Study on temporal and spatial distribution Law of Chlorophyll-a Concentration in Nansi Lake

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Abstract. In order to investigate the Nansi Lake chlorophyll-a concentration spatial distribution, to better cope with the lake eutrophication of lake water and water quality threat, and to ensure the function of the water transport channel and the storage reservoir in the east line project of the south to North Water Transfer in the lake area. By using the correlation analysis and regression analysis in statistical analysis, the best band of chlorophyll-a retrieval is the combined band of blue band, green band and red band, based on the relationship between measured chlorophyll-a concentration and Landsat 8 the reflection values of each band. On the basis of this, the regression fitting equation is constructed. Through the accuracy analysis, the inversion error is smaller and the fitting degree is 0.7, which has good applicability. In 2015, the results show that the chlorophyll-a concentration in Nansi Lake in January was as high as 10mg/m³. The concentration of chlorophyll-a in the lake coast is much higher than the central of the lake area. And the concentration of the Weishan Lake in the lower Lake area is higher than that of the other lake areas.

1. Introduction

The rapid socio-economic development in recent years in the area around Nansi Lake is responsible for the pollution of the water and vegetation in the lake. To protect the water resources and ecological environment of Nansi Lake, it is necessary to adopt more advanced and targeted methods to study and analyze the lake wetlands, body of water and water quality in Nansi Lake. Water quality monitoring by remote sensing can be used for continuous, large-scale and long-term observation and analysis. Water quality parameters of suspended solids and chlorophyll-a can be analyzed by values obtained from remote sensing spectral reflectance. Other parameters, such as dissolved oxygen and total phosphorus, are not highly correlated with the spectral characteristics. The indirect analysis based on remote sensing can be conducted by using the relationship among the water quality parameters[1]. Pure water has a slight blue color because it absorbs other wavelengths of light. When vegetation is in the body of water, the chlorophyll can make the water absorb blue light at the spectral band and the reflection spectrum moves to green and red light direction. The wavelength of chlorophyll shifts to longer wavelengths, so the body of water seems green in the image. When there is suspended sediment, the peak position of the reflection spectrum moves to the yellow light direction. This paper studies the concentration of chlorophyll-a in Nansi Lake, because this concentration is an indicator to evaluate the degree of eutrophication in the body of water. The correlation can be analyzed according to the spectral characteristics of the parameter. Based on these statistical data, empirical and semi-empirical physical models were created to simulate and retrieve the formula of chlorophyll-a concentration[2]. Landsat TM/ETM, MODIS and Landsat8 OIL
are the remote-sensing image devices that are widely used in retrieval. Besides, GF-1 and HY-1A/1B are also used in remote sensing research of water color of lakes\textsuperscript{3-5}. The accuracy of retrieval needs to be improved because of the limitations of retrieval of chlorophyll-a concentration in Nansi Lake based on remote sensing image, model simulation method and sampling time. Area and water quality parameters of Nansi Lake wetland are obtained and retrieved by remote sensing method. Creating technical system to obtain data of body of water and monitor water quality based on remote sensing images could provide a scientific basis to protect Nansi Lake.

2. Study area and data processing

2.1. Overview of study area

Nansi Lake is located in Weishan County, Jining City, Shandong Province. It includes Nanyang Lake, Dushan Lake, Zhaoyang Lake and Weishan Lake, sitting along from south to north. The water surface area is 1,266 km\textsuperscript{2} for many years, the average water depth is 1.5m, and the deepest depth is about 6m. The entire area is named the Nansi Lake Wetland. As the largest freshwater lake in Shandong province, Nansi Lake is the water delivery channel and reservoir for the Eastern Route of South-North Water Transfer Project. Many rivers are flowing into the lake, so monitoring of water quality parameters is particularly important.

2.2. Data processing

2.2.1. Field experiments to determine the chlorophyll-a concentration

Because of the large Lower Lake area in Nansi Lake, 15-30 monitoring points were evenly distributed through grid-point approach according to the need of the study, and the points covered aquatic plant area, the bank and the internal area. Time points at which satellite passed over the area were used for on-site sampling, and monitoring was strengthened during the water delivery for South-North Water Transfer Project. Nansi Lake is not deep, and its water quality is monitored by GPS. The concentration was sampled at the place where the river enters the lake and in the center of the lake. The distribution of the sampling sites was well designed, and the water samples are mainly collected at 0.4 m below the water surface. Field sampling to determine the chlorophyll-a concentration in Nansi Lake was conducted on July 22-23, August 29, November 17 in 2014, and April 6-9, May 15-16, May 22, June 13 and November in 2015, respectively. The concentration of chlorophyll-a was determined by Spectrophotometer.

2.2.2. Remote sensing data processing

In this paper, the Landsat8 remote sensing data was selected as the basic data for chlorophyll-a concentration retrieval. The data was collected from GISClOUD from January to December 2015. And sunny without clouds 1 day before and after the measurement was also required particularly by the images of remote sensing data from 8 field experiments. The radiometric calibration and atmospheric correction were also carried out. The data of body of water was obtained through normalized difference water index (NDWI), and the threshold space was set to 0-1, so the data could be obtained. Calculation and retrieval of chlorophyll-a concentration based on data of body of water were conducted.

3. Research methods

Based on the relationship between Landsat8 remote sensing band and chlorophyll-a concentration, the best retrieval band was identified by the correlation analysis. And the regression analysis was used to develop the empirical formula to fit the chlorophyll-a concentration based on the relevant remote sensing band combinations. Then the accuracy of the simulation results was analyzed by the fitting index to determine the effectiveness and accuracy of the retrieval method.

(1) Calculating the residual sum of squares,

\[ Q = \sum (y - y^*)^2 \]  \hspace{1cm} (1)

where \( y \) denotes the measured value and \( y^* \) denotes predicted value;
4. Analysis of results

4.1. Building of retrieval model and analysis of fitting

There is a relationship between the concentration of chlorophyll-a and the spectral information. In this paper, the Landsat8 Band1-Band7 and three combined bands, including Band4-Band3, Band4/(Band2 + Band3), Band4/(Band5+Band4+Band3), were analyzed. The Landsat 8 images and the data of 173 samples from 8 field measurements were used to analyze the changes in chlorophyll-a and each band. As shown in Table 1, the concentration of chlorophyll-a is highly correlated with Band4/(Band2+Band3), with the value of 0.72. Therefore, the band combination was used to retrieve the concentration of chlorophyll-a in Nansi Lake to develop regression formula for fitting. The formula uses polynomial regression, and the retrieval formula is as follows:

\[
R_{new} = 1 - \left( \sum_{i=1}^{Q} \frac{y_i - \bar{y}}{s_y} \right)^{1/2}
\]

4.2. Spatiotemporal distribution of chlorophyll-a concentration in 2015

The spatiotemporal distribution of chlorophyll-a concentration in 2015 in the Nansi Lake area was retrieved as shown in Figure 1-4. The maximum concentration of chlorophyll-a is 11.38 mg/m³. To compare the concentrations of chlorophyll-a in the lake area, the concentration is divided into five levels, including 0-0.1 mg/m³, 0.1-5.00 mg/m³, 5.00-7.00 mg/m³, 7.00-10.00 mg/m³, 10.00-11.38 mg/m³. It can be seen that the chlorophyll-a concentration in Nansi Lake area was above 7 mg/m³ on average in January, especially at the boundary of Weishan Lake and Dushan Lake where the concentration was above 10 mg/m³. In April, the concentration of chlorophyll-a in most parts of the area decreased to about 5.00 mg/m³. The lowest concentration of 0.1-5.00 mg/m³ was found in the center of the lake, and this value increased from the center to the periphery. In July, the concentration in the lake area increased to 10 mg/m³, with the highest concentration found in southeast Weishan Lake. In October, the concentration in the lake area rose to more than 7 mg/m³.
5. Conclusion
The change of chlorophyll-a concentration in Nansi Lake simulated is summarized in two aspects. First, in terms of temporal distribution, the chlorophyll-a concentration was higher from October to January of the following year, and then gradually decreased to lower level in April, and the concentration increased gradually at Weishan Lake in July, and reached a higher level in October. Second, in terms of spatial distribution, the concentration in the boundary of the Upper Lake area was higher than that in the center, especially the concentrations in the northern Dushan Lake and the southeastern Weishan Lake were all higher except April, which makes the water quality of the lake area worse. Besides, two problems need to be solved. First, the retrieval accuracy needs to be improved. The spatial resolution and spectral resolution of remote sensing need to be improved. And long-term observation of concentration is needed to see whether the formula is simulated in each month. Second, the external factors which influence the change of chlorophyll-a are not used in the modeling, which needs to be further studied to improve the model and accuracy.
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