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Remote sensing retrieval for Chlorophyll-a and Suspended Matter Concentration of Longyangxia Reservoir based on landsat OLI data

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Abstract: In this study, the Longyangxia Reservoir was taken as the research area and the chlorophyll-a and suspended matter concentration data of 20 measured sample points and the simultaneous landsat8 remote sensing image data were used. Firstly, remote sensing images were preprocessed, and then 15 sample data were randomly selected from 20 data points. Through correlation analysis of the 15 sample data and landsat OLI data, bands sensitive to chlorophyll-a and solid suspended matter concentration were found. Using the detected sensitive bands, an inversion model of the relevant concentrations of chlorophyll-a and solid suspended matter was constructed. Finally, the remaining 5 sample data are used to calculate the relevant precision index. By using the calculated determination coefficient, root mean square error and overall relative error, the precision of the inversion model is comprehensively evaluated, so as to find a universal model. Through the established inversion formula, ENVI/IDL and ArcGIS software were used to complete the mapping of chlorophyll-a and suspended matter concentration of Longyangxia Reservoir in 2013 and 2018, providing a reference for the comprehensive treatment of Longyangxia Reservoir.

1. Introduction
Chlorophyll and solid suspended matter are important parameters to measure water quality. The concentration of chlorophyll-a can be used to evaluate the eutrophication level of water, control eutrophication and algae biomass, and reveal the inner essence of eutrophication [1]. Suspended matter concentration is an important parameter for studying hydrological deposition, physical environment and material flux[2].

Water chlorophyll-a and suspended matter concentration inversion method is mainly to experience a statistical method and half half analysis method mainly: (1) By means of satellite remote sensing image data and synchronous ground observation data, the statistical relation model is established directly between the image band information and desired physical quantity; (2) Semi-empirical & semi-analytical model. On the basis of the empirical function relationship between the apparent parameters of water body and the inherent optical parameters, the model between the apparent parameters of water body and the desired physical quantity is added, and the corresponding relationship between the image band information and the desired physical quantity is finally established [3].

According to the slight differences of water spectra in different waters, different satellite sensors and different seasons, domestic and foreign scholars built a series of inversion models of chlorophyll-a and solid suspended matter. The inversion models of chlorophyll-a and solid suspension mainly
include multiple linear regression model, logarithm model, Gordan model and negative exponential model[4].

In this paper, Landsat8 OLI data and field measured data in Longyangxia were used to construct the chlorophyll-a and total suspended matter inversion model suitable for Longyangxia reservoir based on Landsat OLI images. The model can meet the requirements of remote sensing environmental monitoring for Longyangxia reservoir.

2. Remote sensing data preprocessing

2.1. Atmospheric Correction
Atmosphere is an important factor affecting remote sensing inversion accuracy. In order to more accurately reflect the real optical properties of water bodies, it is necessary to select an appropriate atmospheric correction model to eliminate or reduce the influence of atmospheric noise on the inversion accuracy. In this paper, the FLAASH atmospheric correction module in ENVI5.1 is used and the K-T aerosol inversion model is used. By comparing and processing the spectral curves of the image of atmospheric correction results on the same pixel, it can be seen that the spectral curves of the surface features after atmospheric correction are closer to the optical characteristics of the real surface features.

![Figure 1: Spectral curve before atmospheric correction](image1.png)

![Figure 2: Spectral curve after atmospheric correction](image2.png)

2.2. Geometric correction
In order to make the measured experimental data and remote sensing image data accurately match in geographical coordinates, the acquired remote sensing image needs to be geometrically corrected. In this paper, the 1:250,000 topographic map of Longyangxia reservoir is used as the base map, 32 control points are selected and WGS-84 coordinate system is adopted, and then the adjustment is carried out by cubic polynomial fitting method.
3. Inversion of chlorophyll-a concentration

In the study, 15 sample data were randomly selected from 20 data collection points. The 15 sample data and landsat OLI data were used for correlation analysis of water-leaving radiance to find the bands more sensitive to chlorophyll-a concentration. Then the sensitive bands are found to build the related inversion model of chlorophyll-a concentration. Finally, the remaining 5 sample data and related precision indexes are used to evaluate the precision of the inversion model, so as to find a universal model.

3.1. Correlation analysis selects appropriate bands

The peak value of the ionizing radiance of clean water is mainly concentrated in the blue-green light band (450nm -- 570nm), and within this range, the water-leaving radiance will decrease with the increase of wavelength [5]. In other bands, the water-leaving radiance brightness is generally low. However, if the water contains chlorophyll-a, we can see from figure.1 that the radiance of ionized water shows obvious fluctuations in the near-infrared band.

According to the spectral curve analysis of chlorophyll-a in the figure above, the radiation brightness is mainly concentrated in the band from 400um to 750um. In this paper, only band1 to band6 (430nm -- 1570nm) were selected from the Landsat OLI band data, and the correlation analysis was conducted by combining the chlorophyll-a concentration data of 15 selected sampling points. According to the correlation coefficient obtained in table 1, in the Landsat OLI band data, there was a negative correlation between the concentration of band1 to band6 and chlorophyll-a. The strong correlation band (band2, band3, band4, band5) is selected to construct the inversion model.

Table 1 The correlation of Landsat8 OLI’s radiance from water and chlorophyll-a

| Band        | Relativity     |
|-------------|----------------|
| Lansat OLI Band1 | -0.493592396  |
| Lansat OLI Band2 | -0.825544135  |
| Lansat OLI Band3 | -0.826685655  |
| Lansat OLI Band4 | -0.794165173  |
| Lansat OLI Band5 | -0.727153555  |
| Lansat OLI Band6 | -0.255411952  |

3.2. Construction and precision analysis of chlorophyll-a inversion model

In order to evaluate the accuracy of each model, the following three parameters are introduced to evaluate the model[6].

- Determination Coefficient, $R^2$
- Root Mean Square Error——RMSE
Relative Error——RE

\[ \text{RE} = \frac{1}{n} \sum \left( \frac{\text{Ch}_m - \text{Ch}_i}{\text{Ch}_m} \right) \times 100\% \]

\((\text{Ch}_m \text{ is the measured value of chlorophyll-a, and Ch}_i \text{ is the inferred value of chlorophyll-a. Relevant data processing and precision evaluation involved in the model were completed in MATLAB (R2016A) software.})

Regression analysis was used in MATLAB to invert the concentration of chlorophyll-a. The logarithm of the water-leaving radiance of a single band in landsat OLI data with base 10 as the independent variable and the logarithm of chlorophyll-a concentration with base 10 as the dependent variable were used for regression analysis and calculation. However, in the calculation, it is found that no matter which regression analysis model is used for inversion, the accuracy is relatively low. Therefore, this study selected several inversion relations with high precision from the references, and carried out parameter inversion and evaluation of the model[7].

### Table 2: The Landsat OLI estimation model for chlorophyll a concentration

| The dependent variable Y | The independent variables X | R²  | RMES  | RE    | The inversion model |
|--------------------------|-----------------------------|-----|-------|-------|--------------------|
| LG C                     | X-LG (B5/B2)                | 0.83| 6.84  | 28.65 | \( Y = 5.65X + 0.146 \) |
| LG C                     | X-LG (B5/B3)                | 0.87| 5.95  | 21.58 | \( Y = 8.49X + 1.593 \) |
| LG C                     | X-LG (B5/B3)                | 0.72| 17.56 | 47.55 | \( Y = -13.28X + 2.548 \) |
| LG C                     | X-LG (B3/B2)                | 0.73| 4.32  | 21.33 | \( Y = 118.52X^2 + 52.55X + 3.146 \) |
| LG C                     | X-LG (B5/B2)                | 0.70| 26.53 | 58.56 | \( Y = 95.51X^2 + 68.23X + 29.94 \) |

*: the unit of RMES is mg/L and the unit of RE is %

3.3. Application and mapping of inversion results

By evaluating the accuracy of landsat OLI estimation model for chlorophyll-a concentration above, we decided to make use of band5 and band2 in OLI data. Using formula:

\[ \text{lgC} = 5.65 \frac{\text{band5}}{\text{band2}} + 0.146 \] (1)

ENVI5.1 software was used to preprocess the remote sensing image. IDL language was used to program and calculate the image, and formula (1) was used to calculate and invert the concentration of chlorophyll-a. Finally, the processed images were imported into Arcgis10.2 for classification statistics and mapping.

Figure 4 Chlorophyll-a concentration distribution map of longyangxia reservoir in 2013
4. Inversion of suspended matter concentration

4.1. Correlation analysis selects appropriate bands
Since the overall research ideas and methods are roughly the same as chlorophyll-a, some differences will be discussed below. By referring to literatures, band3 to band7 above 0.53um (0.53um——1.57um) were selected to weaken the influence of water absorption and yellow soluble matter absorption on inversion results[8~9]. According to the correlation coefficient obtained in the table, there is a relatively high correlation between band4 and band7 in the Landsat OLI band data and the concentration of suspended matter. However, there is no strong correlation between a band and solid suspension concentration [10]. Of course, this is also consistent with the results of previous studies.

Table 3 The correlation of Landsat8 OLI's radiance from water and suspended matter concentrations

| Band                  | Relativity         |
|-----------------------|--------------------|
| Lansat OLI Band3      | 0.352488956        |
| Lansat OLI Band4      | 0.528947139        |
| Lansat OLI Band5      | 0.352186366        |
| Lansat OLI Band6      | -0.392844916       |
| Lansat OLI Band7      | -0.542984692       |

4.2. Construction and precision analysis of suspension concentration inversion model
Guangjie et al. constructed a suspension estimation model of Taihu lake using landsat TM data and (TM2+TM3)/(TM2-TM3) as independent variables, achieving high accuracy in all seasons [11]. Cui Tingwei et al. constructed a multivariate linear model of BoHai sea suspended matter with the radiance of separation from water of TM2 and TM3 bands as the independent variable [12], and obtained good inversion results. Considering the correlation between the water-leaving radiance and suspended matter concentration obtained in this study and previous research results, this study will use the model built by Guangjie, Cui Tingwei and others to carry out parameter inversion and precision evaluation.

Table 4. The Landsat OLI estimation model for suspended matter concentrations

| The dependent variable Y | The independent variables X | R²    | RMSE  | RE    | The inversion model         |
|--------------------------|-----------------------------|-------|-------|-------|-----------------------------|
| LG SS                    | X = (B1+B4) / (B3+B4)       | 0.56  | 22.84 | 40.65 | Y = 35.2X + 0.504           |
| SS                       | X1=B3                       | 0.65  | 20.95 | 36.32 | Y = -0.250X1 + 0.560X2 - 10.335 |
|                          | X2=B4                       |       |       |       |                             |

As can be seen from the table, the inversion accuracy of both models is not too high. But the second model is more accurate than the first one. Moreover, when we used the formula of model 2 to...
invert the suspended matter concentration of Longyangxia reservoir on August 8, 2013, we found an obvious sediment diffusion phenomenon (Figure 4). According to the historical weather conditions of your county, moderate rain was found in your county on August 5th and 6th, and showers were found on August 7th. This also proves from the side that although our inversion model cannot accurately reflect the concentration of solid suspended matter, it can reflect the general concentration and spatial and temporal distribution of the suspended matter concentration in Longyangxia reservoir.

4.3. Application and mapping of inversion results
Based on the accuracy evaluation of the estimation model of suspended substance concentration above, we decided to use band3 and band4 in OLI data to conduct classification statistics and mapping by using formula (2).

\[
SS = -0.358\text{Band}_3 + 0.568\text{Band}_4 - 10.335
\]

Figure 6  Sediment diffusion by precipitation

Figure 7  Suspended matter concentrations distribution map of Longyangxia reservoir in 2013
5. Conclusion
In this paper, the general principle of remote sensing monitoring of chlorophyll-a concentration and suspended matter concentration in Longyangxia reservoir is introduced. And the quantitative inversion of chlorophyll-a and suspended matter concentration in Longyangxia reservoir is conducted by using landsat 8 remote sensing images. Different inversion model formulae for chlorophyll-a and suspended matter were constructed. And introducing the decision coefficient (R^2), root mean square error (RMSE), the overall relative error (RE) is used to evaluate the precision of each model, the formula. The distribution maps of suspended matter concentration and chlorophyll-a concentration in Longyangxia reservoir in 2013 and 2018 were obtained by using the model with high accuracy and formula inversion mapping. Through the research and analysis of the results, the following conclusions can be drawn: (1) In the chlorophyll-a concentration inversion, certain bands in OLI data have a strong correlation with the chlorophyll-a concentration, and the precision index of the inversion formula is also relatively high. Therefore, the inversion formula obtained in this study can accurately reflect the real situation of chlorophyll-a in Longyangxia reservoir. (2) Compared with the inversion accuracy of chlorophyll a, the inversion accuracy of suspended matter concentration is lower. However, the analysis shows that the inversion formula in this paper can still reflect the general concentration and spatial and temporal distribution of the suspended solids in Longyangxia reservoir. (3) In Longyangxia reservoir, suspended matter concentration is higher at the upstream entrance of Longyangxia reservoir. The concentration of chlorophyll-a and suspended substance is generally distributed as "The farther away from the shore, the lower the concentration". (4) This paper shows that remote sensing image can reflect the distribution of chlorophyll-a and suspended matter in water rapidly, efficiently and objectively, and it is a feasible method and means.

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