanization process of Yulin City.
(3) During the study period, the migration of the focus of urban development in Yulin reflects the imbalance in the process of urbanization in Yulin, mainly in the north and west, while the urbanization in the south is relatively slow.

Combined with the objective reality, this study uses DMSP-OLS night light data and Landsat data to extract the boundary of urban built-up area, which reflects the potential of DMSP-OLS night light data in exploring the process of urbanization. This paper also shows that with the rapid expansion of urban built-up areas in Yulin City, the urbanization process of Yulin City will be greatly improved in the future. This paper puts forward the following suggestions to the relevant government of Yulin City: first, in the process of the development of the north and west, we should mobilize various factors to promote the development of the southern region and improve the imbalance of urbanization development; secondly, we can increase the population mobility between urban and rural areas to balance urban and rural development. Due to the short research period and large research area, this paper is unable to analyze the spatio-temporal characteristics of the longer time series of urbanization in Yulin City, but it also has a certain reference value for the development of urbanization in Yulin City.

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