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Detection and Evaluation System of Lake Water Eutrophication Based on Remote Sensing Technology

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Abstract: Water eutrophication is a global water environment problem. Urban water bodies are greatly affected by human activities. It is of great significance to study its eutrophication. The purpose of this paper is to study the detection and evaluation system of lake water eutrophication based on remote sensing technology. Use C#, IDL and ArcGISEngine for overall system development. The system takes the inversion of water chlorophyll a concentration as the main line, realizes the preprocessing of the original image, and conducts research on the spatial distribution of chlorophyll concentration through different models. The chlorophyll a concentration retrieved by remote sensing was evaluated and analyzed by the water body eutrophication index, and finally the evaluation results were verified. The model was verified by calculation to be ideal and can accurately and reliably evaluate the water body eutrophication degree of Lake M. It also proves that the detection and evaluation system of lake water eutrophication based on remote sensing technology is feasible.

1. Introduction

In recent years, the water quality of lakes in my country has deteriorated, the lake area has been continuously reduced, and the ecological environment problems of lakes have gradually increased. Therefore, how to rationally use water resources to effectively solve the problem of water pollution has gradually become more and more important, and this worldwide challenge needs to be solved by scientists from all walks of life [1-2]. The protection and management of lake water resources is also one of the important issues in the world at this stage. We must actively explore and need the protective clothing of lakes in the ocean of knowledge [3].

The task of remediating the lake was onerous, and Kusunoki K measured two locations collected in the lake. The TOC and TN in the sediment are mainly from plankton, and most of the TS in the surface layer 0-2 cm exists in the form of sulfide, indicating that a large amount of sulfide is deposited around the sediment surface. Assuming that sulfides are mainly formed in the upper layers 0–10 cm, the vertical profiles of TS concentrations above 10 cm indicate that the vertical profiles of Mo concentrations in the core are similar to those of TS concentrations. The vertical profile of molybdenum concentration is likely also related to the historical trend of primary production in Zhonghai Lake [4]. Udokpoh U U collected groundwater samples from three (3) separate boreholes in the area for the same analysis. Fourteen (14) water quality indicators were assessed for their relative importance in determining the quality of water for human consumption. According to laboratory analysis, the pH of these two water sources is acidic, ranging from 5.19 to 6.24 [5]. The monitoring range of satellite remote sensing technology is unmatched by manual monitoring, and it can grasp the water quality situation in real time, which lake water body is polluted, and the eutrophication of the water body exceeds the standard. Using satellite remote sensing technology can quickly and accurately reflect it.. This paper also uses satellite remote sensing technology to detect water quality [6-7].

In this paper, taking M Lake water body as the research object, aiming at the local major water environmental protection needs, a remote sensing rapid inversion model and eutrophication evaluation model of M Lake water body eutrophication key parameters (Chl-a concentration) are established. Due to the spatial characteristics of eutrophication, using different remote sensing data sources, the full remote sensing image is incorporated into the inversion model and evaluation algorithm in the detection and evaluation system of lake water eutrophication, which increases the reliability of the data and avoids the need for single scene images errors caused. This provides an important guarantee for water environment management and prevention and control, as well as ensuring ecological green and high-quality development.

2. Research on Detection and Evaluation System of Lake Water Eutrophication Based on Remote Sensing Technology

2.1. Development Language

The system uses a mix of C# and IDL according to its functional requirements. C# is the main language environment, and IDL is used to realize the reading and processing of remote sensing image data [8-9].

C# is a modern, general-purpose, object-oriented programming language developed by Microsoft. As part of the.NET framework, C# has object-oriented features [10].

IDL Interactive Data Language is the fourth-generation scientific computing visualization language that integrates scientific computing ability, practicality and visualization analysis. As a data analysis and image application program and programming language, the built-in function library in IDL effectively reduces the time and difficulty of image processing algorithm development. In addition, the remote sensing image file reading interface provided makes up for the shortcomings of ArcGISEngine, and provides the COM_IDL_CONNECT primary key to facilitate linkage and parameter transfer between the two languages [11-12].

2.2. Remote Sensing Image Preprocessing

(1) Preprocessing of image data

For water color remote sensing, the remote sensing signal detected by the satellite mainly includes two parts: the water-leaving radiance and atmospheric path radiation noise that carry the water quality concentration information. The formula (1) is as follows:

$$\rho_t(\lambda) = \rho_t(\lambda) + \rho_{as}(\lambda) + \rho_{ra}(\lambda) + t(\lambda)\rho_w(\lambda) \qquad (1)$$

In the formula, ρt is the reflectivity of the top of the atmosphere observed by the satellite; ρr is the reflectivity contributed by Rayleigh scattering; in the vicinity of 400nm~450nm, more than 80% of the signals detected by the sensor are affected by atmospheric scattering, which is called the atmospheric path. Radiation; the water-leaving radiance signal only accounts for about 10% of the total signal, and the proportion of the water-leaving radiance signal at 490nm~580nm is even smaller. The water-leaving radiance signal has a low proportion, so the sum of the absolute errors of radiometric calibration and atmospheric correction should be limited within the technical range of 5%.

(2) Quality control of satellite image data

In order to ensure that the satellite image data and the actual site data can be correctly matched, the following methods are used for data quality control:

Data with a satellite transit time of ±3 hours was used [13].

In the data matching the measured points, the data points with poor uniformity (meaning and mean difference greater than 20%) and valid pixels (<3) in 3 ×3 pixels were removed [14].

When extracting the measured point data, the average calculation is performed by traversing the data points in the 3×3 window [15].

2.3. Evaluation Method of Lake Eutrophication

(1) Evaluation indicators of eutrophication status

Based on the comparative analysis of various eutrophication evaluation methods, this paper selects the widely used and mature remote sensing retrieval index (chl-a) to evaluate the lake water quality. According to the chlorophyll a concentration value obtained by satellite retrieval, The eutrophication evaluation of lake water was carried out by combining the determined nutrient state index method [16-17].

(2) Eutrophication evaluation model

In this paper, the chlorophyll a concentration was used as the standard to calculate the nutritional status index, and then the eutrophication status of lake water was evaluated from this perspective. Its calculation formula is as follows:

$$TSI(chl-a) = 10(6 - \frac{2 - 0.5 In chl - a}{In 2}) \qquad (2)$$

where: TSI (chl-a) is the Carlson nutritional status index, and chl-a is the chlorophyll concentration (mg/m3) [18].

3. Design and Research on Detection and Evaluation System of Lake Water Eutrophication Based on Remote Sensing Technology

3.1. System Key Technologies

This system adopts ArcGISEngine, C# and IDL, and uses MySQL database (database is mainly used to store measured data, remote sensing data and algorithm information). Specific requirements are as follows:

Operating system: Windows 10;

Development environment:.NETFramework4.5, ArcGISEngine10.4;
Programming language: C#, IDL;
Database: MySQL;

3.2. The Functional Module Structure of the System

According to the system design objectives and software architecture planning, the functions of this system are divided into four main functional modules: data management module, remote sensing image preprocessing module, lake water quality remote sensing inversion module, and lake eutrophication comprehensive evaluation module. The functional modules of the system are shown in Figure 1.

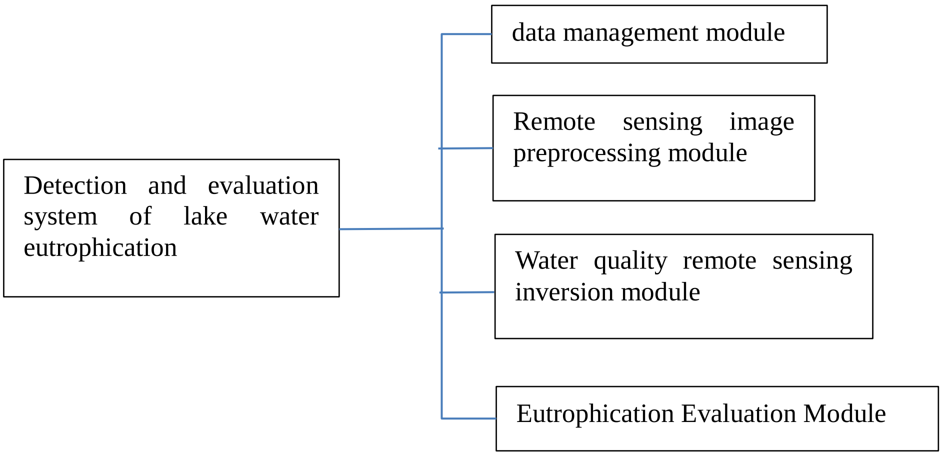

Figure 1. Functional modules of the system

(1) Data management module

The data management module includes three data functions: measured water quality data, remote sensing image data and band data. Including adding, modifying, deleting and viewing data, it is convenient to manage and maintain the system.

(2) Remote sensing image preprocessing module

The remote sensing image preprocessing module includes two sub-function modules: radiometric calibration and atmospheric correction of remote sensing images. Radiometric calibration can convert the brightness gray value of remote sensing images into absolute radiance; atmospheric correction eliminates the influence of various factors on the reflectivity of ground materials, so as to obtain the real surface reflectivity.

(3) Water quality remote sensing inversion module

The water quality remote sensing inversion module mainly realizes the remote sensing inversion of lake water quality based on multiple models, and provides a reference for studying the changes of lake water quality.

(4) Eutrophication evaluation module

The eutrophication evaluation module makes judgments on the nutrient state of the lake by establishing the indexes related to lake nutrition and the relationship between the indexes.

In order to make a more accurate judgment on the trophic state of the lake, it is necessary to evaluate the eutrophication level through the indexes related to the trophic state of the lake and the relationship between the indexes. Based on the eutrophication evaluation model, the system evaluates the eutrophication status of the water body based on the chlorophyll of the lake, and draws a concentration map of the eutrophication status of the lake.

4. Application and Research of Detection and Evaluation System of Lake Water Eutrophication Based on Remote Sensing Technology

4.1. Overview and Data Sources of the Study Area

Lake M is in the shape of a long and narrow belt as a whole, distributed along the SW-NE direction. In this paper, two field samplings were carried out respectively, and the sampling time was basically synchronized with the transit time of the selected satellites. 10 sampling points were set on the entire lake, as shown in Figure 2, the sampling points were evenly spaced and had a certain representativeness. GPS receivers were used to locate the position of each water quality measurement point during sampling.

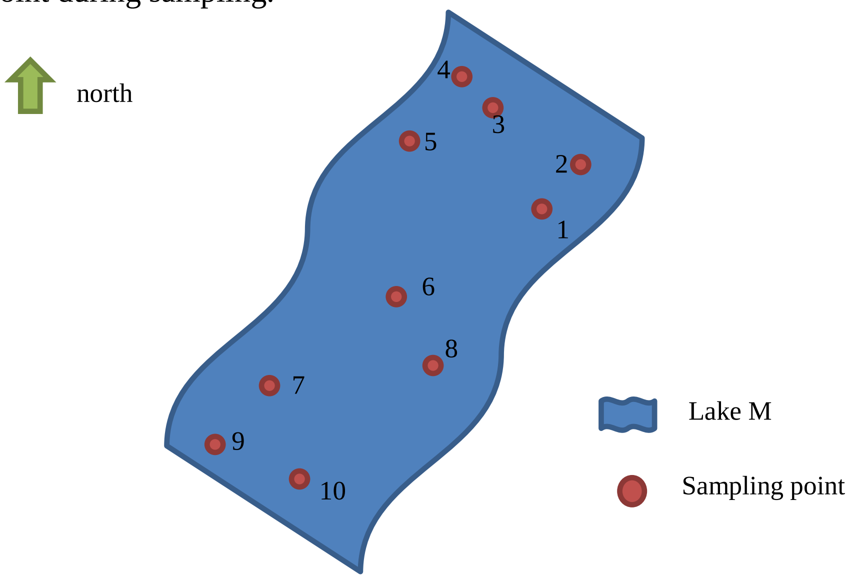

Figure 2. Setting up sampling

4.2. Classification of Eutrophication Grades of Lakes (Reservoirs)

The TSI value based on the inversion model is calculated through the eutrophication evaluation model, and the eutrophic state is divided into 4 grades using 0~100, namely oligotrophic (<35), mesotrophic (36~60), eutrophic (61~80) and extremely eutrophic (⩾80). The corresponding relationship between the TSI value and the nutrient state of lake water is shown in Table 1.

Table 1. Corresponding table of eutrophication grades

Nutritional status index (TSI)	Degree of eutrophication
<35	Poor nutrition
36~60	Medium nutrition
61~80	Nutrient rich
⩾80	Extremely nutritious

4.3. Eutrophication Evaluation Results

According to the nutritional status index (TSI) calculated from the chlorophyll a concentration value, it can be seen that due to the generally high chlorophyll a concentration value in Lake M during this period, the nutritional status index (TSI) value is also relatively high. The central (sampling points 6, 8) and upper (sampling points 9, 10) are affected by other nutrient input factors and the environment, the TSI value is slightly higher than other areas, and the distribution of water nutrient status is less, from south to north, higher than other areas, It first increased and then decreased, and the spatial distribution was similar to that of chlorophyll a concentration. It can be concluded that M Lake is mainly due to the comprehensive action of various environmental factors such as domestic sewage and industrial wastewater, which leads to the increase of nutrients in the water body, and finally presents an eutrophic state.

4.4. Verification of Evaluation Results

In order to further test the accuracy and reliability of the evaluation results, the nutrient state index calculated from the measured chlorophyll a concentration is the true value, and it is compared with the remote sensing evaluation results, as shown in Table 2.

Table 2. Comparison of eutrophication status evaluation results

Sample number	Truth value	Inversion value
1	60.32	66.21
2	59.21	58.46
3	48.62	45.92
4	55.66	51.82
5	66.79	68.77
6	63.88	63.28
7	67.14	67.39
8	52.14	52.37
9	60.18	65.17
10	69.71	68.28

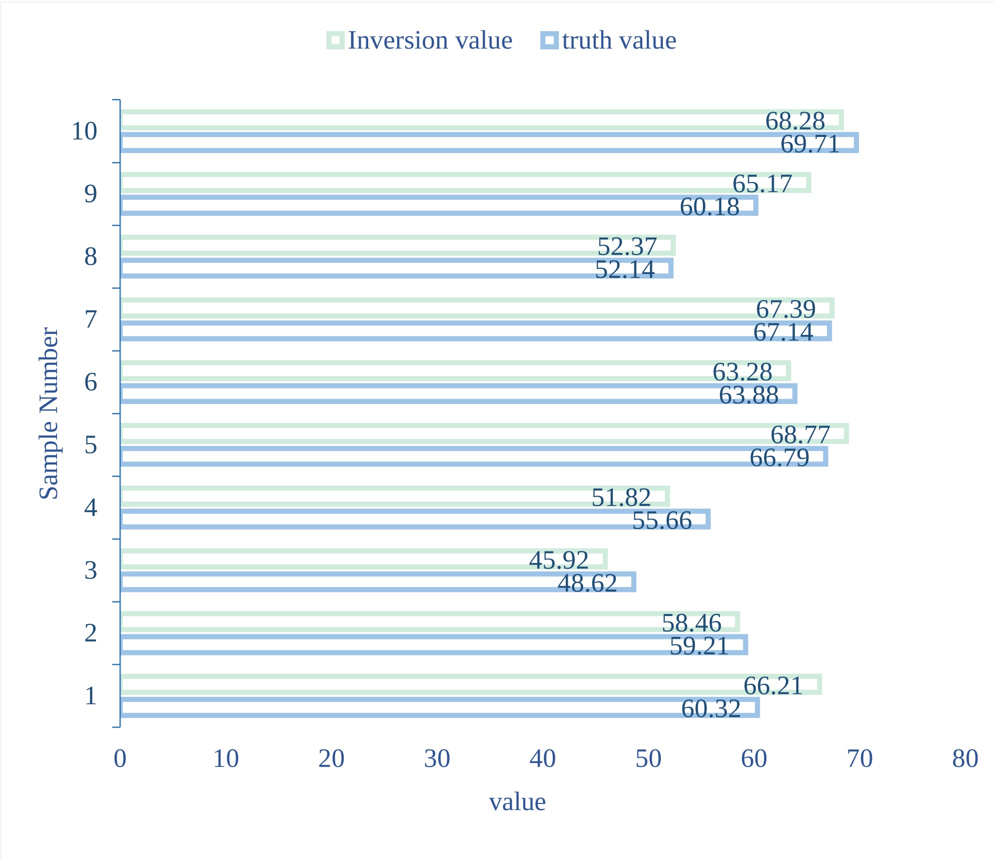

Figure 3. Validation of evaluation results

It can be seen from Figure 3 that the model has high accuracy. Therefore, this study believes that the detection and evaluation system of lake water eutrophication based on remote sensing technology can better evaluate the degree of eutrophication of lake water.

5. Conclusion

With the increasing frequency of human activities, the production wastewater and domestic sewage discharged into lakes, reservoirs and rivers continue to increase, which gradually pollutes natural water bodies and deteriorates water quality. Today, with the rapid development of society and economy, our demand for water resources is increasing, but we are facing an increasingly serious water crisis. Based on the secondary development of the primary key ArcGISEngine, this paper uses a mixture of visual language C# and IDL, integrates remote sensing image preprocessing, lake chlorophyll a inversion and water quality evaluation to complete the design of a lake water eutrophication detection and evaluation system based on remote sensing technology. According to the evaluation method of water eutrophication in the system, the determination of the model and the classification of eutrophication grades, the eutrophication evaluation results of Lake M are finally summarized.

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Data Availability

The datasets used during the current study are available from the corresponding author on reasonable request.

Conflict of Interest

The author states that this article has no conflict of interest.

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