# Study on Extraction Method of Urban Built-up in Tianjin Based on Night-light Data


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**KEY WORDS:**Night-light Data; Urban Built-up Area; Pseudo Invariant Features; Threshold Segmentation Method



**ABSTRACT:** This paper used DMSP/OLS night-light data as the main data source.High resolution land cover classification image data was used as auxiliary data.Correction of night-light data in Tianjin applying the pseudo invariant feature method.The multi-data source threshold segmentation method was applied to extract the urban built-up area in Tianjin from 1998 to 2013 based on the correction of multi-temporal night-light data. The results show that the digital value of night-light data statistics in different years was steadily increasing year by year. The continuity and comparability of digital value were significantly enhanced. The area of urban built-up area was increased from 397.00 km$^2$to 776.00 km$^2$ in the studied time period.But the rate of expansion gradually tends to be slow. The average relative error of the urban built-up land information was 9.28% using the multi-data source threshold segmentation method,which can more accurately reflect the actual situation of the urban built-up area expansion in Tianjin.The results can provide a reference scheme for the selection of urban built-up area extraction technology based on night-light data.


## Introduction

Cities are the residence area of human life,and urban construction and development is an important way of human social development and economic progress. Urban built-up area planning is an important research field in urban spatial structure, and quantifying the regional changes of urban built-up area has always been an important content in this field(XU Xueqiang,2009).The extraction of traditional urban built-up areas relies on statistical data, which is highly subjectivity and non-universality (LIU Yuan,2019).Remote sensing image are widely used in the study of urban expansion monitoring and evaluation, because of its advantages of wide detection range, strong timeliness, less ground limitation and convenient acquisition.Night-light data is widely used in regional development measurement,because of its small data volume and convenient processing.The OLS（operational linescan system,OLS）sensor on DMSP (defense meteorological satellite program,DMSP) has the ability of low-light detection capability,which can detect the low-intensity light emitted by night city lights and even smaller residential areas and traffic flow.The light area and dark area of the urban can be clearly distinguished by the sensor, which is suitable for large-scale dynamic monitoring of human activities and urban development (MI Xiaonan,2013). The night-light data of urban central area has strong accessibility, small processing volume,and the index strength has been proved to be positively correlated with economic development.It can be applied to the extraction of urban centers of different scales and spaces (CHEN Zuoqi,2017).

The night-light data of Tianjin comes from 4 sensors including F12,F14,F16 and F18 in the studied time period.The data between different years cannot be directly compared and studied,because of the difference performance between different sensors of DMSP/OLS data.To solve comparability, it is necessary to perform sensor and continuity calibration on the acquired original night-light data.Therefore,this paper extract the urban built-up area of Tianjin in 1998, 2003, 2008, and 2013 using the multi-source data threshold method to determine the threshold value of night-light data.And the quantitative characteristics of the changes in the urban built-up area of Tianjin are analyzed during 1998 to 2013.It accurately extracts the threshold value of the urban built-up areas at different development stages and provides relevant technical references for the measurement of urban built-up areas in Tianjin.

## 1 Sketchy circumstances in the studied area

Tianjin (“JIN”for short) is located in the northeast of the North China Plain and the lower reaches of the Haihe River basin, and is called to be " Downstream of the Nine Rivers".Tianjin is located in the southern part of Beijing-Tianjin-Tangshan regions,and is the center of Bohai rim ranging from 38°34’-40°15’ north latitude and 116°34’-18°04’ east longitude. It is located in the economically developed center of Northeast Asia and has significant geographical advantage.The urbanization level of Tianjin reached 82.93%, and the urban population increased by 6.023 million compared with 1998 in 2017 with the rapid development of economy(Tianjin Statistic Bureau,2003-2013), the urban built-up area are expanded significantly,and huge demand for urban space research are created .

## 2 Data source and research method

### 2.1 Data source

In this paper, night-light data was used to extract the urban built-up areas in Tianjin, and higher-resolution image data was introduced as the auxiliary data to determine the threshold value of the built-up area extraction in 1998, 2003, 2008 and 2013.DMSP/OLS stable night-light data(sourced from https://www.ngdc.noaa.gov/) was obtained through the OLS (operational linescan system,OLS) carrying by the DMSP (defense meteorological satellite program,DMSP).The Digital Number（DN）value range of the data was 1-63, which represented the ground lighting information. The larger the DN value of the regional night-light data, the more likely it’s the urban built-up area.The spatial resolution of the data was 1km.The auxiliary data was the land cover classification product MCD12Q1 in the MODIS with the same year (sourced from https://lpdaac.usgs.gov/ website).The data set contained 17 main types of land cover types,and it was an annual synthetic data product with a resolution of 0.5km since 2001.Therefore,the higher-resolution auxiliary data in 1998 was the interpreted Landsat TM land cover classification image. The statistical data came from Tianjin Statistical Yearbook.

### 2.2 Research method

First of all, a series of preprocessing,such as resampling, projection conversion, and cliping of the downloaded night-light image data were required. The data was available through sensor and continuity calibration.Secondly,the higher-resolution images and DMSP/OLS data were combined to determine the optimal segmentation threshold in different years, and the range of urban built-up area was determined based on this.Finally, the precision analysis of the extracted urban built-up area was made based on the statistical data.

The determination of the threshold was a key link in the extraction of urban built-up areas. This paper used higher-resolution images as auxiliary data. The threshold segmentation method was used to extract the urban built-up area using multi-temporal night-light data, the MCDQ12 land cover classification data and the interpreted Landsat TM image data. It was assumed that the urban construction area in the higher-resolution land cover classification image data was the real urban built-up area, and this range was taken as the standard threshold to extract the urban built-up area in the night-light data. The approximate range of urban built-up area was determined on the night-light data of the same period based on the classification result of auxiliary data. As shown in Fig.1, the DN value change of the night-light in this range was analyzed, and sensitive area was taken as the DN value drastically changes range. The red line in Fig.1 was the high sensitive area of DN value in 2003(SHU Song,2011). Iterative optimization was used to determine the optimal threshold for the extraction of urban built-up areas that year.

Taking 2003 as an example (other years are treated in the same way),the urban built-up area in the higher-resolution image was used as the masking range to extracted the urban built-up area of Tianjin in the night-light data,based on ArcGIS. The distribution curve of the number of pixels was made with the digital numbers of night-light as the horizontal axis and the corresponding pixel numbers as the vertical axis through counting the frequency of DN value . It could be seen that when the DN value increases to a certain range, there will be a explosion occurs, which is an important reference range for threshold setting in Fig.1.After selecting the threshold, the extracted urban built-up area and the area range in the reference image were compared, and then the optimal threshold for the night-light data extraction in Tianjin was determined by iterative optimization(Imhoff M L,1997).

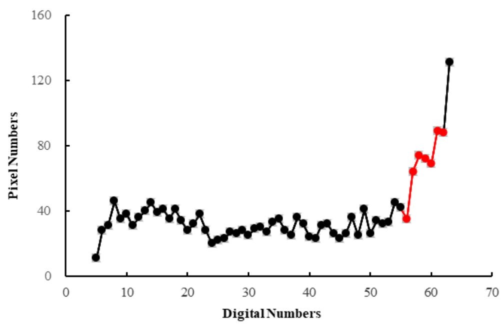



Fig.1 Frequency distribution of DN value of night-light data after Masking in 2003

# 3 Results and analysis

## 3.1 Evaluation of night-light image correction results

Taking the night-light image data in 1998, 2003, 2008 and 2013 as the data source, the Pseudo Invariant Features method was used to correct the long time series of images. As shown in Fig.2, the average digital numbers and the number of bright pixels show orderly fluctuations on the time scale after the long time series of DMSP/OLS images were corrected. The performance of different sensors was different, because DMSP/OLS images originated from different sensors. The performance of the same sensor will also degrade over time, and this leaded to differences between images obtained by different sensors in the same year and images obtained by the same sensor in different years. So before the study, the images should be corrected mutually and continuously(CAO Ziyang,2015). The average digital numbers and the total number of bright pixels in the corrected night-light data set showed an increasing trend year by year, and indicated that the corrected night-light image was relatively stable and continuous. The images of consecutive years in the corrected night-light image data set were comparable, because of using the same reference image to correct the images of different years.

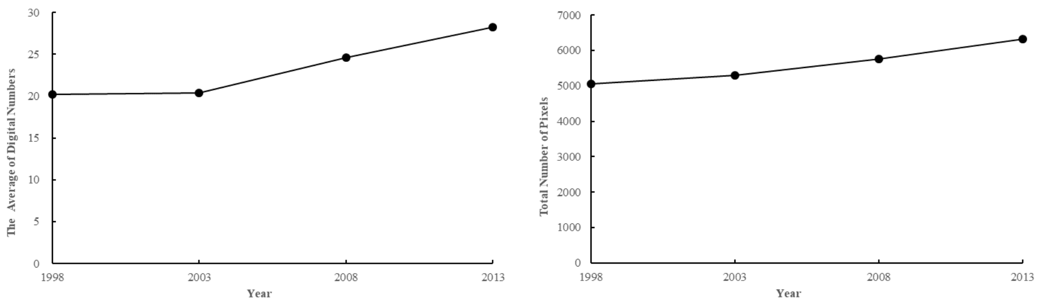



Fig.2 The average of digital numbers and total number of pixels of night-light Data after correction

## 3.2 Extraction and accuracy assessment of urban built-up area

The multi-data source threshold segmentation method was used to extract the urban built-up area from the night-light images of Tianjin in 1998, 2003, 2008, and

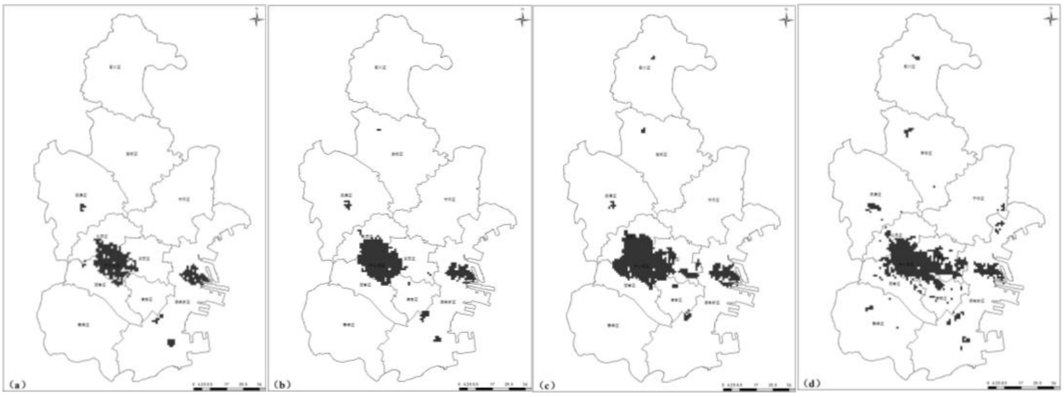
2013. The thresholds in each year were 61, 58, 62, and 61, respectively. The extracted urban built-up area in Tianjin from 1998 to 2013 were shown in Fig 3.The area of urban built-up area of Tianjin extracted in each year was compared with the area of urban construction land in the Tianjin statistical yearbook of the same year. According to the data analysis in the Table 1, it could be seen that the multi-source data threshold method was a new data source to obtain the urban area information, which can effectively identified the urban land information in different development stages.

According to Table 1, the built-up area of Tianjin increased by 379$km^2$ from 1998 to 2013.The newly increased urban built-up area from 1998 to 2003 was 126$km^2$.The increased area of the built-up area 2003 to 2008 was 215 $km^2$, and the expansion scale was significantly expanded in the studied time period. Meanwhile,the urban expansion gradually stabilized in 2008 to 2013, and the newly increased urban built-up area was only 38 $km^2$.The urban built-up area extracted by night-lights data was larger than the area in the statistical data in each year. This result was mainly affected by three factors. First, because there was a certain degree of information loss in space expression due to restricted spatial resolution of DMSP/OLS stable night light data with 1km.Second, the maximum peak value of night-light DN was 63,which was affected by the characteristics of DMSP / OLS image sensor. Light saturation effect would occur in densely dense region such as town centers. Through the previous data correction processing, the influence of light saturation effect cannot be completely eliminated. Thirdly, the urban built-up area in the statistical data only includes the urban area. In this study, some counties and cities that contain large residential areas within Tianjin were contained in the urban built-up area extracted by night-light data .

According to Fig.3, the agglomeration and expansion of urban built-up area in Tianjin were mainly concentrated in three directions. First, the built-up areas of cities and towns were mainly concentrated near the central city. With the passage of time, the urban built-up area gradually expanded towards the surrounding six districts with the central city as the origin. Compared with other districts, the expansion area towards Dongli District presented an absolute advantage. Second, the urban built-up areas in the northwest were concentrated in Baodi District and Wuqing district. Third, the urban built-up area in the southeast were concentrated in New Coastal Region of Tianjin, and the expansion was mainly in the middle of New Coastal Region.

In all years, the absolute error of the urban built-up area extracted from the night-light data in 2013 was the smallest, with an absolute error of 39.65$km^2$ and a relative error of 5.38%.Compared with 2003 and 2008, the area extraction error in 2013 presents a significant advantage. The relative errors in 2003 and 2008 were 7.29% and 15.16%, respectively, which were higher than the built-up area extraction error in 2013.The threshold in 2013 was 61. The urban built-up area extracted from the segmentation threshold had the smallest error. Applying the segmentation threshold in 2013,2003 and 2008, the absolute error of two years were -179.47$km^2$ and 231.15$km^2$, and the relative error was -36.82%, 36.07%.The error in the urban built-up area extracted in 2003 and 2008 were significantly higher than in 2013, and there were large errors in reflecting the scale of urban built-up area. Therefore, the optimal threshold for urban built-up area determined in a certain year cannot be directly applied to other years in the same series of data. The segmentation threshold for extracting urban built-up area from stable night-light data was not universal in all years of the same series of data.

Specifically, the 1998 Tianjin Statistical Yearbook data cannot be obtained because of time period affected.



(a) 1998 (b) 2003 (c) 2008 (d)2013 . White represents non urban built-up area and black represents urban built-up area.

Fig.3 Temporal and spatial variation of urban built up area in Tianjin from 1998 to 2013

Table 1 Validation of Extraction accuracy of urban built up area in Tianjin from 1998 to 2013

| | 1998 | 2003 | 2008 | 2013 |
|---|---|---|---|---|
| DMSP/OLS image /$km^2$ | 397.00 | 523.00 | 738.00 | 776.00 |
| statistical data /$km^2$ | - | 487.47 | 640.85 | 736.35 |
| absolute error /$km^2$ | - | 35.53 | 97.15 | 39.65 |
| relative error /% | - | 7.29 | 15.16 | 5.38 |

## 4 Conclusions

This paper collected images of Tianjin DMSP/OLS night-light data, and performed preprocessing such as sensor and continuity calibration on the images. The multi-source data threshold method was used to determine the range of urban built-up area. The urban built-up area extracted by this method could well circumvent the subjectivity and non-universality characteristics of traditional land use data, and make the acquired urban built-up area data more scientific and reasonable.

1) Through a series of systematic calibrations to the original night light data, it could effectively alleviated the effect of night-light data saturation. The results showed that the difference in images obtained by different sensor in the same year were decreased, and the abnormal fluctuations in data in adjacent years was reduced to improve continuity and comparability of data in different years.

2) The multi-source data threshold method was used to extract the built-up area of cities and towns in Tianjin and evaluate the accuracy of built-up area. The average error rate was 9.28%. The spatial pattern was basically consistent with the results of the land cover classification data of the reference image. The urban built-up area information extracted by this method could effectively reflect the actual situation of regional urban development.

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