

# Research on the Spatio-temporal Differences in the Living Standards of the Counties under the Shandong Province

Hongwu CUI<sup>1,\*</sup>, and Qian YANG<sup>2</sup>

<sup>1</sup> Shandong University of Science and Technology, College of Geomatics, Qingdao, China, 266590

<sup>2</sup> Shandong University of Science and Technology, Auditing Department, Qingdao, China, 266590

**Abstract.** Using the method of district statistics to verify the correlation of NPP-VIIRS night light data and GDP, the difference between counties in Shandong from 2012 to 2019 can be analysed and the changes of living standards can be quantified. After obtaining the total value of night light brightness in each county, the coefficient of variation is used to calculate the degree of dispersion of each county, and then the regional differences of each city in 2019 and the inter-annual changes from 2012 to 2019 are analyzed and displayed. In conclusion, living standards of different countries in Shandong are different, and the difference becomes obvious with the growth of GDP. However, the difference of living standards of most countries becomes smaller in recent years.

## 1 Introduction

With the continuous improvement of social living standards, the differences between residents' living standards are gradually increasing, and the gap between rich and poor is becoming more and more obvious. The living standard of the residents is affected by many factors, including material and spiritual factors, which makes it difficult to reasonably evaluate and quantify the living standard of the residents. In order to quantify the gap between the living standards of residents, the night light data is used to simulate the living conditions of residents by using the brightness value of night light, and then the living standards of residents are numerically calculated.

Night light data is widely used in all aspects closely related to residents' lives<sup>[1]</sup>, such as residents' income, population, power consumption<sup>[2]</sup>, carbon emissions<sup>[3]</sup>, natural disasters, environment<sup>[4]</sup>, health<sup>[5]</sup>. By fitting the long-time series of night light data with residents' income, it is proved that the night light data can better reflect the income status of residents. The light data are used to explore the balance of regional economic development, so as to facilitate the proposal of relevant development policies in the future. With the global VIIRS nighttime lighting products<sup>[6]</sup> from 2012 to 2019 calculated by monthly average of Elvidge CD, the Chinese region is selected to better reflect the living standards of Chinese residents.

In this paper, the night light brightness value is used to simulate and quantify the living standard of residents, and the night light value difference between counties under the jurisdiction of the city is used to quantitatively analyze the living standard difference of residents in counties under the jurisdiction of the city. It is expected to study the

difference in the living standards of the residents in the cities and counties of Shandong Province, the gap between the rich and the poor among the residents, resource reasonable configuration, targeted assistance and the formulation of relevant policies will play a guiding role.

## 2 Data sources and methods

### 2.1 Data source

The research data used in this paper mainly include the following two types:

(1) The NPP-VIIRS nighttime light data from 2012 to 2019 are derived from the VIIRS Nighttime Light (VNL) V2 series products of Earth Observation Group (EOG). The new method uses the twelve-month median radiance to discard high and low radiance outliers, filtering out most fires and isolating the background. Download address(<https://eogdata.mines.edu/products/vnl/#download>)

(2) Shandong province county administrative boundary vector map. According to the latest administrative divisions of Shandong Province published by the People's Government of Shandong Province at the end of 2018, the vector data of the boundary line of county-level administrative divisions in Shandong Province in 2018 provided by the National Basic Geographic Information Center, the county-level administrative division map of Shandong Province in 2018 is obtained. The main difference is that Laiwu is divided into Jinan.

\* Corresponding author: 201982020009@sdust.edu.cn

## 2.2 Research method

The total nighttime light values of counties in Shandong Province from 2012 to 2019 were obtained by using the method of zoning statistics, and the nighttime light values per capita of each county were calculated. After determining the relationship between residents' living standard and night light brightness value, the coefficient of variation analysis model is established to calculate the dispersion degree between counties under each city. Through the analysis of variation coefficient in two dimensions of time span and regional span, and the coupling analysis with GDP, the spatial and temporal differences of residents' living standards in Shandong Province are determined.

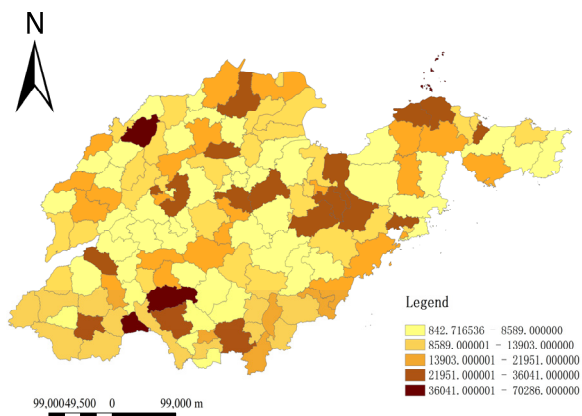
## 3 The calculation of county living standard difference

### 3.1 Correlation calculation of county-level light brightness value

According to the vector data of county-level administrative divisions in Shandong Province, the nighttime light images of each county in Shandong Province are cut, and the total light brightness of the county is calculated. The specific calculation formula is shown in Equation (1).

$$TDN_{\text{county}} = \sum_{i=1}^n DN_i \quad (1)$$

In formula (1),  $TDN_{\text{county}}$  is the total brightness value of a county under Shandong Province,  $n$  is the total number of nighttime lighting image grids contained in the county, and  $DN_i$  is the brightness value of the  $i$  grid of the grid.



**Figure 1.** The total value of lighting brightness of each county in Shandong Province in 2019

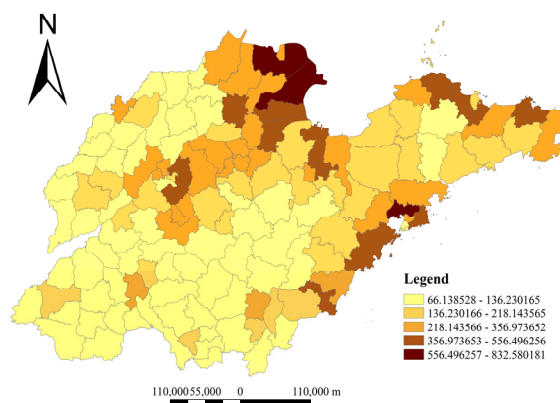
As shown in Figure 1, the total value of night light brightness in Shandong Province was observed and analyzed. It was found that the counties with relatively high brightness were mainly concentrated in the central and eastern regions of Shandong Province, and the counties with high brightness were concentrated. The total

value of light brightness in each county was significantly different. The lowest brightness value was Changdao County ( 842.7 ), and the highest was Huangdao District ( 70287 ).

In order to better represent the difference in living standards of residents in each county, the ratio of nighttime light data of a county to the total population at the end of the year is calculated to obtain the per capita light brightness value, as shown in Equation (2).

$$PDN_{\text{county}} = \frac{TDN_{\text{county}}}{POP_{\text{county}}} \quad (2)$$

In formula (2),  $PDN_{\text{county}}$  represents the county's per capita light brightness value ( 10,000 people ),  $TDN_{\text{county}}$  represents the county's total light brightness value,  $POP_{\text{county}}$  represents the county's total population.

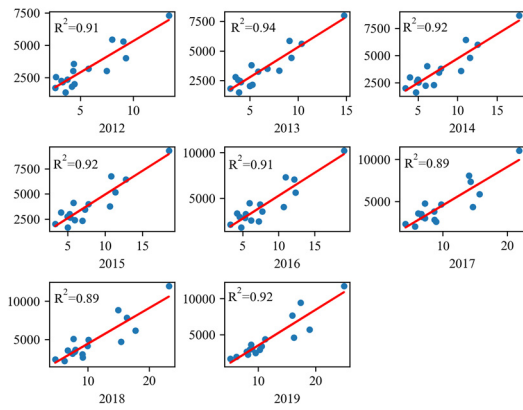


**Figure 2.** Per capita light brightness value of each county in Shandong Province in 2019

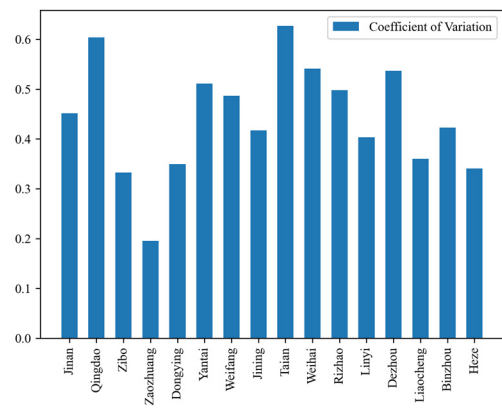
It can be found from the per capita light brightness value of each county that in 2019, the per capita night light value of each county in Shandong Province was significantly different, with the lowest in Juancheng County ( 66.1 / 10,000 people ) and the highest in Hekou District ( 832.6 / 10,000 people ). The average brightness value of each county is different from the distribution of the total brightness value, that is, the average brightness value of the counties with high total brightness value is not necessarily high, which to some extent reflects the gap between the living standards of each county.

### 3.2 Correlation test of city GDP and night light brightness

According to the administrative divisions of cities in Shandong Province, the total nighttime light brightness of each city from 2012 to 2019. In order to verify the relationship between light brightness value and GDP in Shandong Province and its effectiveness in Shandong Province, correlation analysis was used to calculate. The calculation results show that  $R^2$  is about 0.9, which proves that there is a strong correlation between GDP and light brightness value in Shandong Province, and also shows that the night light brightness value can reflect the living standards of residents in various cities to a certain extent.



**Figure 3.** Correlation between GDP and light intensity in cities from 2012 to 2019



**Figure 4.** Variation coefficient of light brightness value in Shandong Province in 2019

**3.3 Calculation of coefficient of variation**

The coefficient of variation is used to express the comprehensive level of the dispersion degree and the average distance of the night light brightness value between the counties under the jurisdiction of the city, and it can eliminate the influence caused by the excessive scale, so as to better reflect the difference of the living standards of the residents between the counties. The calculation formula of coefficient of variation is as follows :

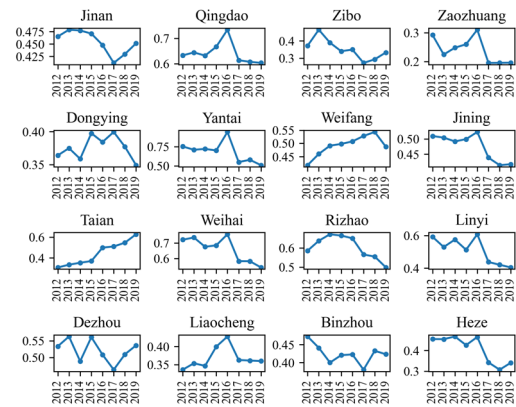
$$CV_{city} = \frac{\sqrt{\sum_{i=1}^N (PDN_{county\_i} - \bar{X})^2}}{\bar{X}} \quad (3)$$

In formula ( 3 ), N is the total number of counties under the jurisdiction of the city,  $PDN_{county\_i}$  is the per capita light brightness value of a county in the city, and  $\bar{X}$  is the average per capita light brightness value of all counties in the city.

In the variation coefficient histogram of night light value in Shandong Province in 2019 shown in Figure 4, the variation coefficient of counties under the jurisdiction of each city is above 0.15, which belongs to the moderate or strong variation level. According to this, the living standards of residents in the counties under the jurisdiction of each city are significantly different. Specifically, the difference in residents' living standards among counties and districts in Zaozhuang City is relatively small. Tai an City has the largest coefficient of variation, and the coefficient of variation is about 0.63, indicating that the coefficient of variation of counties and districts in Shandong Province is seriously unbalanced.

**3.4 Annual variation of coefficient of variation in cities**

The variation of the coefficient of variation of nighttime light brightness values in 16 cities of Shandong Province from 2012 to 2019 is analyzed and sorted out. Through the comparative analysis of the annual variation of each city, it can be seen that except Tai ' an City, other cties are generally in a downward or fluctuating trend after experiencing the initial rise. To a certain extent, it shows that the difference in the living standards of residents between counties and districts under the jurisdiction of each city in Shandong Province is gradually decreasing or has been decreasing.

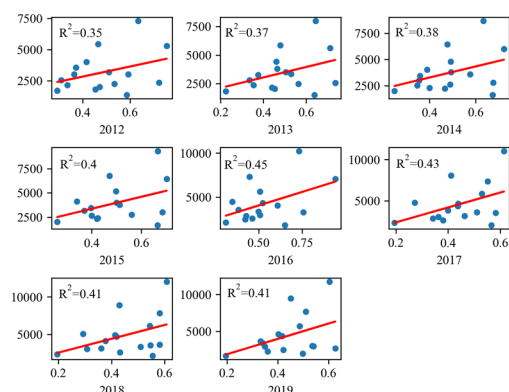


**Figure 5.** Analysis of variation coefficient of cities from 2012 to 2019

**3.5 Correlation between annual variation index and GDP**

The correlation between the coefficient of variation and GDP of each city from 2012 to 2019 is analyzed. According to  $R^2$ , it is between 0.3 and 0.4, indicating that there is a weak correlation between GDP and coefficient of variation. At the same time, according to the trend line, it can be seen that to a certain extent, the gap between GDP and residents' living standards is positively correlated. With the continuous improvement of residents' income

level, the gap between residents' living standards shows a trend of gradual expansion.



**Figure 6.** Correlation analysis between variation index and GDP in 2012-2019

## 4 Conclusion

With the help of VIIRS Nighttime Light (VNL) V2 series of nighttime light data products, the total nighttime light brightness and per capita light brightness of counties and districts in Shandong Province from 2012 to 2019 are counted through zoning statistics. Through the correlation analysis with GDP, it is determined that it can be used as a specific quantitative indicator to reflect the living standard of residents. After research and analysis, it is found that :

(1)The living standards of nighttime residents in Shandong Province are obviously unbalanced in the region, and the regions with high living standards are mainly concentrated in the central and coastal areas.

(2) There are significant differences in living standards between counties and districts under the jurisdiction of Shandong Province. Tai'an City is the most obvious in 2019, and Zaozhuang City is the smallest.

(3) In 2012-2019, except Tai'an City, Shandong Province, the difference in living standards has been growing, other cities showed a gradual narrowing or narrowing trend.

(4) There is a weak positive correlation between the living standards of residents in counties and districts of Shandong Province and the GDP of the city, that is, the higher the GDP of the city is, the more obvious the difference in living standards among residents is.

Through the evaluation and analysis of the differences in the quality of life of residents in Shandong Province, it is expected to provide some theoretical support for the resource allocation of Shandong provincial government and municipal governments, so as to reduce the gap in the living standards of residents between counties and achieve accurate support.

## References

1. B. Yu, C. Wang, W. Gong, Z. Chen, K. Shi, B. Wu, Y. Hong, Q. Li, J. Wu, Nighttime light remote sensing and urban studies: Data, methods, applications, and

- prospects, *Journal of Remote Sensing*, **25**: 342–364, (2021).
2. C. D. Elvidge, K. E. Baugh, E. A. Kihn, H. W. Kroehl, E. R. Davis, and C. W. Davis, Relation between satellite observed visible-near infrared emissions, population, economic activity and electric power consumption, *International Journal of Remote Sensing*, **18**: 1373–1379, (1997)
3. W. Lu et al., Global proliferation of offshore gas flaring areas, *Journal of Maps*, **16**: 396–404, (2020)
4. T. Mazor et al., Can satellite-based night lights be used for conservation? The case of nesting sea turtles in the Mediterranean, *Biological Conservation*, **159**: 63–72, (2013)
5. S. E. Bauer, S. E. Wagner, J. Burch, R. Bayakly, and J. E. Vena, A case-referent study: light at night and breast cancer risk in Georgia, *Int J Health Geogr*, **12**:23, (2013).
6. Elvidge C D, Zhizhin M, Ghosh T, et al. Annual time series of global VIIRS nighttime lights derived from monthly averages: 2012 to 2019[J]. *Remote Sensing*, **13**: 922, (2021).