Detection and Analysis of Spatial Differentiation of Potential Water Quality Status in Dianchi Lake Based on GF-5

HU Lin¹, GAN Shu¹,²*, YUAN Ling¹,³

¹Land Resources and Engineering Faculty, Kunming University of Science and Technology, Kunming, Yunnan, 650011, China
²Plateau Mountain Survey Technique Application Engineering Research Center at Yunnan Province's Universities, Kunming, Yunnan, 650011, China
³Yunnan Energy Investment Group Co., Ltd, Kunming, Yunnan, 650093, China

* Correspondence Author Gan Shu's e-mail: 1193887560@qq.com

Abstract. The outbreak of cyanobacterial blooms and the deterioration of potential water quality status caused by the eutrophication of Dianchi Lake is a hot topic in the research of Dianchi Lake environmental protection. Based on Gaofen No.5 (GF-5) hyperspectral remote sensing data, Normalized Vegetation Index (NDVI) is used to indicate the impact of aquatic plants on potential water quality status in Dianchi Lake. And through the spatial statistical classification analysis of NDVI value range, the focus is on the spatial differentiation characteristics of the potential water quality status in Caohai and Waihai. The results are as follows: ① General quantitative statistical analysis of NDVI range shows that the mean values of NDVI in Caohai and Waihai are -0.387 and -0.713 respectively, indicating that the potential water quality status in Caohai are more serious than Waihai; ② According to the classification and statistics of NDVI range in Caohai, NDVI mid-value area accounts for 51.99% of the total area of Caohai. The spatial distribution ratios of NDVI low-value area and high-value area are less, 38.20% and 9.81% respectively; ③ According to the classification and statistics of the potential water quality status in Waihai, the spatial distribution of NDVI low-value area, mid-value area and high-value area account for 47.16%, 51.45% and 1.39% of the total area of Waihai; ④ The spatial distribution of the potential water quality status in Dianchi Lake shows the pattern characteristic of "north is heavy and south is light". The potential water quality status in Caohai are generally worse than that of Waihai, and there are more serious potential water quality problems than Waihai. In general, the application of high-resolution remote sensing data can effectively monitor and identify the potential water quality status and spatial distribution of plateau lakes in real time, enriching the methods of monitoring the water quality of lakes based on hyperspectral remote sensing, which is conducive to promoting the protection and management of water resources environment in Dianchi Lake.

1. Introduction
Abnormal growth of cyanobacteria due to eutrophication of lake water leads to the formation of blooms, which damages the ecosystem of water and seriously affects the survival and health of human beings and the development of social economy[1]. Dianchi Lake in the Yunnan-Guizhou Plateau is the lake prone to potential water quality problems with cyanobacterial blooms. According to data query, the water of Dianchi Lake was Class II in the 1960s, and it was Class III in the 1970s. The water of Caohai was Class V and the water of Waihai was Class IV in the 1980s. In the 1990s, the
water quality was worse. The water of Caohai was above Class V and the water of Waihai was Class V[2]. In recent years, the water quality of Caohai and Waihai has been improved through a series of management work. In 2019, Caohai reached Class IV standard and Waihai reached Class V standard. But serious pollution still exists. Therefore, considering the heterogeneity of the Dianchi Lake's ecological environment, it is particularly important to strengthen the research on the potential water quality status in Dianchi Lake.

Remote sensing technology plays an important role in the management and protection of lakes. In particular, the monitoring of potential water quality by remote sensing technology has been widely valued. For example, domestic and foreign scholars have proposed many indexes application methods like NDVI[3], Floating Algae Index (FAI)[4], Normalized Difference Water Index (NDWI)[5], Enhanced Vegetation Index (EVI)[6] and so on. Among them, NDVI is defined as the normalized ratio of red band and near-infrared band, which can better reflect the steep slope effect and improve the monitoring efficiency. NDVI is now the most widely used remote sensing index methods. NDVI is also used as a basic method to research the potential water quality status in Dianchi Lake. Specifically, based on GF-5 image data, the research will identify the potential water quality status in Dianchi Lake through NDVI value range classification. And taking Caohai and Waihai as the spatial objects, the spatial distribution characteristics of the potential water quality status in Dianchi Lake were analyzed and researched.

2. Research area and research data

2.1. Research area
Dianchi Lake in the central Yunnan Plateau is the sixth largest freshwater lake in China[7]. The lake is located in the urban area of Kunming city, whose water area is 309.5 km² when the elevation of the lake is 1887.4 m. As shown in Figure 1, the whole area of Dianchi Lake is divided into north and south parts by an artificial lake dike. The north is the Neihai, also known as Caohai, whose surface area only accounts for 3.4% of Dianchi Lake area. The water depth is 1~3 m and there are plenty of aquatic plants in the water. The south is Waihai, whose surface area accounts for 96.6% of Dianchi Lake area. It is the main body of Dianchi Lake with an average depth of about 5 m[7].

2.2. Research data
The remote sensing data used in the research is the GF-5 hyperspectral archived data of China. The data acquisition time is December 16, 2019. The image space includes the whole Dianchi Lake. According to the relevant basic parameters of GF-5, the spatial resolution of GF-5 AHSI hyperspectral remote sensing data is 30 m. The spectral data set is divided into visible light near infrared (VNIR) subset and shortwave infrared (SWIR) subset according to different spectral resolutions, with a total of 330 bands. VNIR band range is about 0.39~1.03 μm, spectral resolution interval is 5 nm, VNIR has 150 bands; SWIR band range is about 1.0~2.5 μm, spectral resolution interval is 10nm, SWIR has 180 bands[8]. GF-5 data sources have good hyperspectral resolution and appropriate spatial and temporal resolution[9]. Therefore, it can satisfy the needs of monitoring and analyzing the water quality of Dianchi Lake in central Yunnan Plateau.
3. Application of research methods

3.1. Construction and calculation of NDVI based on hyperspectral analysis
In order to use remote sensing technology, the spatial distribution characteristics of potential water quality status in Dianchi Lake are analyzed and known scientifically. Firstly, hyperspectral analysis should select bands to construct NDVI and calculate the NDVI values of all pixels in Dianchi Lake. In the research, because the used image data was hyperspectral data, there were a total of 330 bands. Red band is 620~760 nm, and near infrared band is 760~3000 nm. Therefore, in the application of NDVI index method, red bands participating in the construction of NDVI value are the mean values of five hyperspectral bands, namely the 52nd band (609 nm), the 59th band (639 nm), the 66th band (668 nm), the 73rd band (698 nm) and the 80th band (728 nm), as the red band value. Similarly, near-infrared bands participating in the construction of NDVI value are the mean values of five hyperspectral bands, namely the 115th band (878 nm), the 137th band (972 nm), the 175th band (1207 nm), the 215th band (1545 nm) and the 275th band (2050 nm), as the near-infrared band value. Based on the process above, the hyperspectral precision NDVI values of all pixels in Dianchi Lake were obtained.

3.2. The research program is used to compare and analyze Caohai and Waihai
In order to compare and analyze Caohai and Waihai, NDVI thematic layers of space objects in Caohai and Waihai were calculated after hyperspectral refinement. The histogram of pixel frequency, mean value of NDVI and so on in Caohai and Waihai are obtained. Through the comparison and analysis of NDVI quantity statistics, the potential water quality status in Caohai and Waihai were obtained. In this way, we can get a general understanding of the difference between the potential water quality status of Caohai and Waihai in Dianchi Lake.

Secondly, in order to classify, evaluate, analyze, research and discuss the spatial distribution of the potential water quality status in Caohai and Waihai, based on the NDVI values, the potential water quality status corresponding to the refined NDVI was graded and the grading diagram was drawn. By classifying the potential water quality status, the spatial distribution characteristics of the potential water quality status in Dianchi Lake can be researched based on remote sensing identification technology and represented by NDVI.

4. Results and analysis

4.1. Comparison and analysis of statistical characteristics of spatial distribution of potential water quality status in Caohai and Waihai
NDVI value of Caohai was counted and histogram was drawn, as shown in Figure 2. According to the preliminary quantitative statistics and analysis, the mean value of NDVI in Caohai is -0.387, the minimum value is -0.961, the maximum value is 0.594 and the standard deviation is 0.235. As Caohai is a lake wetland, the NDVI values of its pixels is concentrated in [-1,0], and a large number of peak values of its pixels are consistent with the indicative characteristics of NDVI. However, Caohai also distributes some positive NDVI pixels. There are 889 pixels greater than 0, with a ratio of 10.48%.
In the same way, NDVI value of Waihai was counted and histogram was drawn, as shown in Figure 3. According to the preliminary quantitative statistics and analysis, the mean value of NDVI in Waihai is -0.713, the minimum value is -0.997, the maximum value is 0.732 and the standard deviation is 0.122. As Waihai is a lake wetland, the NDVI values of its pixels is concentrated in [-1,0], and a large number of peak values of its pixels are consistent with the indicative characteristics of NDVI. However, Waihai also distributes some positive NDVI. There are 2145 pixels greater than 0, with a ratio of 0.91%.

In order to know the spatial distribution of potential water quality status in Caohai and Waihai. NDVI values were divided into three categories by geometric interval classification method. In other words, the dividing point obtained by geometric interval of respective NDVI values in Caohai and Waihai is taken as the dividing threshold. NDVI values were divided into NDVI low-value area, NDVI mid-value area and NDVI high-value area. The specific partition rules are shown in Table 1. By drawing the spatial distribution diagram of the potential water quality status in Caohai and Waihai, the spatial distribution characteristics of the potential water quality status in Dianchi Lake can be more intuitively known.

Table 1. The classification table of the potential water quality status of Caohai and Waihai by NDVI threshold

| Classification | NDVI low-value area | NDVI mid-value area | NDVI high-value area |
|----------------|---------------------|---------------------|---------------------|
| Caohai         | -0.961<NDVI<-0.488  | -0.488<NDVI<0.029   | 0.029<NDVI<0.594    |
| Waihai         | -0.997<NDVI<-0.726  | -0.726<NDVI<-0.220  | -0.220<NDVI<0.732   |

4.2. Comparison and analysis of cartographic characteristics of spatial distribution of potential water quality status in Caohai and Waihai

According to the classification criteria of the potential water quality status in Caohai, a spatial distribution diagram of the potential water quality status in Caohai was drawn (Figure 4). It can be seen that the NDVI low-value area accounts for 38.20% of the total area of Caohai, which is mainly distributed in the center of Caohai and there is some distance from the lake shoreline. The NDVI value in this area is low and the water quality is good; Caohai was dominated by NDVI mid-value area, accounting for 51.99% of the total area of Caohai. Because aquatic plants are abundant, NDVI mid-value area covers more. There are some potential water quality problems in this area; NDVI high-value area takes up the least area, which accounts for 9.81% of the total area of Caohai, is mostly distributed near the lake shoreline (except along Haigen Dam), the potential water quality status of this area are relatively serious and the water quality is poor.
According to the classification criteria of the potential water quality status of Waihai, a spatial distribution diagram of the potential water quality status of Waihai was drawn (Figure 5). The NDVI low-value of Waihai accounts for 47.16% of the total area. It is mainly distributed in the middle of Waihai, reaching Huiwan in the north and Guanyin Mountain in the south. This area has low NDVI value and good water quality. The NDVI mid-value area accounts for 51.45% of the total area of Waihai. It is mainly distributed in the north coast and most of the south coast, but rarely in the east coast. There are some potential water quality problems in this area; The NDVI high-value area takes up the least area, accounting for 1.39% of the total area of Waihai. It is scattered and mainly distributed near the lake shoreline. In comparison, the distribution of the south coast is more than that of the north coast. And the potential water quality status in this area are serious and the water quality is poor. On the whole, the potential water quality problems on the east coast are more serious than those on the west coast, and the potential water quality problems on the south coast are more serious than those on the north coast.

With reference to Table 1, by comparing the spatial distribution diagram of the potential water quality status in Caohai with Waihai, we can find that the coverage of potential water quality status in Caohai is more serious than that of Waihai. The spatial distribution of the potential water quality status in Dianchi Lake is characterized by the pattern of "the north is heavy and the south is light". The potential water quality status of Caohai are worse, and it is more prone to potential water quality status. So the water quality of Caohai is worse than that of Waihai.

5. Conclusion
This paper makes a comprehensive use of remote sensing technology and GIS spatial analysis technology. Based on the hyperspectral NDVI method, the potential water quality status in Dianchi Lake are detected and processed, and the spatial distribution characteristics of Caohai and Waihai in Dianchi Lake are compared, analyzed, tested and studied respectively. The main conclusions are as follows: 1) Through the comparison and analysis of statistical characteristics of spatial distribution of potential water quality status in Caohai and Waihai, we can know that the mean value of NDVI in Caohai and Waihai are -0.387 and -0.713 respectively. It indicates that the potential water quality status in Caohai is more serious than that of Waihai; 2) Through the comparison and analysis of cartographic characteristics of spatial distribution of potential water quality status in Caohai, we can know that the NDVI low-value area accounts for 38.20% of the total area of Caohai. Caohai was dominated by NDVI mid-value area, accounting for 51.99% of the total area. The NDVI high-value area takes up the least area, accounting for 9.81% of the total area of Caohai. 3) Through the comparison and analysis of cartographic characteristics of spatial distribution of potential water quality status in Waihai, we can know that the NDVI low-value area accounts for 47.16% of the total area of Waihai. The NDVI mid-value area accounts for 51.45% of the total area of Waihai. The NDVI
high-value area takes up the least area, accounting for 1.39% of the total area of Waihai. 4) The spatial distribution of the potential water quality status in Dianchi Lake is characterized by the pattern of "the north is heavy and the south is light". The potential water quality status of Caohai are generally worse, and it is more prone to potential water quality problems. Therefore, the water quality of Caohai is worse than that of Waihai.

Based on GF-5 image data, this paper uses NDVI to identify the potential water quality status in Dianchi Lake, and further researches the spatial distribution characteristics of the potential water quality status in Dianchi Lake by classifying the NDVI value. The obtained results are consistent with the conclusions of previous researches[7][10]. Therefore, the methods and conclusions of this paper are feasible. Although NDVI is fast and efficient for the identification of potential water quality status, it has limitations due to the influence of water as a medium. So the obtained results tend to expand or reduce the scope of potential water quality status. In order to identify the potential water quality status more accurately and quickly, the precision can be improved by refining research methods and enriching data sources in the future. Because GF-5 is a satellite that has only been launched in recent years, historical data is limited. After the image is gradually improved, combined with the characteristics of hyperspectral data, continuous optimization of research methods can achieve prediction and early warning of water pollution in inland lakes, and promote the research on water quality of lakes based on remote sensing technology.

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