Research on Ecological Environment Changes Based on Remote Sensing Monitoring Perspective

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Abstract: Accelerating process of urbanization has brought about a series of ecological and environmental problems. In this paper, vegetation index, humidity index, surface temperature, and building-bare soil index are used to quantitatively characterize the four ecological element indexes of greenness, humidity, heat and dryness. Through principal component analysis, a remote sensing ecological index model is established, and this article comparatively analyzes the remote sensing ecological index in 2014 and 2019 from the two dimensions of time and space. The results show that the ecological environment of Qingdao is partially optimized and improved but the overall trend is decreasing.

1. Introduction
In recent years, scholars at home and abroad have carried out a lot of research in the field of ecological environment evaluation and analysis. Satellite remote sensing has the advantages of high spatial resolution, time resolution, and spectral resolution, as well as large-area, real-time, rapid, and periodic repeated observations. It is widely used in this field[1,2,3,4,5,6]. In 2006, in order to strengthen the ecological environment protection, the former Ministry of Environmental Protection proposed the "Technical Standards for Evaluation of Ecological Environment Conditions" [7]. The ecological environment condition index is used to realize the assessment of my country's ecological environment condition and change trend. However, this method needs to adjust the weights for different regions and different surface coverage factors, which is greatly affected by human factors, and the accuracy consistency is difficult to achieve uniformity[8]. The remote sensing ecological index effectively reduces the difficulty and complexity of data acquisition, avoids the influence of human factors to the greatest extent, and can quickly realize the monitoring, evaluation and visualization of the ecological environment in the study area. This paper compares and analyzes remote sensing ecological indexes in different periods from space and time scales, evaluates the changes in the ecological environment of Qingdao, and further analyzes and explores the impact factors of changes in the ecological environment, providing data references for Qingdao's ecological city construction and optimization of urban spatial layout.

2. Data and research methods

2.1 Data source and data preprocessing
Under the premise of ensuring data quality, select Qingdao summer Landsat 8 OLI/TIRS, ZY-3 and other high-resolution satellite data as research data. Landsat 8 OLI/TIRS data is used for ecological index calculation, and multi-source high score data is mainly used for calculation of index data related
to the ecological environment such as surface change information and road information. In order to objectively and truly reflect the surface coverage and reduce errors caused by data factors, the multi-source, multi-resolution remote sensing image data is subjected to atmospheric correction, radiometric calibration, orthorectification, geometric correction, image mosaic, image cropping and other pre-processing work.

2.2 Research methods
The Remote Sensing Ecological Index (RSEI) is an embodiment of the livability level of a city in a region. It can achieve rapid assessment of the ecological environment through the superposition of indicators such as humidity, greenness, heat, and dryness that are closely related to human survival[9].

\[
\text{RSEI} = f(G, W, T, D) \tag{1}
\]

In the formula, G is greenness; W is humidity; T is heat; D is dryness.

The humidity index is mainly represented by the humidity component (wet) obtained by the remote sensing tasseled cap transformation[10].

\[
\text{Wet} = \alpha_1 \rho_{\text{blue}} + \alpha_2 \rho_{\text{green}} + \alpha_3 \rho_{\text{red}} + \alpha_4 \rho_{\text{nir}} - \alpha_5 \rho_{\text{swir1}} - \alpha_6 \rho_{\text{swir2}} \tag{2}
\]

In the formula, \( \rho_{\text{blue}}, \rho_{\text{green}}, \rho_{\text{red}}, \rho_{\text{nir}}, \rho_{\text{swir1}}, \rho_{\text{swir2}} \) represents the reflectivity of blue, green, red, near-infrared, short-wave infrared 1, short-wave infrared 2. \( \alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6 \) is the weight coefficient, for Landsat 8 they are 0.1511, 0.1973, 0.3283, 0.3407, 0.7171, 0.4559.

The normalized vegetation index (NDVI) is undoubtedly the most widely used vegetation index, which is closely related to plant biomass, leaf area index and vegetation coverage. Therefore, NDVI is chosen to represent the greenness index.

\[
\text{NDVI} = \frac{\rho_{\text{nir}} - \rho_{\text{red}}}{\rho_{\text{nir}} + \rho_{\text{red}}} \tag{3}
\]

In the formula, \( \rho_{\text{nir}} \) is near-infrared reflectance. \( \rho_{\text{red}} \) is red band reflectivity.

The heat index is mainly characterized by the surface temperature, which is mainly obtained by temperature inversion in the thermal infrared band. The radiant flux received by the satellite mainly includes surface thermal radiation, atmospheric upward thermal radiation and atmospheric downward thermal radiation reflected back to the sensor part by the surface. From the radiation transmission equation, the expression of the thermal infrared radiation brightness \( L_{\lambda} \) received by the satellite sensor can be written for:

\[
L_{\lambda} = [\varepsilon B(T_{S}) + (1 - \varepsilon)L_{1}]\tau + L_{1} \tag{4}
\]

In the formula, \( \varepsilon \) is the surface emissivity; \( T_{S} \) is the radiance temperature; \( B(T_{S}) \) is the black body thermal radiance; \( \tau \) is the transmittance of the atmosphere in the thermal infrared band; \( L_{1} \) and \( L_{1} \) are the upward and downward heat of the atmosphere, respectively. Radiation can be obtained from NASA’s atmospheric parameter calculation website. The surface radiance temperature can be calculated by the Planck function.

\[
T_{S} = \frac{K_2}{\ln(B(T_{S}) + 1)} \tag{5}
\]

For Landsat 8 thermal infrared band 10, \( K_1 = 774.89 \text{ W/(m}^2\text{·μm·sr)}; K_2 = 1321.08 \text{ K.} \)

The radiance temperature only represents the temperature of a black body, and most objects in nature are not black bodies, so it should be corrected with specific emissivity to make it the surface temperature, the formula is as follows:

\[
T = \frac{T_{S}}{(1 + (\lambda T / \rho)) \ln \varepsilon} \tag{6}
\]

In the formula, \( T \) is the surface temperature; \( \lambda \) is 11.5μm; \( \rho \) is 0.01438 mk; \( \varepsilon \) is the surface emissivity.

The dryness index is a quantification of soil desiccation. The research area includes the entire Qingdao city (including built-up areas), so the dryness index is expressed by the combination of the bare soil index (SI) and the building index (IBI).

\[
\text{NDBSI} = \frac{SI + IBI}{2} \tag{7}
\]
\[ SI = \frac{(\rho_{\text{swir1}} + \rho_{\text{red}}) - (\rho_{\text{blue}} + \rho_{\text{nir}})}{(\rho_{\text{swir1}} + \rho_{\text{red}}) + (\rho_{\text{blue}} + \rho_{\text{nir}})} \]

\[ IBI = \frac{a - b}{a + b} \]
\[ a = \frac{\rho_{\text{swir1}} + \rho_{\text{nir}}}{2 \rho_{\text{swir2}}} \]
\[ b = \frac{\rho_{\text{nir}} + \rho_{\text{green}}}{\rho_{\text{swir1}} + \rho_{\text{green}}} \]

In the formula, NDISI is the dryness index, \( \rho_{\text{nir}}, \rho_{\text{green}}, \rho_{\text{red}} \), represents the reflectivity of blue, green, red, near-infrared, short-wave infrared 1, short-wave infrared 2.

Using the principal component analysis method, calculate the contribution rate of each index such as greenness, humidity, heat, dryness, etc., to achieve the purpose of a single variable to comprehensively represent multiple ecological indicators. Because the four indicators of greenness, humidity, heat, and dryness are inconsistent in units and dimensions, it is necessary to complete the normalization process and map all the values to the range of [0,1]. At the same time, in order to avoid the influence of the water area on the principal component analysis, the water body mask is set. Finally, according to the contribution rate, generate a remote sensing ecological index (RSEI) calculation model:

\[ \text{RSEI} = \sum_{i=1}^{n} \alpha_i \text{PC}_i \]

In the formula, \( n \) is the number of sub-indices; \( \alpha_i \) is the index weight coefficient; PCi is the main component. In order to facilitate the comparative analysis of ecological indices in different years, the RSEI is again normalized.

3. Result

Based on the above model, using the principal component analysis method to calculate the weight coefficients of greenness, humidity, heat, and dryness, generate a picture of the remote sensing ecological index of Qingdao in 2014 and 2019, and divide the ecological level at 0.2 intervals. The results of principal component analysis are shown in Table 1, and the remote sensing ecological index levels are shown in Figure 1.

| Time | Index | First principal component | Second pc | Third pc | Fourth pc | Mean | Standard deviation |
|------|-------|---------------------------|-----------|---------|-----------|------|-------------------|
| 2014 | humidity        | 0.522                      | 0.657     | 0.199   | 0.437     | 0.730 | 0.207             |
|      | greenness       | 0.446                      | -0.743    | 0.036   | 0.497     | 0.390 | 0.328             |
|      | dryness         | -0.698                     | 0.081     | 0.044   | 0.712     | 0.332 | 0.310             |
|      | heat            | -0.097                     | -0.108    | 0.978   | -0.147    | 0.489 | 0.391             |
|      | characteristic value contribution rate | 0.169       | 0.041    | 0.002   | 0.001     | 0.794 | 0.33%             |
|      |                  | 79.43%                     | 19.28%    | 1.05%   | 0.33%     |       |                   |
| 2019 | humidity        | 0.584                      | 0.484     | 0.394   | 0.518     | 0.658 | 0.280             |
|      | greenness       | 0.350                      | -0.767    | -0.22   | 0.489     | 0.470 | 0.236             |
|      | dryness         | -0.712                     | 0.115     | 0.004   | 0.692     | 0.318 | 0.285             |
|      | heat            | -0.168                     | -0.405    | 0.892   | -0.110    | 0.317 | 0.326             |
|      | characteristic value contribution rate | 0.169       | 0.040    | 0.008   | 0.001     | 0.775 | 0.37%             |
|      |                  | 77.51%                     | 18.53%    | 3.59%   | 0.37%     |       |                   |

It can be seen from Table 1 that the contribution rate of the first principal component exceeds 77%, which realizes the integration of most index data and avoids human interference factors to a certain extent. Among the four indicators, the contribution rate of humidity and greenness is positive, the higher the value, the better the ecological environment, and the negative contribution rate of the dryness and heat index, the higher the value, the worse the ecological environment, which is consistent with actual perception. Qingdao is a coastal city and is significantly affected by the marine environment. Therefore, its humidity is relatively high and has the greatest positive impact on the ecological environment. Compared with 2014, the contribution rate of greenness index has decreased, and the contribution rate of dryness and heat index has increased. To a certain extent, it can indicate the decrease of green area.
(may be caused by the phenological characteristics of vegetation), and the increase of impervious surface and bare land in cities. This will further increase the surface temperature and increase the urban heat island effect. At the same time, it can also be seen that dryness contributes the most in the first principal component, which is directly related to the deterioration of the remote sensing ecological environment index.

![Figure 1](image-url) The remote sensing ecological index levels

It can be seen from Figure 1 that the darker the color, the better the remote sensing ecological index level. In general, the ecological environment of Qingdao has obvious differences between urban and rural areas, with the central city as the core and scattered to suburban towns. Areas with poor ecological environment are mainly concentrated in Shibei District, Licang District, Chengyang District, Hongdao Economic Zone, the east of Jiaozhou City, the east of West Coast New District, Laixi City, and the middle of Pingdu City. The average value of the remote sensing ecological index in Qingdao dropped from 0.62 in 2014 to 0.58 in 2019, with a decline rate of 6.5%. Compared with 2014, the remote sensing ecological index level in 2019 was poor, the area decreased by 26.34%, and the level was excellent The area of the region decreased by 56.17%, showing partial optimization and improvement, and an overall downward trend. The remote sensing ecological index deterioration area is located in several core areas such as Laixi City, Qingdao Jiaodong International Airport, and Huangdao Economic and Technological Development Zone, which are directly related to factors such as large-scale construction and demolition.

4. Conclusion
This paper uses the four indicators of greenness, humidity, heat, and dryness to construct a remote sensing ecological index model to compare and analyze the changes in the ecological environment in 2014 and 2019 from the two dimensions of time and space. The results showed that:

The average value of the remote sensing ecological index dropped from 0.62 to 0.58, showing a downward trend as a whole. By comparing and analyzing the contribution rate of each index, it can be seen that the increase of impervious surface and bare land in the city is the main factor. While the city is developing rapidly, the urban spatial pattern needs to be further optimized.

Compared with 2014, the area of Qingdao with a poor remote sensing ecological index in 2019 has been reduced by 26.34%. The ecological environment of the central city has been partially improved, and ecological environmental governance has achieved certain results.

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