Ecological Environment Quality Monitoring in Jinan City based on Landsat Remote Sensing Data

Fangfang Li and Rui Wang [+]

School of Civil Engineering, Shandong Jiaotong University, Jinan, Shandong, China

Abstract. In order to comprehensively and objectively evaluate and monitor the ecological environment quality of Jinan City, this paper selects Landsat TM/OLI series data from 2007, 2013, 2018 and 2021, and uses principal component analysis to construct the Remote Sensing Ecological Index (RSEI) based on four components: vegetation coverage, soil moisture, building-bare soil index and land surface temperature. And the grading and difference treatment were carried out to monitor the changes in the quality of the ecological environment in Jinan. The results show that the remote sensing ecological index (RSEI) in 2007, 2013, 2018 and 2021 was 0.5911, 0.6153, 0.6488 and 0.6708, respectively, and its values showed an upward trend, indicating that the ecological environment of Jinan City was gradually improving. Combined with the classification map of each year, it is found that the areas with poor ecological environment in Jinan are mainly the areas with dense population, high economic level and low vegetation coverage in the city center or counties, while the ecological environment in the southern mountainous areas and the northern part of Jinan City is better. This study can provide a reference for the subsequent policy adjustment of the environmental status of each county in Jinan, and can also provide a theoretical reference for the ecological environment monitoring of other cities of the same type.

Keywords: remote sensing data, RSEI, ecological environment quality monitoring

1. Introduction

The quality of the ecological environment is closely related to people's production and life, and promoting the construction of ecological civilization and strengthening ecological protection is not only related to the immediate interests of the people, but also to the long-term plan for the future of the nation. How to quickly and objectively assess the urban ecological environment, comprehensively grasp its spatiotemporal evolution law, and understand its change factors and influencing factors is of practical significance for the sustainable development of the urban environment and the formulation of related environmental policies in the future. Compared with traditional environmental monitoring methods, remote sensing technology has the advantages of high efficiency, large area and low cost, and is widely used in the monitoring of ecological environment quality[1-4]. However, the influencing factors of the ecological environment in different regions are complex, and in the past, a single evaluation index based on remote sensing data often could not comprehensively summarize the ecological status of the study area. Based on the normalized vegetation index, humidity index, dryness index and heat index[5-7], Xu Hanqiu constructed an index that can objectively and comprehensively evaluate and monitor the quality of the ecological environment, namely the Remote Sensing Ecological Index (RSEI)[8]. At present, this method has been widely used in the field of urban ecological environment assessment. As the capital city of Shandong Province, the construction of "Beautiful Jinan" is an inevitable choice to adapt to the new development, and it is also an important topic to comprehensively improve the ecological environment quality in the province, and it is an inevitable requirement to ensure the sustainable development in the future.

[+] Corresponding author. Tel.: 13698622520.
   E-mail address: 939054580@qq.com.

2. Research Area and Methods

2.1. Study Area

Jinan, also known as Quancheng and Qizhou, is the capital city of Shandong Province. The geographical coordinates are located between 36°01' and 37°32'N, 116°11' and 117°44'E longitude, with an area of about 10,244 square kilometers, connecting with Liaocheng City, Dezhou City, Binzhou City, Zibo City and Tai'an City, and occupying an extremely important position on the territory of Shandong Province. Jinan has a number of administrative divisions, including 10 municipal districts and 2 counties. Jinan is located in the middle latitudes, surrounded by mountains on three sides, and its climate is a typical warm temperate monsoon climate. The topography is high in the south and low in the north, from the mountains to the plains, it slopes to the north in turn, and the lowest height is 5 meters. Therefore, the height difference between the north and south of Jinan City is more than 1,100 meters. It is precisely because of such topographical factors that Jinan has formed a natural wonder of multiple springs converging in history. Groundwater and surface water converge here, forming countless springs, among which Baotu Spring, Wulong Pond and Black Tiger Spring are the most famous.

2.2. Research Data and Preprocessing

The Landsat data used in this study came from the Landsat TM and OLI series satellites in the Geospatial Data Cloud (http://www.gscloud.cn/), which were launched by the National Aeronautics and Space Administration (NASA) with a 16-day coverage period. Landsat remote sensing image data covers 4 years of 2007, 2013, 2018 and 2021, and the imaging time is selected from April to May of that year due to the influence of cloud cover and plant growth, and TM, OLI and TIRS sensors are used respectively. Among them, the Landsat5 data in 2007 needs to be covered by three images in Jinan, and the strip numbers are 12135, 12234, and 12235 respectively. The remaining three years can cover the study area with two images of Landsat8 data, and the band numbers are 12234 and 12235, respectively. In order to ensure the accuracy of the selected images, the cloud cover is controlled below 2%.

In order to reduce the geometric distortion of the image, make the image closer to the real situation on the ground, and ensure the objectivity of the subsequent image in the establishment of the ecological index, it is necessary to preprocess the image. The processing process of Landsat image preprocessing is as follows: radiometric calibration of the image, conversion of the gray value of the remote sensing image into radiance value, atmospheric correction to remove the interference of the reflection of ground objects caused by natural factors such as atmospheric conditions and light intensity, and cropping and mosaic of the image in the study area. Since the remote sensing ecological index is mainly applicable to the land-based area, in order to avoid the influence of the existence of a large area of water on the humidity index, the pretreatment in this paper also includes the use of the improved normalized water index to mask the water body in the study area[9].

2.3. Construction of the RSEI

In this study, four components of greenness index, humidity index, dryness index and heat index were constructed based on remote sensing data, and the four components were normalized respectively, and finally the four normalized components were subjected to principal component analysis, and the first principal component was selected as the remote sensing ecological index RSEI, which can quickly monitor and evaluate the regional ecological quality with high objectivity and accuracy.

3. Results and Analysis

3.1. Grading of Remote Sensing Ecological Index

Table 1 shows the calculation of RSEI for each period in Jinan.

Table 1: Remote Sensing Ecology Index (RSEI) results

Year	2007	2013	2018	2021
RSEI	0.5911	0.6153	0.6488	0.6708

From Table 1, it can be seen that the remote sensing ecological index (RSEI) in 2007, 2013, 2018 and 2021 were 0.5911, 0.6153, 0.6488 and 0.6708, respectively, showing a stable upward trend, indicating that the ecological environment quality of Jinan City is gradually improving.

In order to reflect the changes and distribution of ecological environmental conditions, the RSEI values obtained were divided into five grades with reference to the Technical Specifications for Ecological Environmental Status Assessment: Poor, Fair, Average, Good, Excellent[8], the range of corresponding RSEI values is [0, 0.2), [0.2, 0.4), [0.4, 0.6), [0.6, 0.8), [0.8, 1.0]. The RSEI index was graded by the grading standard, and the results are shown in Fig. 1.
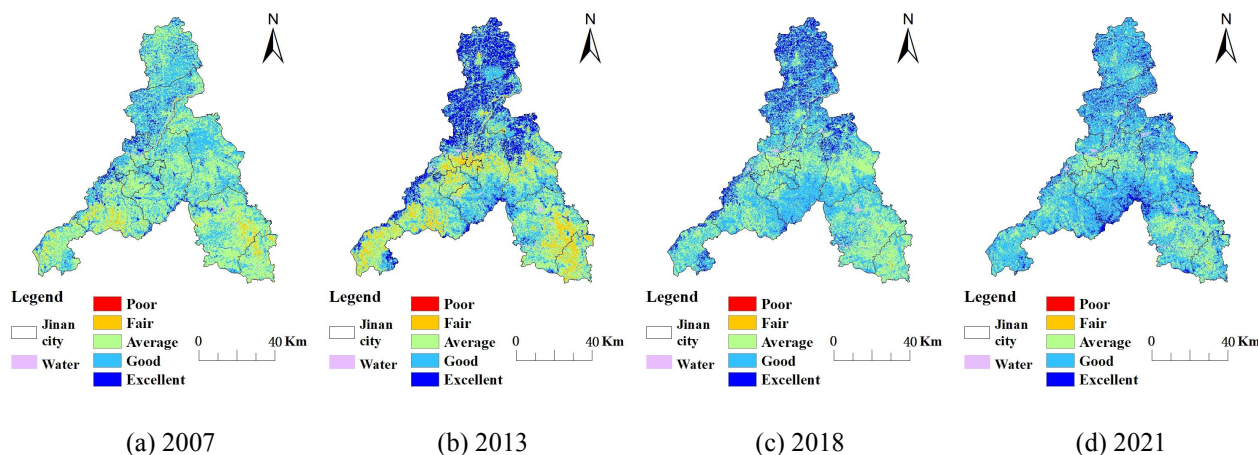

| (a) 2007 | (b) 2013 | (c) 2018 | (d) 2021 |

Fig. 1: RSEI grading chart

According to Fig.1, from a spatial point of view, the areas with poor ecological environment are mainly distributed in the central and southern parts of Jinan, and the northern areas of Jinan City have better ecological environment. From the perspective of time, from 2007 to 2021, the ecological environment is gradually improving. From the perspective of various counties and districts, the ecological environment of Tianqiao District, Huaiyin District, Lixia District and Shizhong District has been poor, but with the passage of time, the evaluation of ecological environment quality has changed from poor to moderate, and the ecological environment is gradually improving in the past 15 years. The ecological environment in Shanghe County and Jiyang District showed a trend of first getting better and then worse, from excellent to good at the beginning, and a few areas were medium. Licheng District and Zhangqiu District are in line with the general trend of overall improvement. The environment in the southern mountainous area is relatively good due to the lack of human activities and development.

3.2. Monitoring and Analysis of Changes in Ecological Environment Quality

In order to further study for the 15 year ecological changes in Jinan from 2007 to 2021, this paper assigns the five grades of poor, poor, moderate, good, and excellent to 1, 2, 3, 4, and 5 by using the Arcmap10.8 software resampling tool, respectively, and makes the difference between the RSEI classification data in 2021 and the RSEI classification data in 2007, and the obtained data are reclassified, and the difference results are divided into five categories: obvious deterioration, deterioration, unchanged, improvement, and obvious improvement. Table 2 shows the results and percentages of the differences.

According to Table 2, in the past 15 years, the proportion of ecological environment changes in Jinan City has been significantly better and worse, which is negligible. The proportion of deterioration is smaller, accounting for 8%. The change categories with a large proportion were better and unchanged, of which 49% were unchanged and 43% were better. The statistical results show that the ecological environment of Jinan City continues to improve in maintaining a stable trend.

Table 2: Difference results of remote sensing data from 2007 to 2021

Change Category	Number	Number of cells	Percentage (%)
Obvious variation	-4,-3	1081	0
Variation	-2,-1	946873	8
Unchanged	0	5444168	49
Improve	1,2	4787812	43
Obvious improve	3,4	10103	0

The specific ecological changes in Jinan from 2007 to 2021 as shown in Fig.2.
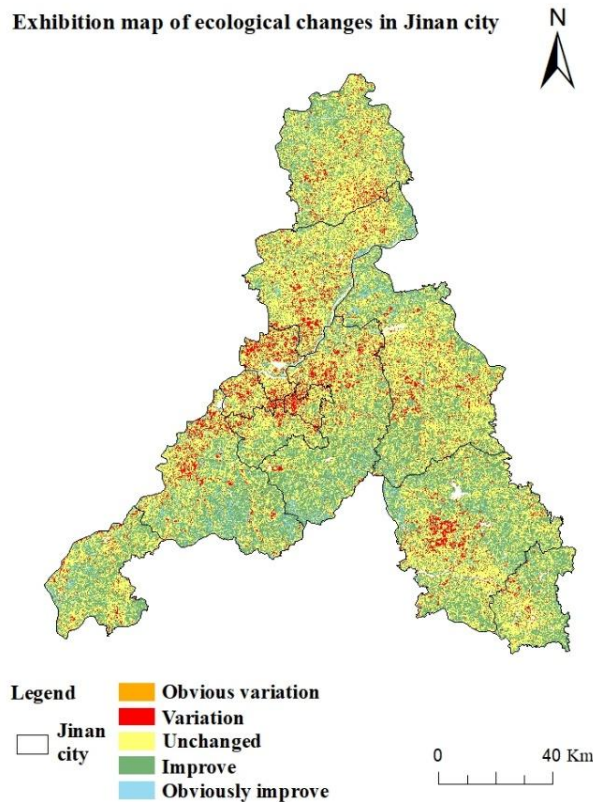

Fig. 2: RSEI grading chart

Fig.2 shows the changes in counties and districts of Jinan from 2007 to 2021.The orange area represents the obvious deterioration of the ecological environment quality in the region, and there are few areas reflected in the figure, and it can be considered that there is almost no area with obvious deterioration of the ecological environment in Jinan. According to the analysis of the above figure, the red areas are mainly distributed in the eastern part of Pingyin County, the southern part of Shanghe County, the central and western parts of Laiwu District, the northern part of Licheng District, Jiyang District, Tianqiao District, Huaiyin District and other areas. The yellow area indicates that the ecological environment of the region has not changed, and it can be seen from the map that the ecological environment of most areas in Laiwu District and Jiyang District has not changed, and the area with a high level of development in the center of Jinan is alternately distributed with the area of variation and unchanged. The green part indicates that the ecological

environment of the region is improving, and the quality of the ecological environment in the mountainous areas in the south of Jinan City and some areas in Shanghe County is improving. The blue area indicates that the area is significantly better, and the area in the figure is not obvious.

4. Conclusion

This paper takes Jinan, Shandong Province as the research area, and selects the corresponding Landsat data in 2007,2013,2018 and 2021. By using the principal component analysis method, the remote sensing ecological index RSEI is extracted through the constructed green index, humidity index, dryness index and heat index, and combined with numerical grading, difference method operation and other related operations, Jinan City is realized from 2007 to 2021.However, only four indicators are selected to construct a single evaluation model, and the selection of index categories in the evaluation range is not comprehensive, and the results of the evaluation of ecological environmental quality in Jinan City depend on the calculated value of the remote sensing ecological index (RSEI), which has certain limitations in the evaluation of ecological environmental quality. The influencing factors of a city's ecological environment quality are often very complex, and they have a certain correlation with its economic factors, geographical location, cultural history, ecological geology, etc. Therefore, in the future research, it is necessary to combine multiple aspects, comprehensively analyze and study, so as to improve the accuracy and objectivity of ecological environment quality assessment, so as to achieve better evaluation results.

5. Acknowledgement

6. References

[1] J.X. Zhang, Y.X. Gu, J.Q. Shen, M.Q. Zhang, M. Cong, and L.W. Yang. Analysis of Spatiotemporal Changes and Driving Factors of Ecological Environment Quality in the Yellow River Basin. Environment Science.2024,1-23.

[2] Z.L. Zhao, W.Q. Zhao, Y. Su, L. Huang, W. Li, and J.H. Luo. Spatio-temporal Evolution Patterns and Spatial Differentiation Attribution of Ecological Quality in Guiyang from 1991 to 2020.Environment Science.2024,1-17.

[3] C.Y. Ni, W. He, and Y.F. Yao. Analysis of Ecological Environment Quality and its Influencing Factors of the Lijiang River Basin Based on Landsat8.Science Technology and Engineering.2024,24(12):5227-5238.

[4] H.F. Zhang. Ecological Environment Change Monitoring and Development Trend Forecast Based on Time Series Data Analysis. Geomatics & Spatial Information Technology.2024,47(04),92-95.

[5] W.J. Sun, L. He, Q. Yu, Y.L. Miao, J.K. Zhao, and W. Liu. Spatial-temporal Evolution of Ecological Environmental Quality and Driving Factors in Shenmu City of Shaanxi Province from 2010 to 2020.Bulletin of Soil and Water Conservation.2024,44(01):284-292.

[6] L. Ma, Y. Liang, Y.Q. Zhang, and Y.P. Li. Spatiotemporal Change and Driving Factors of the Eco-Environment Quality of Different Land Covers in Shandong Province Based on RSEI. Research of Soil and Water Conservation.2024,31(02):389-400.

[7] H.B. Ren, and C. Du. Dynamic Analysis of Ecological Environment Quality Change in Kaifeng City Based on RSEI Model. Jilin Water Resources.2024,(01):64-70.

[8] H.Q. Xu. A Remote Sensing Urban Ecological Index and its Application. Acta Ecologica Sinica.2013,33(24):7853-7862.

[9] W. Zhang. Compared of Impervious Surface Extraction Methods based on Landsat8 OLI -A Case Study of the Core Area of Changsha-Zhuzhou-Xiangtan Urban Agglomeration. Anhui Agricultural Science Bulletin.2019,25(21):83-85+102.